Combinatorial Clock-Proxy Exchange for Carrier Collaboration

Haoxun Chen

Laboratoire d’optimisation des systèmes industriels (LOSI)
Institut Charles Delaunay (ICD), UMR CNRS 6281, Université de Technologie de Troyes
12 rue Marie Curie, CS 42060, 10004, Troyes Cedex, France
haoxun.chen@utt.fr

Mots-clés : Collaborative logistics, carrier collaboration, combinatorial exchange, combinatorial auction, collaborative transportation planning.

Résumé

Collaboration among small to medium-sized freight carriers are emerging as an effective strategy for them to improve profitability by increasing vehicle fill rates and reducing empty vehicle repositions. An empirical study conducted by Cruijssen et al. (2007) indicates significant benefits of horizontal cooperation in logistics. In carrier collaboration, multiple carriers form an alliance and exchange their transportation requests so that each carrier can find its complementary requests from other carriers while outsourcing unprofitable requests. One problem for carrier collaboration is to optimally exchange requests among carriers so that their total profit is maximized. This request exchange among carriers can be realized by using a centralized approach based on a global mathematical programming model or by using a decentralized approach such as combinatorial auctions or exchanges. Because carriers are generally autonomous units or even competitors, they don’t want to reveal their confidential business data such as transportation costs and prices paid by their customers for serving requests to other carriers. For this reason, the dominating approach for collaborative transportation planning is combinatorial auctions (Ackermann et al., 2011, Dai, et al., 2014). A combinatorial auction may be a single round sealed-bid auction or an iterative multi-round auction. In the first case, all carriers first submit their bids (desired bundles of requests and associated prices) to the auctioneer, who then determines which carriers are the winners and which bids are the winning bids of this auction by solving a winner determination problem. In the second case, the auctioneer determines/updates the price for servicing each outsourcing request, and each carrier determines which requests to acquire from the other carriers based on the prices announced by the auctioneer in each round. The main problem for the implementation of a single-round combinatorial auction is that each carrier who is a bidder has to identify one or few desired bundles of requests from an exponential number of possible bundles. This problem may be intractable in terms of computational complexity. On the other hand, an iterative multi-round combinatorial auction may suffer from the difficulty of reaching market-clearing prices, which may lead to an inefficient request allocation. Moreover, most combinatorial auctions proposed in the literature are not well adapted to carrier collaboration since all carriers are both sellers and buyers. Since each carrier plays double roles in carrier collaboration, it is natural to apply combinatorial exchanges rather than combinatorial auctions for the exchange of requests among them. However, to the best of our knowledge, no previous study applied combinatorial exchanges to carrier collaboration.

In this paper, we consider carrier collaboration in less-than-truck load transportation, where multiple carriers exchange their pickup and delivery requests with service time windows in order to improve their profitability. Each carrier has two types of requests: reserved requests that must be served by itself or exchangeable requests that can be outsourced to other carriers. Motivated by the clock-proxy
auction proposed by Ausubel, Cramton, and Milgrom (2006), we develop a combinatorial clock-proxy exchange for carrier collaboration. This exchange has two phases. The first clock phase is an iterative exchange. In each round (iteration) of the exchange, the auctioneer announces an anonymous linear outsourcing price for each exchangeable request. Each carrier (bidder) responds with a list of requests to offer (sell) and a list of requests to acquire (buy). The outsourcing prices are then increased for requests without demand, i.e., the requests that no carrier bids for, while other outsourcing prices remain unchanged. This process is repeated until demand equals supply for all requests or there is no request without demand. In the second proxy phase, each bidder first submits a set of supplementary bids as well as all its bids submitted in the clock exchange phase to its proxy agent. The proxy agents then bid in an ascending package exchange on the behalf of their real bidders. Each proxy agent bids straightforwardly to maximize the profit of its real bidder, while the objective of the auctioneer is either to maximize its revenue or to maximize the efficiency of the exchange, i.e., the total profit of all carriers.

The clock exchange is designed based on Lagrangian relaxation. In order to do so, a centralized planning MILP model for carrier collaboration is first formulated with the constraints that the number of carriers bidding for each exchangeable request equals the number of carriers offering the request. The outsourcing prices of the exchangeable requests correspond to the Lagrange multipliers associated with the constraints.

The supplementary bids submitted by each bidder (carrier) to its proxy agent are determined based on the information observed by the bidder in the clock phase. In each round of the clock exchange, two types of information can be collected by each carrier (bidder). One is the price information of each exchangeable request, and the other is the demand deficit/surplus of each request in each round.

The performance of the Combinatorial Clock-Proxy Exchange (CCPE) for carrier collaboration was evaluated on randomly generated instances. Two sets of 10 instances were tested. Each instance in both sets involves 3 carriers, 2 vehicles for each carrier, 15 or 24 transportation requests. Other data of these instances were randomly generated. We tested two mechanisms for price updating in the clock exchange phase: the ascending mechanism and the walrasian mechanism. Numerical experiments on the instances show that our CCPE can find an efficient (optimal) request allocation for 14 instances and a quasi-efficient (near-optimal) request allocation for 6 instances tested. They also show that the proxy phase is indispensable for CCPE to be effective and the walrasian mechanism outperforms the ascending mechanism for price discovery in the clock phase of CCPE.

Références


