The supply chain of enterprise software
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Chapter 6

A business perspective on web service composition

6.1 Introduction

Delivering software functionality as a service over the Internet is becoming increasingly popular. Ranging from basic services such as the search engine of Google to complete applications such as the customer relationship management system of Salesforce.com, the widespread adoption of software as a service (SaaS) gives rise to new supply chain structures in the software industry.

Traditionally, software products are sold and delivered through an extensive network of resellers, which add value by distributing the software, installing it on the customer’s hardware, and tailoring it to the customer’s specific requirements (see Chapter 5). However, if the current trend towards SaaS continues to develop, significant changes in the industrial organization of the software industry can be expected as traditional intermediaries such as resellers are now longer required. Instead, proponents of SaaS paradigm envision a supply chain structure in which service providers publish their web services on registries, where customers can find and then invoke them (Curbera et al., 2003; Huhns and Singh, 2005). Some of these services are directly invoked by end users, while others are composed by so-called service aggregators to create new services that are capable of performing higher-level business transactions (Yang, 2003; Orriëns et al., 2004). The resulting composite services may be used as applications or again be used as building blocks in further service compositions (Papazoglou and Georgekopoulos, 2003).

Most researchers analyze web service composition from a technical perspective by focusing on issues like ontologies, modeling languages for web service description and composition, and message mediation. This more technology-oriented type of research is important because it provides the means to bringing service-oriented computing to its full potential: dynamic discovery and composition of web services; see e.g. Fensel and Bussler (2002).
However, it does not directly contribute to a better understanding of the market conditions under which service aggregators can make a profit by offering a composite service. In order to assist potential service aggregators in deciding whether or not to enter the market, this chapter develops a quantitative model for estimating and predicting whether the accumulated benefits from offering the composite service are sufficiently large to compensate for the total cost of developing and operating the service. Our focus will be on the e-commerce domain, where firms use web services to create an online channel for communication, transaction, and sometimes even delivery (e.g. information goods). Airlines, for example, support their online customers throughout the purchasing process by providing several web services, such as ‘search flights’ (communication), ‘book flight’ (transaction), and ‘online check-in’ (delivery). In such a setting, service aggregators can add value by providing composite services that enable customers to acquire the products or services of various suppliers from a single source, thereby reducing the transaction cost that a customer would incur if he or she were to invoke the web services of the different suppliers directly.

The remainder of the chapter is organized as follows. First, the basic concepts and principles behind service-oriented computing are introduced. Then, the functions performed by service aggregators in the e-commerce domain are identified and discussed by comparing and contrasting two examples: the first example considers an online travel arrangement service that allows customers to book multi-city trips; the second example considers a flight comparison service that allows customers to compare the flights provided by different airlines. Subsequently, the basic version of our model is constructed and the market conditions under which service aggregators can make a profit by offering a composite service are derived. Next, the basic model is extended to include a multi-period decision horizon. Finally, the chapter concludes with a brief summary and suggestions for further research.

6.2 Service-oriented computing

Web services, i.e. "self-contained, web-enabled applications capable of not only performing business activities on their own, but also possessing the ability to engage other web services in order to complete higher-order business transactions" (Yang, 2003), can be characterized in different ways. In this chapter, we follow the Web Service Modeling Ontology (WSMO), a conceptual model for describing various aspects related to semantic web ser-
6.2. Service-oriented computing

vices. In WSMO, a web service description consists of two elements: the service’s capability and the service’s interface (De Bruijn et al., 2005; Feier and Domingue, 2005; Roman et al., 2006).

The capability of a web service is a formal description of its functionality in terms of preconditions (i.e. requirements on the state of the information space before execution of the service) and postconditions (i.e. the state of the information space after execution of the service). For example, one of the preconditions of a train reservation service could be that the customer must have a valid credit card, whereas one of the postconditions could be that successful execution of the service results in a reservation for the desired trip.

The interface of a web service provides further information on how its capability is fulfilled and consists of two parts: the choreography and the orchestration. The choreography describes the interaction pattern of the web service by specifying what kind of messages are expected as input and what kind of messages can be expected as output, whereas the orchestration describes how the web service makes use of other, more elementary services in order to achieve its capability. Web services that invoke other web services to achieve its functionality are generally referred to as composite services; web services that do not rely on the invocation of other web services are called basic or elementary services (Papazoglou and Georgekopoulos, 2003; Bussler, 2006).

In business-to-business (B2B) situations, web services are often invoked through the use of open, XML-based communication protocols, such as SOAP (Curbera et al., 2002; Huhns and Singh, 2005). This requires service requesters to be aware of the messages that need to be exchanged. The open standard called WSDL has been developed to support service providers in specifying these messages in a uniform way (Curbera et al., 2002). Alternatively, a web browser may be used to mediate communication between a service requester and a service provider. This latter strategy is generally applied in business-to-consumer (B2C) situations, such as online ordering of goods or home banking.
6.3 Web service composition in the e-commerce domain

6.3.1 Example 1: travel arrangement service

Our first example is concerned with an online travel arrangement service (TAS) that enables customers to book multi-city trips. As a use case, consider a customer who wants to travel from Groningen (The Netherlands) to Galway (Ireland). Because there are no direct connections between these two cities, the customer has to divide his or her trip into several legs to reach the final destination. To assist customers in performing this task, the TAS is capable of detecting and generating itineraries automatically. For our use case, two possible itineraries are found: (i) Groningen - Amsterdam (train); Amsterdam - Dublin (plane); Dublin - Galway (train), and (ii) Groningen - Bremen (bus); Bremen - Dublin (plane); Dublin - Galway (train). Based on the provided information on overall traveling time, waiting time between two stages of the journey, and ticket prices, the customer selects the trip that he or she prefers, after which the TAS invokes the web services of the involved public transport providers to make all the required reservations.

6.3.2 Example 2: flight comparison service

As a second example, we consider a flight comparison service (FCS) that allows customers to (i) compare the flights provided by different airlines and (ii) to book the flight that they consider to be the most appropriate. Figure 6.1 shows that the choreography of the FCS consists of five steps. First, the customer specifies his or her traveling request by entering the place of departure, the place of destination, and date of departure in a form generated by the web browser. Next, the FCS invokes the web services of all registered airlines to determine whether they offer one or more flights that comply to the customer’s request and presents the results of this query to the customer. Subsequently, the customer reserves the flight that he or she considers to be the most appropriate by selecting this flight from the list of returned flights and by providing the required passenger information. In the fourth step, the customer is asked to fill in his or her credit card details in order to complete the booking of the flight. Finally, the FCS confirms the booking by generating an acknowledgement, which is presented to the customer via the web browser.
6.3. Web service composition in the e-commerce domain

6.3.3 Comparing the examples

In the first example, the service aggregator adds value by enabling a customer to acquire all tickets required to complete the various legs of his or her trip from a single source. This phenomenon is well-known in retailing, where it is generally referred to as “one-stop shopping” (Oxenfeldt, 1966). The rationale behind it is that customers can save time and money (e.g. cost of traveling, cost of searching for the goods, etc.) by purchasing many items from the same shop. In the second example, the service aggregator adds value by assisting customers in evaluating competing flights from different airlines. This time, the service aggregator performs a different function, called “building up an assortment of goods”: retailers such as grocery stores and supermarkets, for example, usually stock the products of several competing brands in order to reduce the number of unproductive shopping trips made by their customers (Oxenfeldt, 1966; Coughlan et al., 2001).

What is common about these two examples is that both service aggregators add value by providing composite services that enable customers to acquire the products or services of various suppliers from a single source, thereby reducing the transaction cost that a customer would incur if he or she were to invoke the web services of the different suppliers directly. Fig-

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**Figure 6.1:** A schematic overview of the flight comparison service’s choreography.
Chapter 6. A business perspective on web service composition

Figure 6.2 illustrates this point graphically. The left-hand side of the figure shows the number of contacts in absence of the service aggregator. Because there is no channel intermediary, each customer has to exchange messages with each service provider in order to make all necessary reservations and obtain all available flights that comply to the customer’s specifications. For the situation depicted in Figure 6.2, this implies that each customer has to visit three different websites. If, in contrast, each customer invokes the composed web services indirectly by using the composite service (right-hand side of Figure 6.2), the total number of websites that needs to be visited reduces to just one. As a result, a customer’s transaction cost—i.e. the costs incurred when acquiring a product or service, such as the cost of locating the websites of the different service providers, the cost of specifying the service requests, etc.—will generally be lower when the composite service is invoked: the customer does not need to provide the same information (e.g. personal information, credit card details, and date of travel) at several locations, which would be the case if he or she were to invoke each of the composed services individually.

Figure 6.2: The number of contacts required to complete all required message exchanges when (i) each of the composed services is invoked individually (left-hand side) and (ii) the composed services are invoked indirectly by using the composite service (right-hand side).
6.4 Basic model

6.4.1 Model specification

The model considers a service aggregator that attracts potential customers to its website by spending a total amount of $A$ on advertising. Let $V(A) = \alpha A^\beta$ denote the advertising-response function, where $\alpha$ and $\beta$ are a positive constant and the constant visitor-advertising elasticity (i.e. $\frac{\partial V}{\partial A} = \beta$), respectively. It is assumed that $\beta < 1$, which implies that the advertising-response function exhibits diminishing returns to scale: the number of visitors increases with an increase in advertising expenditure, but each additional unit of advertising brings less in incremental visitors than the previous unit did (Hanssens and Parsons, 1993).

From the perspective of the service aggregator, there are two different types of visitor: (i) visitors who make a purchase, and (ii) visitors who leave the website of the service aggregator without making a purchase. Let $q$ be the fraction of visitors who decide to make a purchase, and let $n = qV(A)$ be the total number of purchasing customers. In addition, let $m$ be the number of products (or services) that can be acquired from the website of the service aggregator. It is assumed that the supplier of product $j, j \in \{1, \ldots, m\}$ is charged a commission of $f p_j$ for each unit that is sold through the website of the service aggregator, where $f$ represents the constant commission rate, and $p_j$ represents the product’s sales price (which is determined by the supplier). Let $X_i = \sum_{j=1}^{m} p_j y_{ij}, i \in \{1, \ldots, n\}$ be the value of the purchase of the $i$th customer, where $y_{ij}$ denotes customer $i$’s total demand for product $j$. In the analysis below, we assume that $X_1, \ldots, X_n$ are independently and identically distributed random variables with an expected value of $\mu$.

As a result of offering the composite service, the service aggregator incurs a fixed cost $c_f$, which consists of two main elements: (i) the cost of developing the service, and (ii) the cost of operating the service. The cost of developing the composite service can be further decomposed into the cost of implementing the service’s functionality, which depends on the amount of tool support provided by the underlying implementation technology, and the cost of creating the web interface through which the customer consumes this functionality; the cost of operating the composite service will mainly be determined by the amount of capacity (e.g. computational power, bandwidth, etc.) that needs to be maintained in order to meet peak demand. The variable costs associated with hosting the composite service are negligible, i.e. it is assumed
that the service aggregator operates against zero unit cost.

6.4.2 Analysis

In order to determine the optimal level of advertising expenditure $A^*$, we consider the service aggregator’s profit maximizing problem

$$\max_A E(\pi(A)),$$  \hspace{1cm} (6.1)

where $E(\pi(A)) = E(f \sum_{i=1}^{q\alpha A^\beta} X_i - A - c_f) = f \sum_{i=1}^{q\alpha A^\beta} E(X_i) - A - c_f =fq\alpha A^\beta\mu - A - c_f$ denotes the service aggregator’s expected profit at advertising expenditure level $A$. By taking the derivative with respect to $A$ and setting it equal to zero, we obtain the first-order condition

$$\beta fq\alpha A^{\beta-1} \mu - 1 = 0,$$

which can be solved for $A$ to obtain

$$A^* = \left( \frac{1}{\alpha \betafq\mu} \right)^{\frac{1}{\beta-1}}.$$  \hspace{1cm} (6.2)

The service aggregator is willing to enter the market when the expected benefits from offering the composite service are sufficiently large to compensate for the fixed cost of developing and operating the service. By substituting (6.2) into the profit function and solving it for $c_f$, we can formally express this condition as

$$c_f \leq \left( \frac{1}{\alpha \betafq\mu} \right)^{\frac{1}{\beta-1}} \left( \frac{1 - \beta}{\beta} \right).$$  \hspace{1cm} (6.3)

6.4.3 Example

Consider again the FCS as discussed in Section 6.3.2. In order to parameterize the advertising-response function, suppose that every 2% increase in advertising expenditure will result in a 1% increase in the number of visitors, which implies that $\beta = 0.5$. In addition, suppose that the scale parameter of the advertising-response function is equal to 500 and that the fraction of visitors who decide to make a purchase is equal to 25% (i.e. $\alpha = 500$ and $q = 0.25$). Finally, suppose that all registered airlines are charged a commission of 2% for each flight ticket that is acquired through the website of the service aggregator and that the average value of a customer’s purchase is equal to $225 (i.e. f = 0.02$ and $\mu = 225$).
By substituting these parameter values into Equation (6.2), we find that the service aggregator’s optimal level of advertising expenditure is equal to

\[
A^* = \left( \frac{1}{500 \cdot 0.5 \cdot 0.02 \cdot 0.25 \cdot 225} \right)^{\frac{1}{0.5-1}} = $79,102,
\]

which yields a total number of visitors of 140,625. The corresponding number of purchasing customers is equal to 35,156. The expected benefits from offering the FCS can now be obtained by multiplying the number of purchasing customers by the average value of a customer’s purchase and the fixed commission rate. This yields a total cash inflow of 35,156 \cdot 225 \cdot 0.02 = $158,204. Finally, by subtracting the optimal level of advertising expenditure from the total cash inflow, we conclude that the service aggregator will find it economically feasible to offer the FCS as long as the fixed cost of developing and operating the service does not exceed $158,204 - $79,102 = $79,102. Note that this upper bound on the service aggregator’s development and operating cost could also have been obtained by using Equation (6.3):

\[
\left( \frac{1}{500 \cdot 0.5 \cdot 0.02 \cdot 0.25 \cdot 225} \right)^{\frac{1}{0.5-1}} \left( \frac{1 - 0.5}{0.5} \right) = $79,102.
\]

### 6.5 Extended model

#### 6.5.1 Model specification

In this section, we extend our model from the previous section to include a multi-period decision horizon, keeping the basic terms and definitions of the previous model unchanged. Let \( T \in \mathbb{N} \) be the length of the decision horizon, which is typically ranging between three and five years, and let \( \frac{1}{1+d} \) be the discount factor, which reflects the time value of money (i.e. having \( (1 + d) \) dollar next year is equivalent to having one dollar this year). In order to include intertemporal dynamics into the model, we assume that the advertising-response function has the following shape:

\[
V_{t+1} = (1 - \lambda)V_t + \alpha A_t^\beta, \quad t = 0, \ldots, T - 1,
\]  

(6.4)

where \( V_t \) is the number of visitors in year \( t \), \( t \in \{0, \ldots, T\} \), \( A_t \) is the advertising budget for year \( t + 1 \), \( t \in \{0, \ldots, T - 1\} \), and \( \lambda \) is the visitor decay rate, which represents the decrease in the number of visitors in the absence of promotion (Vidale and Wolfe, 1957). Equation (6.4) has the following interpretation: at the end of year \( t \), the service aggregator determines next year’s
advertising budget $A_t$, which is spent in year $t + 1$ to attract $\alpha A_t^\beta$ new visitors to its website. In addition to these newly attracted visitors, the service aggregator is able to recapture a fraction of $(1 - \lambda)$ of last year’s visitors, which yields a total number of visitors of $(1 - \lambda) V_t + \alpha A_t^\beta$. The costs associated with offering the composite service are divided into an upfront cost of $c_i$, which includes the composite service’s initial development cost as well as the cost of acquiring the required IT infrastructure (e.g., hardware, broadband connections, etc.), and an annual operating and maintenance cost of $c_m$.

### 6.5.2 Analysis

The service aggregator’s objective is to maximize the present value of its stream of profits. The present value of the cash inflows associated with offering the composite service, denoted by $R(V_1, \ldots, V_T)$, can be expressed as

$$R(V_1, \ldots, V_T) = \sum_{t=1}^{T} \left( \frac{1}{1 + d} \right)^t R_t(V_t), \quad (6.5)$$

where the function $R_t(V_t) = E(f \sum_{i=1}^{qV_t} X_i) = f q \mu V_t$ returns the service aggregator’s expected revenue in year $t$, $t \in \{1, \ldots, T\}$. Similarly, the present value of the cash outflows associated with offering the composite service, denoted by $C(A_0, \ldots, A_{T-1})$, is equal to

$$C(A_0, \ldots, A_{T-1}) = c_i + \sum_{t=1}^{T} \left( \frac{1}{1 + d} \right)^t c_m + \sum_{t=0}^{T-1} \left( \frac{1}{1 + d} \right)^{t+1} A_t, \quad (6.6)$$

where $c_i + \sum_{t=1}^{T} \left( \frac{1}{1 + d} \right)^t c_m$ represents the present value of the composite service’s development and maintenance costs, and $\sum_{t=0}^{T-1} \left( \frac{1}{1 + d} \right)^{t+1} A_t$ represents the present value of the service aggregator’s advertising expenditure. By subtracting (6.6) from (6.5) and adding condition (6.4), we can formulate the service aggregator’s multi-period profit maximizing problem as

$$\max_{\{A_0, \ldots, A_{T-1}\}} \sum_{t=1}^{T} \left( \frac{1}{1 + d} \right)^t f q \mu V_t - c_i - \sum_{t=1}^{T} \left( \frac{1}{1 + d} \right)^t c_m$$

$$- \sum_{t=0}^{T-1} \left( \frac{1}{1 + d} \right)^{t+1} A_t \quad (6.7)$$

such that $V_{t+1} = (1 - \lambda) V_t + \alpha A_t^\beta$, $t = 0, \ldots, T - 1$. 
In order to determine the optimal control sequence \( \{A_0^*, \ldots, A_{T-1}^*\} \), we define the per-period profit functions

\[
\begin{align*}
\pi_0(V_0, A_0) &:= fq\mu V_0 - c_i - \left(\frac{1}{1+d}\right) A_0, \\
\pi_t(V_t, A_t) &:= \left(\frac{1}{1+d}\right)^t (fq\mu V_t - \left(\frac{1}{1+d}\right) A_t - c_m), \ t = 1, \ldots, T - 1, \\
\pi_T(V_T) &:= \left(\frac{1}{1+d}\right)^T (fq\mu V_T - c_m).
\end{align*}
\]

These per-period profit functions allow us to reformulate (6.7) as the following dynamic programming problem:

\[
\max_{\{A_0, \ldots, A_{T-1}\}} \pi_T(V_T) + \sum_{t=0}^{T-1} \pi_t(V_t, A_t)
\]

such that

\[
\begin{align*}
V_0 &= 0, \\
V_{t+1} &= (1 - \lambda)V_t + \alpha A_t^\beta, \ t = 0, \ldots, T - 1,
\end{align*}
\]

which can be solved backwardly to obtain

\[
A_t^* = \left(\frac{1}{fq\mu\beta\alpha \sum_{j=1}^{T-t} \left(\frac{1-\lambda}{1+d}\right)^{j-1}}\right)^{\frac{1}{\beta-1}}, \ t = 0, \ldots, T - 1.
\]

The service aggregator is willing to enter the market when the present value of the cash outflows associated with offering the composite service is less then or equal to the present value of the cash inflows associated with offering the composite service. By substituting (6.9) into the profit function and solving it for \( C(A_1^*, \ldots, A_{T-1}^*) \), we can formally express this condition as

\[
c_i + \sum_{t=1}^{T} \left(\frac{1}{1+d}\right)^t c_m + \sum_{t=0}^{T-1} \left(\frac{1}{1+d}\right)^{t+1} \left(\frac{1}{fq\mu\beta\alpha \sum_{j=1}^{T-t} \left(\frac{1-\lambda}{1+d}\right)^{j-1}}\right)^{\frac{1}{\beta-1}} \leq \left(\frac{1}{fq\mu\beta\alpha \sum_{j=1}^{T-t} \left(\frac{1-\lambda}{1+d}\right)^{j-1}}\right)^{\frac{1}{\beta-1}}.
\]

\[
6.5.3 \quad \text{Example}
\]

In order to illustrate the functioning of our extended model, let us reconsider the example of the FCS. In addition to the parameter values provided in the previous section, suppose that the initial investment cost associated with offering the composite service is equal to $200,000 and that the annual operating and maintenance cost is equal to $50,000 (i.e. \( c_i = 200,000 \) and \( c_m = 50,000 \)). In addition, suppose that the yearly interest rate is equal to 10% and that the visitor decay rate is equal to 70% (i.e. \( d = 0.10 \) and \( \lambda = 0.7 \)). Finally, suppose that our service aggregator is willing to wait for at most
Table 6.1: The optimal control sequence \( \{A_0^*, A_1^*, A_2^*\} \).

<table>
<thead>
<tr>
<th>( t )</th>
<th>0</th>
<th>1</th>
<th>2</th>
<th>3</th>
</tr>
</thead>
<tbody>
<tr>
<td>( A_t^* )</td>
<td>143,550</td>
<td>128,130</td>
<td>79,100</td>
<td>-</td>
</tr>
<tr>
<td>( V_t )</td>
<td>0</td>
<td>189,440</td>
<td>235,810</td>
<td>211,370</td>
</tr>
</tbody>
</table>

three years for the initial investment cost to be amortized, which implies that \( T = 3 \).

Table 6.1 provides an overview of the optimal control sequence \( \{A_0^*, A_1^*, A_2^*\} \), which has been obtained by substituting the parameter values \( f = 0.02, q = 0.25, \mu = 225, \alpha = 500, \beta = 0.5, \lambda = 0.7, \) and \( d = 0,1 \) into Equation (6.9). The number of visitors in each of the time periods under consideration are shown as well. By substituting the optimal values of \( A_0, A_1, \) and \( A_2 \) into Equation (6.6), we find that the present value of the cash outflows associated with offering the composite service is equal to

\[
C(A_0^*, A_1^*, A_2^*) = 200,000 + \sum_{t=1}^{3} \left( \frac{1}{1.1} \right)^t \cdot 50,000 + \left( \frac{1}{1.1} \right) \cdot 143,555 \\
+ \left( \frac{1}{1.1} \right)^2 \cdot 128,130 + \left( \frac{1}{1.1} \right)^3 \cdot 79,100 \\
= \$620,160.
\]

Similarly, by using Equation (6.5), we find that the present value of the cash inflows associated with offering the composite service is equal to

\[
R(V_1, \ldots, V_3) = 0.02 \cdot 0.25 \cdot 225 \cdot \{(\frac{1}{1.1}) \cdot 189,440 \\
+ (\frac{1}{1.1})^2 \cdot 235,810 + (\frac{1}{1.1})^3 \cdot 211,370\} \\
= \$591,640.
\]

The present value of the cash outflows exceeds the present value of the cash inflows, so the service aggregator does not find it economically feasible to offer the FCS. For this example, it holds that the length of the decision horizon should be at least four years in order to make it worthwhile for the service aggregator to offer the composite service (i.e. a four-year decision horizon yields a total discounted profit of $44,889).
6.6 Conclusion

Most researchers analyze web service composition from a technical perspective by focusing on issues such as ontologies, modeling languages for web service description and composition, and message mediation. Although this technology-oriented type of research is important, it does not directly contribute to a better understanding of the market conditions under which service aggregators can make a profit by offering a composite service. The quantitative model presented in this chapter can support potential service aggregators in deciding whether or not to enter the market by estimating and predicting whether the accumulated benefits from offering the composite service are sufficiently large to compensate for the total cost of developing and operating the service. Our focus is on the e-commerce domain, where service aggregators can add value by creating composite services that enable customers to acquire the products or services of various suppliers from a single source, thereby reducing the transaction cost that a customer would incur if he or she were to invoke the web services of the different suppliers directly.

Future research can extend our model in various ways. First, it has been assumed that all cash inflows associated with offering the composite service result from the commission fees that are charged to the suppliers of the acquired products or services. In reality, other sources of revenue exist as well, such as advertising banners on the service aggregator’s website or commission fees charged to the buyer of the product or service. Second, in the multi-period version of our model, we have assumed that the scale parameter of the advertising-response function does not depend on the number of visitors in the previous time period. This assumption can be relaxed by including a saturation effect, which can be achieved by letting the scale parameter of the advertising-response function decrease as the number of visitors increases. Finally, it has been assumed that the cost of operating the composite service does not depend on the total amount of use of the service. In practice, however, the amount of IT capacity required to provide a certain service level (e.g. waiting time) will generally increase as the number of visitors increases. Future research may therefore be directed at including this scaling effect into our model.