Design and Analysis of Dynamic Batching Policies for E-Commerce Order Fulfillment

Keywords: Dynamic batching, Parts-to-picker system, E-commerce order fulfillment

Extended Abstract:

In today's competitive era of e-commerce, companies are struggling to provide a wide range of products with fast delivery to the end consumers. One of the most important metric to meet customer's expectations, is the order fulfillment time which is the time from receiving an order to the time it gets delivered to the customer. An efficient order picking process can minimize the time for retrieval of required order items from storage. In this research, we attempt to improve order picking performance through efficient order batching strategy. We particularly focus on reducing item picking process times by investigating how to design and operate dynamic batching policies in parts-to-picker systems.

E-commerce orders require piece picking because most of the order sizes are one and there could be item commonalities between orders that can be leveraged for improving the throughput times in the picking process. There are two primary piece picking systems, employing humans: (1) a picker-to-parts system, where a human order picker travels to the aisles to pick the items, and (2) a parts-to-picker system, where using automated storage and retrieval system, items are brought to pick stations manned by human operators (De Koster et al., 2007). A parts-to-picker system is efficient because it eliminates the need for the pickers to navigate the aisles but at the same time, it has high infrastructure cost.

The piece-picking of orders in a parts-to-picker system can be implemented in three ways, namely, sequential processing, static order batching, and dynamic order batching. In sequential processing, orders are fulfilled one at a time on a first-come, first-served (FCFS) basis. Hence, the orders are released as soon as they are completed, which is beneficial for meeting the order fulfillment deadlines. Also, the order picker is concerned with only one order at a time so less space is required at the pick station. However, sequential processing can increase the total order picking time for all orders because it does not leverage the presence of commonalities of items among the orders. In static order batching, different orders are combined in a group (based on characteristics such as item commonality, or identical due dates) and processed simultaneously. An order is released when all the orders in its batch have been filled. Therefore, the release time of an individual order greatly depends on the batch size and the order profiles of the other orders in the batch.

In dynamic batching, multiple orders are processed in parallel but an individual order is released as soon as it is complete. The leaving order is replaced by another order to keep the order batch size constant. This dynamic batching policy combines the advantages of both sequential processing (by meeting individual order deadlines) and static order batching (by fulfilling orders in batches thereby reducing the completion time per order leveraging item commonalities). The execution of a dynamic batching policy in a distribution center necessitates investment in a complex and expensive material handling system that enables the release of order totes which violate FCFS queue discipline (see RapidPickTM System developed by Dematic).

While there has been substantial research on how to design batching strategies in picker-to-parts systems (see Bukchin, Khmelnitsky et al. (2012) and the references within), the literature on batching in parts-to-picker systems is limited (e.g., see Pazour and Meller (2012) for batching in S/R machines), and we are not aware of any work that considers a dynamic batching policy. The goal of this research is to understand how best to design and operate a dynamic batching system in a parts-to-picker system. Specifically, we are interested in how the order batch size, item commonalities among orders, wait for items, item pick time and tote-interchange time can affect the performance of dynamic batching policy. Specifically, our research questions are: 1) What is the throughput of a pick station that uses a dynamic batching policy? We will explore various environmental factors (such as item commonality between orders, batch size, and order delivery deadline schedules), and 2) What is the effect of alternate dynamic batching technologies on system performance?

We develop a two-level stochastic model to answer our research question. In level 1, we model the changing mix of order profiles in the order batch, using a Discrete Time Markov Chain (DTMC). In level 2, we analyze the performance of the system with a multi-class closed queuing network corresponding to a specific mix of order profiles. Level 2 models the three activities involved in the order fulfillment process - 1. Waiting for the required item tote; 2. Picking item from the item tote and putting the item into the order tote; and 3. Waiting for the placement of all required items in the order tote to complete that specific order. The new analytical contribution here is to develop approximations to the throughput of the overall pick station and, throughput performance for specific order profiles.

References:

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