A comparison study of metaheuristic approaches for the earliest arrival flow problem

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Network flow is an important topic in combinatorial optimization. Static network flow models have been well known as valuable tools for many applications [1]. However, these models can not consider the evolution over time of several real life applications such as evacuation planning, communication systems and financial problems. Thus, dynamic network are introduced firstly by Ford and Fulkerson [4]. In dynamic netwotk, flow takes time to pass an arc, the flow can be delayed at nodes and the network parameters (capacity and travel time) can change over time. Several dynamic network flow problems have been treated with dynamic network [3] [4]. In this paper, we deal with the earliest arrival flow problem.

Given a dynamic network $G = (N, A, T)$, where each arc $(i, j) \in A$ has an associated capacity $u_{ij}(t)$ and a transit time $\lambda_{ij}(t)$ for each unit time $t \in [0, T]$, the flow over time that simultaneously maximizes the amount of flow reaching the sink for every interval $[0, t]$ is called the earliest arrival flow (EAF).

Gale [5] showed, in discrete and continuous time respectively, the existence of an EAF on a single-source single-sink network. Minieka [6] have proposed polynomial algorithms for the EAF with constant parameters. EAF with time-dependent attributes has been treated later by Tjandra [7]. In the case of flow-dependent transit time, Baumann [2] have showed that the earliest arrival property can not be verified. This means that if we try to maximize the flow at each unit time, we can't obtain the maximum at the end of the horizon time. Hence, they proposed a relaxation which looks for the maximum flow with minimum lateness which is NP-hard problem.

Metaheuristic algorithms have a good potential for resolving various NP-hard problems since they use strategies to escape local solutions and to allow the search space to be explored efficiently [8]. This paper presents two metaheuristic approaches to solve EAF with flow-dependent transit time. The first one is based on ant colony optimization where ants simulate flows and the pheromone information defines the transit time from the given node to the destination depending on the crowdedness in this path. The second one is the genetic algorithm where the solution defines the flow on each node at each unit time. Experimental results are performed in real case study of evacuation planning in the cardiology department in the Charles Nicolle hospital in Tunisia. Comparison results between these approaches are provided.

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