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The decentralized field service routing problem

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ABSTRACT

Companies that provide service at geographically dispersed locations face the problem of determining the technician that will serve each location as well as setting the best route for each technician. Such a scenario is known as the field service routing problem. Large companies often outsource their field service tasks to several contractors. Each contractor may serve several companies. Since the contractors cannot share the information about the tasks of their other clients, the most common practice involves allocating the tasks to the contractors heuristically based on geographical considerations. In this approach, the tasks for which the contractors have already been committed to other companies are not considered. As a result, the allocation of new tasks can be inefficient. This study develops 2-stage task allocation mechanisms that cope with the problem and result in nearly optimal allocations.

In the first stage, a feasible allocation of tasks to contractors is generated. We consider two possible allocation procedures: sequential combinatorial auctions and sequential negotiations. The sequential combinatorial auctions procedure implements the Generalized Vickrey auction, which is a strategy-proof mechanism for the allocation of multiple goods among several competing agents. A sequential negotiation method is suggested as an alternative task allocation mechanism. The method automates a multi-lateral negotiation process in which the company is the leader, and the contractors are followers. In the second stage, the contractors are allowed to exchange the tasks among themselves so as to decrease their operational costs. The exchanges may or may not include money transfers.

We found that the first-stage procedures yield fairly efficient allocations and the second stage further improves them. The obtained allocations are considerably more efficient than the solutions generated by a reasonable benchmark heuristic. Moreover, the allocations' costs are close to a lower bound established by the optimal allocation of a central planner. That is, the price of decentralization is shown to be small.

1. Introduction

Field service organizations operate in a dynamic, ever-changing world that combines long-range planning with emergency responses. Both temporal and spatial aspects are pivotal in the operation of field service systems. The former is important because the working hours of field service personnel cannot be stored and used later, and the latter is important because the locations of the demand points are typically spread over a large geographical area.

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The standard approach in practice and the main research direction in the literature are based on a centralized view. A central planner who is assumed to have access to all the relevant information determines the schedules and routes of all the field crews in order to optimize an objective function, which represents the total cost of the operation. Commercial software packages support this approach.

In recent decades, many organizations have outsourced their field service operation to contractors. In particular, the field service of a single company is outsourced to multiple contractors who, in turn, may serve other companies, and their geographic coverage areas may overlap. In such a market configuration, planning of the field service operation of a company cannot be carried out centrally. Moreover, since the company has no access to the information about the tasks of other companies served by the contractors, it cannot allocate its service tasks efficiently. In practice, the allocation of service tasks to the contractors is carried out based on some simple arbitrary rules. A smarter coordination mechanism that results in a more efficient operation, profitable to both the company and the contractors, is needed. This observation is based on personal communications with researchers and managers in a leading software company in the domain of Field Service Management (Beniaminy, 2013; Kolka, 2017).

In this paper, we consider the problem of a service company that wishes to allocate service tasks to contractors in a manner that allows for an efficient solution of the routing problem later faced by the contractors. We refer to this problem as the Decentralized Field Service Routing Problem (DFSRP). The input of the problem consists of a set of tasks and a set of contractors. Each task is characterized by its location and service time. In addition, each contractor is pre-committed to his own set of tasks, which are not revealed to the company. Each contractor is interested in maximizing his revenue net of the labor and routing costs. The company, on the other hand, aims to minimize its payments to the contractors. However, because the business relations between the parties are of a long-term nature, the company also wishes to maintain the profits of the contractor at a reasonably high level.

Centralized versions of the Field Service Routing and Scheduling (FSRS) problem have been the prime focus of many studies carried out in the recent decades. We discuss several representative papers that highlight important aspects of the state of the art.

Beniaminy et al. (2009) introduce several solution methods for the FSRS problem. First, a genetic algorithm, in which each gene in the chromosome is a pair (R_i,D_j) implying that demand D_j is assigned to technician R_i, is presented. Elective chromosomes along with crossovers and mutations comprise the next generation of the population. Next, the authors present an Ant Colony Optimization (ACO) algorithm in which separate pheromone tables for each resource are created. This algorithm is amendable for parallelization. Finally, a Greedy Randomized Adaptive Search Procedure (GRASP), modified to include pheromone tables, is suggested. The genetic algorithm and the ACO are found to perform well for a complex instance with 620 demands and 88 resources with different skills.

Cortés et al. (2014) consider a real-life setting of the FSRS problem. The planning horizon is one working day. Each customer has a soft time window and a different priority related with that window. Scheduling a customer to be served in the next day is allowed but bares a penalty. The objective function is minimizing a weighted sum of travel cost, lateness cost and the penalties incurred by postponing the service to the next day. The authors develop a Branch-and-Price algorithm that utilize a constraint programming framework in the column generation phase. Numerical experiments are used to demonstrate the applicability of the method.

Kovacs et al. (2012) also study a variant of the FSRS problem. The problem consists of a set of geographically dispersed tasks that needs to be served during a single day by a set of technicians. Each technician possesses certain skills. Each skill has several levels of expertise. Each task requires one or more skills at some level. Each task may or may not have a related time window. Outsourcing of tasks at a given cost is allowed. The authors aim at finding the allocation of the tasks to the technicians that minimizes the total cost of routing and outsourcing. The authors also consider a version of the problem where, for some tasks, no single technician possess all the required skills. In this case, the problem also deals with grouping the technicians to appropriate teams. The two versions of the problem are solved by ALNS algorithms.

Zamorano and Stolletz (2017) study a similar problem and consider a planning horizon with multiple periods. They aim at finding weekly schedules that minimize the total cost of routing, customer waiting and overtime. A weekly schedule is obtained by solving three allocation problems for each day of the week: (1) The daily grouping of technicians to teams, (2) the allocation of teams to tasks and (3) the creation of daily routes. Each task has a set of possible time windows. The authors present a mixed integer linear programming (MILP) formulation of the problem and two versions of a Branch-and-Price solution strategies.

Pillac et al. (2013) solve a dynamic version of the FSRS where the service requests over time. The service requests are characterized by time windows, required skills, tools and spare parts. These requests may be rejected at a given penalty. Technicians may replenish their spare parts and tools at a central depot at any point of the day. The objective function is to minimize the total routing and penalty costs. The authors argue that the sequence by which requests are served as well as which requests are rejected should be determined dynamically. They present two solution methods for the problem based on parallel adaptive large neighborhood search (pALNS) and on a multiple plan approach (MPA). Numerical experiments show that the pALNS outperforms the MPA method considerably.

Souyris et al. (2013) present a robust optimization method for the FSRS with stochastic service times and soft time windows. The objective function is minimizing the sum of total travel time, total lateness time and total penalty incurred if service is postponed to a later period. The authors explore a version of the problem where service times are correlated and the total service time does not exceed some threshold. The authors present a set-partitioning model for the problem and