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A multidimensional procurement auction for trading composite services ☆

Benjamin Blau [a,*], Tobias Conte [b], Clemens van Dinther [a]

[a] Institute of Information Systems and Management, Karlsruhe Institute of Technology, Karlsruhe, Germany
[b] Research Center for Information Technology, Karlsruhe, Germany

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ABSTRACT

Recently, static value chains have gradually been giving way to highly agile service value networks. This involves novel economic and organizational challenges. Added value for customers is created by feasible compositions of distributed service components. This work focuses on the design of a multidimensional procurement auction for trading service compositions and the analysis of strategies for service providers that participate in the procurement process. The mechanism implementation is incentive-compatible, so that it results in an equilibrium in which revealing the true multidimensional type (quality of service and valuation) is a weakly-dominant strategy for all service providers. Due to combinatorial restrictions imposed by the underlying graph topology, the winner determination problem can be solved in polynomial time, in contrast to computationally-intractable combinatorial auctions which cannot be solved this way. Furthermore, we provide a simulation-based analysis based on a reinforcement learning model of bundling and unbundling strategies of service providers that participate in the auction. Based on our results we discuss strategic recommendations for service providers depending on how they are situated within the network.

1. Introduction

Industries are moving from vertical integration to horizontal specialization. Hierarchically-organized firms that started to cooperate in tightly-coupled strategic networks with stable interorganizational ties recently have been exploring the benefits of exploiting more loosely-coupled configurations of legally- independent firms. A prime example for such highly dynamic fields of application is the software industry. Specialized service providers are beginning to leverage their core competencies in so-called *service value networks* (SVNs) in order to jointly offer complex services. *Complex or composite services* typically involve the assembly and invocation of many pre-existing, standardized services, possibly offered by diverse enterprises to complete the functionality of a multi-step business process (Papazoglou, 2008). Business value is provided through the agile and market-based composition of such complex services from a steady, but open pool of complementary as well as substitutable standardized service modules by the use of easily accessible information technology (IT) (Blau et al., 2009). This development and the advent of service value networks are illustrated in Fig. 1.

The logical consequence of the current trend toward *software-as-a-service* (SaaS) and Web services, combined with the emergence of SVNs, is a shift of software providers' offerings to an "Internet of services." SaaS is a software distribution model in which applications are hosted by a service provider and made available on a one-to-many basis over a network such as the Internet. Until now the term "Internet of services" has not been exactly defined in the academic world. Combining recently-provided perspectives from industry-oriented research (Ruggaber, 2007; Schroth, 2007; Schroth and Janner, 2007), we define the *Internet of services* as a global network which enables the design, retrieval, combination, trade and utilization of interoperable, electronic services in the Web.

Analogous to complex products, services will be composed of several modules provided by different partners of the underlying CVN. With the rise of highly standardized lightweight Web service technologies (Fielding, 2000), the realization of *ad hoc* compositions in an automatic fashion is simplified and manageable from a technical perspective. Due to the rapid standardization process and the renaissance of lightweight approaches, former technical problems in the context of service composition will be able to be solved (Ulkuniemi and Seppaenen, 2004). Today's SaaS and Web service market already shows the way towards such an Internet of services. The market can be divided into four quadrants as shown in Fig. 2.

This typology classifies the service on-demand market by the composition *complexity* of the service and the *degree of*

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* Corresponding author. Tel.: +49 7216088383; fax: +49 7216088399.
E-mail addresses: benjamin.blau@kit.edu (B. Blau), conte@fzi.de (T. Conte), clemens.vandinther@kit.edu (C. van Dinther).

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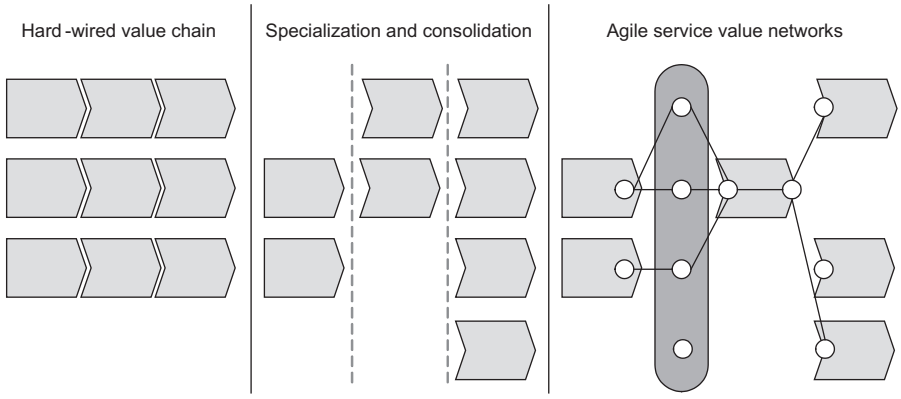

Fig. 1. From hard-wired value chains to adaptive service value networks. *Note:* adapted from Heuser et al. (2007).

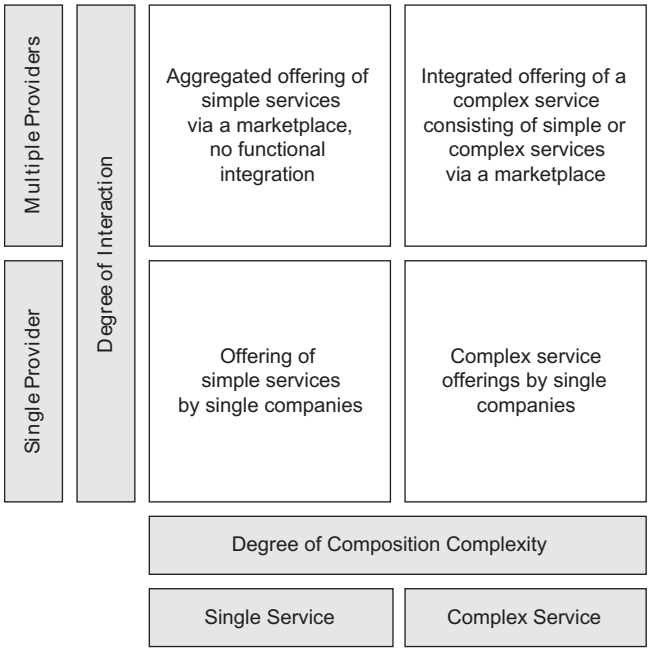

Fig. 2. Typology of on-demand services.

cross-organizational interaction when developing and offering the service. The variety of single Web services offered by individual service providers is already vast. Prime examples are services provided by Google such as Google Docs (www.docs.google.com) as a Web-based offering to create and share work online or Google Maps (www.maps.google.com), a map service that can be easily embedded in Web sites or service mashups. Another example that enjoys high popularity is the Amazon Simple Storage Service (S3) (www.aws.amazon.com/s3), a simple Web service that can be utilized to store and retrieve data. On the other hand, not only rather simple, but also complex services supporting multi-step business processes are offered on-demand. For instance, providers such as SaleForce.com (www.salesforce.com) or Netsuite Inc. (www.netsuite.com) successfully entered the business software market with their entirely Web-based on-demand customer relationship management (CRM) suites. Components offered within these suites can be dynamically composed to customized processes. Additionally, Web service marketplaces such as StrikeIron (www.strikeiron.com) recently have emerged, making available platforms for service providers to offer their services via joint distribution channels.

Additional infrastructural services for service providers are quite rudimentary though. Besides a catalogue of offered services and a search function, more sophisticated mediation support is not available. For instance, neither functional integration nor dynamic pricing schemes are provided. AppExchange (www.salesforce.com/appexchange), the application marketplace offered by SalesForce.com, offers a range of pre-integrated complementary services provided by third-party vendors grouped around the core service, Salesforce CRM. However, each Web service is based on a common platform and the same core application, which facilitates the provisioning of such integrated services. Again, the variety of pricing mechanisms is comparably low, lacking support involving multilateral approaches.

There is further need of research in the field of complex services that are composed of elements provided by different vendors. Thus, we aim to shed light on the Internet-based offering and coordination of composite services by means of an auction mechanism. We raise two main research questions.

First, how can we efficiently find good matches of service offerings that maximize utility across all participants? The core challenge is to handle the complexity of combining different services since a flawless service execution and the requester's valuation highly depend on the accurate sequence of its functional parts. Composite services only generate value through a valid order of their components. Auctions have proven to be particularly useful in such situations in which the conventional ways of establishing price and ownership are inadequate, because costs are difficult to be estimated and to be established (Smith, 1989). Nevertheless, traditional approaches in the area of combinatorial auctions are not suitable to enable the trade of composite services, since the sequential dependencies of services are not being considered. Besides with the mechanism design requirements of individual rationality, allocation efficiency, and incentive-compatibility, it is essential that such a mechanism solves the *winner determination problem* in polynomial time and that it is capable to aggregate different complex service attributes.

Second, how can we explain the strategic behavior of service providers? From the providers' perspective, is it beneficial to offer one single service or to offer a service bundle together with complementary services from other providers? Consequently, we study providers' strategies depending on how they are situated within the network. From the results of our analysis we derive strategic recommendations for service providers in such an Internet of services.

This paper is structured as follows Section 2 reviews of the literature. Section 3 introduces a formalization of a service value network that serves as the basis for our bidding language and mechanism design. The mechanism is presented in detail and the