An Iterative Auction for Carrier Collaboration in Truckload Pickup and Delivery

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The full truckload shipping industry is highly fragmented and competitive. In the full TL freight shipping industry, a carrier operates a fleet of trucks to pick up and deliver customers' TL freight requests. After delivering a request, a truck typically runs empty on the way to pick up the next request or backhaul. Fulfilling a request generates a revenue but traveling with no freight incurs only costs. To reduce deadhead empty traveling miles, carriers can strategically collaborate with each other by jointly creating ongoing movement of freight that reduces one-way movements and empty traveling miles (Barbara et al., 2012). Request exchange in the collaboration allows carriers to sell or buy requests so that each carrier can strategically optimize their pickup and delivery routes to improve economies of scope and profits.

However, realizing the full benefits of carrier collaboration is challenging. It is generally difficult to optimize the routes that minimize the empty traveling miles even in the centralized setting. Furthermore, the effective collaboration requires the carriers to share their private and sensitive operating cost information. Considering that each carrier is self-interested and aims to maximize his own profit in the collaboration, it is therefore of necessity to design an easily computable and truthful mechanism to facilitate the collaboration among the carriers.

We develop an iterative auction mechanism through multi-round exchange of freight requests. At each iteration of the auction, each carrier first acts as a buyer and places multiple single-request bids (demand); with all the bids from other carriers, each carrier then acts as a seller and decides a bundle of requests to sell (supply). Though a carrier places purchasing bids as a buyer and reveals the selling bundle as a seller, he cannot take both roles at the same time in the exchange. The mechanism optimally decides each carrier to be either buyer or seller and matches the supply with the demand. During the iterations, a carrier may be rotated to different roles and his profit is monotonically increased. The auction continues until no exchange is possible.

The iterative auction mechanism for carrier collaboration in truckload pickup and delivery has the following features. First, the auction mechanism is computationally efficient and introduces flexibility for bidding. The new auction does not require the carriers to evaluate an exponential number of bundles for either selling or buying, and hence reduces computational efforts. The auction neither requires that each carrier can only bid one request at a time, which typically stops too soon and results in high efficiency gap Li et al. (2015). Instead, each carrier is allowed to bid for multiple requests and propose a bundle for selling. In this way, the rate of matching the demand

with the supply can be high while the efficiency gap is small. Furthermore, our auction separates the buying and selling decisions of a carrier, so that there is no competition on the sellers' side but only on the buyers' side. In this way, the bidding process is simplified for the carriers and it guarantees that the supply always has a demand. Second, the mechanism is proved to be incentive compatible, individually rational, and budget balanced. In addition, the auction can monotonically increase the carriers' total profits and converge in finite steps, as shown by both theoretical proofs and evidence from computational experiments. Computational results show that the auction converges fast, the efficiency gap is typically less than 2.5%, and the profit of a carrier is improved by more than 4% on average. Finally, we show that the auction mechanism can be extended to the case with transactions cost with minor changes and the theoretical results still hold.