Auctions for Service Brokerage in Business Value Networks

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1. Introduction

In the past few years a strong trend towards service orientation could be observed: undoubtedly the modern economies develop to service industries. While observing the adaptation of the service mantra in companies, we can identify a trend of replacing traditional applications by fine-grained service infrastructures. This development has fundamentally changed the way complex applications have been engineered in the past. A more business-oriented perspective forms the vision of the next generation Internet as being the "*Internet of Services*" or "*Business Web*". The participants in this future market will offer auxiliary services by extending their core competencies through the consumption of provided services, paving the way for a global service economy in which efficient service procurement becomes a major success factor. Traditionally, industrial procurement for manufacturing processes has been based on hierarchical bill of materials data structures. For complex service offerings we can define a similar concept, namely that of a bill of services. The key issue that arises here is the right choice of service offerings and providers and how to combine them while satisfying constraints such as the minimum and maximum amount of providers as well as appropriate service attributes such as price or quality. For consumers, a service is needed that orchestrates individual offerings into a complex, value added service. Providers on the other hand need to realize economies of scale and/or scope in order to stay competitive. A neutral broker has to employ sophisticated market mechanisms in order to align those requirements.

2. Service Brokerage

In principle, there are a number of services and roles that a broker may perform in a future service ecosystem (Resnick et al., 1994; Bichler and Segev, 1999):

Aggregating and disseminating information: a broker can aggregate information about both, offered and requested services and their functionality as well as prices and willingness to pay.

Absorbing risk: a broker might insure the contracting parties against the risk that the counterparty defaults on the contract.

Establishing reputation and trust: a reputation mechanism can be provided in order to publish and punish defaulting behavior, thus establishing reputation and trust in the service ecosystem that endures a single transaction.

Protecting privacy: in some cases, the service requester or provider prefer not to reveal its true identity to the market. The broker can then act as intermediary, thus shielding a party's true identity while guaranteeing the provisioning of the service. Masaud-Wahaishi et al. (2003) suggest several techniques for privacy-based brokering services.

In our work we focus on the aggregation and dissemination of information. Complex business relationships cannot simply be described using a single parameter. Multidimensional auctions address this issue by taking multiple attributes, units or items into account. We use both, combinatorial (multi-item) and multi-attribute auctions as a market-oriented brokering mechanism.

3. Combinatorial and multi-attribute auctions

According to Cramton et al. (2006), combinatorial auctions (CA) have become a popular and interdisciplinary research topic throughout the past few years. In a CA bidders can place bids on combinations of items, called "*packages*" rather than just individual items. These auctions have found application in various domains ranging from transportation the allocation of spectrum licenses for wireless communication services. CAs can achieve high levels of economic allocative efficiency in the presence of complex bidder valuations (Kwasnica et al., 2005; Ausubel at al., 2006). In comparison to sealed-bid designs, iterative CAs (ICA) have been applied in many practical settings, since they allow bidders to express their preferences by providing feedback, such as provisional pricing in each round. Unfortunately, the use of package bids, as they are used in CAs lead to a number of hard problems.

The Winner Determination Problem (WDP) has to be solved in each round of an ICA to compute a provisional allocation of items to bidders. The main task of determining non-overlapping bids that maximize the seller revenue is NP-

complete (Lehmann et al., 2006). For some restricted cases of the WDP, polynomial-time solutions (Rothkopf et al., 1998) exist. The general WDP for CAs has a straightforward integer programming formulation.

The Preference Elicitation Problem (PEP) of a bidder, which is NP-complete in the number of auction items, is much less studied. In opposition to the WDP, which is solved centrally by the auctioneer, each bidder carries out preference elicitation individually (Sandholm and Boutilier, 2006). The problem can be subdivided into the bundle selection and the bundle evaluation problem. Additionally, the strategy problem of calculating bid prices in various auction formats has been a main focus in the game-theoretic auction literature, but turns out to be difficult to solve for ICAs.

Communication Complexity is related to the PEP and describes the problem of having to transfer an exponential number of valuations from the bidder to the auctioneer (Nisan, 2000).

In a real world setting, these main issues need to be solved efficiently. Under the strong assumption that markets can be structured in tree form, as described by Rothkopf et al. (1998) and Carlsson and Andersson (2005), dependencies (substitutes or complementaries) between goods can be handled in a tractable way. It has been shown that for single-unit, single-sided combinatorial auctions with tree-structured packages the WDP can be computed in polynomial time. It is even possible to extend this to multi-unit double-sided markets. Under certain conditions the computation time is still polynomial. Goeree and Holt (2007) study a hierarchical combinatorial auction format that is based on a simple pricing mechanism tailored for the tree based package structure proposed by Rothkopf et al. (1998) to avoid computational complexity. There, several hierarchy levels of disjoint packages are used with varying package sizes (contained items). In this case, the WDP can be solved recursively in linear time. In iterative auctions, this combination provides the necessary feedback for bidders to derive successful bidding strategies for subsequent rounds and to coordinate responses to aggressive package bids. The design is compared to two alternative designs using laboratory experiments that involve different levels of value synergies. Under their settings, it exhibits high levels of allocative efficiency. Communication complexity is addressed by Cavallo et al. (2005). They introduce a tree-based logical bidding language (TBBL) for preference elicitation in combinatorial exchanges (CEs) (two-sided markets with agents that are both buying and selling items). Its rich semantics allow the language to capture new structures, making it more concise than existing bidding languages for expressing user preferences that can be found in realistic settings for ICAs. The language can represent partial information about valuations, can be used to express complex package demands and is designed in a way that bids can be captured directly in mixed-integer programs for the allocation problem. In summary, TBBL can be regarded as a generic and expressive and powerful bidding language.

4. Summary and conclusions

Our approach to use market-based brokers in Business Webs has the potential to solve the service orchestration problem efficiently. A broker offers services to optimally design complex services, which is essential to stay competitive in an opaque world of service offerings. We transfer current and highly relevant techniques from the area of industrial procurement with a broad acceptance amongst business users to the service brokerage domain. With the aim of deriving practicable auction designs that lead to high levels of economic efficiency, a main challenge of our work is to evaluate and select from a number of possible approaches that impose different trade-offs. Generally applicable solutions are highly demanding with respect to computational complexity and users' cognitive abilities, in contrast to more simple ones, which are more restricted and domain specific.

5. References

Resnick, P., Zeckhauser, R., Avery, C.: *Roles for Electronic Brokers. Toward a Competitive Telecommunication Industry*: Selected Papers from the 1994 Telecommunications Policy Research Conference. Mahwah, New Jersey: Lawrence Erlbaum Associates (1995) 289_306

Bichler, M., Segev, A.: *A Brokerage Framework for Internet Commerce*. Distributed and Parallel Databases 7(2) (1999) pp. 133-148.

Masaud-Wahaishi, A., Ghenniwa, H., Shen, W.: *Brokering services in cooperative distributed systems: Privacy-based model.* In: EC-Web. (2003) pp. 435-444

Cramton P., Shoham Y., Steinberg R., editors: *Combinatorial Auctions.* MIT Press, Cambridge, MA, 2006.

Kwasnica T., Ledyard J. O., Porter D., DeMartini C.: *A new and improved design for multi-objective iterative auctions.* Management Science, 51(3):419–434, 2005.

Ausubel L., Crampton P., Milgrom P.: *The clock-proxy auction: A practical combinatorial auction design*. In Cramton P., Shoham Y., Steinberg R., editors: *Combinatorial Auctions*. MIT Press, Cambridge, MA, 2006.

Lehmann D., Mueller R., Sandholm T.: *The winner determination problem*. In Cramton P., Shoham Y., Steinberg R., editors*: Combinatorial Auctions*. MIT Press, Cambridge, MA, 2006.

Rothkopf M. H., Pekec A., Harstad R.: *Computationally manageable combinatorial auctions*. Management Science, 44, 1131 – 1147, 1998.

Carlsson P., Andersson A.: *A Flexible Model for Tree-Structured Multi-commodity Markets*. CEC 2005: 50-57

Nisan N.: *Bidding and allocations in combiatorial auctions*. In ACM Conference on Electronic Commerce (EC-2000), Minneapolis, MI, 2000.

Cavallo R., Parkes D. C., Juda A.I., Kirsch A., Kulesza A., Lahaie S., Lubin B., Michael L., Shneidman J.: *TBBL: A Tree-Based Bidding Language for Iterative Combinatorial Exchanges.* In Multidisciplinary Workshop on Advances in Preference Handling, 2005

Goeree J., Holt C. A.: *Hierarchical Package Bidding: A Paper & Pencil Combinatorial Auction*, Working Paper, 2007

Sandholm T., Boutilier C.: *Preference elicitation in combinatorial auctions*, in Combinatorial Auctions, Cramton P., Shoham Y., and Steinberg R., editors: MIT Press, Cambridge, MA, 2006.