Chapter 4
Assessing Multi-Site Distributed Coordination in Dynamic Assignment of Time-Critical Entity via Agent-Based Simulation

Yu Teng
Purdue University, USA

Nan Kong
Purdue University, USA

ABSTRACT
This chapter investigates distributed coordination in dynamic assignment of time-critical entities among multiple sites. The authors develop an agent-based simulation model in which each agent applies some adaptive assignment rule to match supplies and demands that are generated at its own site. They assume each agent has autonomy to design its hierarchical assignment rule and update it based on periodical review of its assignment performance. The authors model the benefit of each assignment based on the life spans of the resource and the need, and a distance measure between them. They consider two distinct centralized initial assignment rules and assess how agents update their rules. The authors also evaluate the impact of different agent environments, numbers of supply/demand agents, and ratios of supply/demand rates.

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INTRODUCTION

In general term, dynamic assignment deals with the problem of assigning resources from suppliers to needs from recipients over time. The amount of available resources on the supplier side and the needs on the recipient side for the resources are given at each time point although they may vary over time. The problem intends to dynamically update the assignment in a way that one or several of the following goals are achieved.

1. **Overall Benefit**: The total benefit generated by the assignments should be maximized.
2. **Recipient Fairness**: The deviation on the relative amount of resource given to the recipients should be kept as small as possible. By “relative amount of resource”, we mean the amount of resource a recipient receives divided by the amount of resource it demands. This is one possible way to describe consumer fairness in a dynamic assignment problem.
3. **Supplier Fairness**: The deviation on resource utilization among the suppliers should be kept as small as possible. As in the previous goal, this is also a fairness measure, but from the supplier side.

The problem arises in many applications in manufacturing (Harris, Cook, & Lewis, 1998; Sennott, 2006), transportation (Powell, 1996; Psaraftis, 1980; Yang, Ye, Tang, & Wong, 2003), and telecommunication (Buddhikot, 2007; Everitt & Manfield, 1989; Zhao & Sadler, 2007). It is common to assume that the arrivals of resources and needs are random (e.g., known only through a probability distribution) over time. It is also often the case that resources and needs are only available for a period of time, and the quality and desirable level of a resource varies over time. Each assignment generates a contribution to benefits, which may also be random. In a centralized allocation system, the assignment activities follow some centralized rule, which is either predetermined or varies according to the resource and need conditions. However, the rule is determined by a centralized decision maker and specified uniformly to all suppliers and to all recipients. On the other hand, in a decentralized allocation system, the assignment activities can follow different rules specified by individual suppliers and recipients. These entities in the system may take an adaptive approach to modify their own rules with the changes in the assignment environment. Even though each entity designs its own assignment rule adaptively, system-wide coordinative behavior may gradually emerge. Research on coordination and distributed resource allocation has been extended in the design of future-generation wireless networks who must cope with the scarcity of the spectral resource in areas with heavy user demand. We refer interest readers to a tutorial by (Gesbert, Kiani, Gjendemsjø, & Øien, 2007).

In this chapter, we apply agent-based simulation to investigate distributed coordination in dynamic resource assignment and sharing within a multi-site system, in which both resources and needs can arrive at any site. We assume that suppliers and recipients are each characterized by a set of possible unique attributes, where the contribution generated by an assignment depends on the attributes of the involved supplier and recipient. One important attribute is the location of the supplier or the recipient. We also assume that the benefit of an assignment decreases with increased delay along the assignment process, which is commonly made for time-critical resources and needs.

We consider two distinct assignment rules as the initial rules, with which suppliers either behave according to their own interests (egoism) or according to the overall societal interest (altruism). We next explore the impact of decentralized rules that are adaptive and can be different across the sites. We assume that only the supplier at each site has the autonomy to alter its assignment rule by a simple rational decision making process, depending on the assignment performance at the site.