Flow problems resolution for strategic airline network planning

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Introduction

An airline network consists in a combination of basic elements called flight legs. These flight legs are characterized by a departure date and time at a certain airport, an arrival date and time at another airport and a specific aircraft. However, airline networks are of various types, from highly connected to sparse ones [1]. One of the most important challenge faced by airlines when creating one's own airline or expanding an already existing airline's network is to develop an optimal strategy network planning. This latter raises several issues concerning the constraints and parameters to be taken into account:

- Find the combination of departure and arrival airports to get an interesting network,
- Schedule properly the flight legs,
- Assign the best aircraft size on each specific scheduled flight leg,
- Get the succession of flights performed by the same aircraft on a specific week,
- Assess the number of aircraft needed to perform an assigned and scheduled flight planning,
- Schedule the maintenance tasks,
- Establish the crew planning.

In this work, we tackle two of the major topics amongst network planning steps: the fleet assignment and the rotations of the aircraft. To achieve these objectives, the authors use the flow problems resolution methodology [2]. The next section presents the problem to solve and discusses the results, and the last section concludes this study.

Problem description and results

Let's consider an airline which already knows what flight legs to perform on the network, and when these are scheduled. This airline also has a fleet composed of a certain number of aircraft types, each one having a different size, a different range and a different monthly ownership cost. Performing a specific scheduled flight leg on an aircraft from a specific aircraft type induces a specific profit. The fleet assignment problem comes like this: *what aircraft type should be assigned on each scheduled flight leg in order to maximize the overall profit?*
Let's now assume that each scheduled flight leg is assigned to a specific aircraft type. The rotations' problem is: *what is the minimum number of each aircraft type that is needed to perform all the assigned scheduled flight legs while respecting constraints like a given turnaround time between two flights?*

These two problems are deeply linked and they can both be modelled as flow problems with a time space network (see Figure 1). Each node of the graph represents a given airport at a given time (arrival time or departure time of a flight at this airport). There are two types of edges: some edges represent scheduled flight legs between two airports (the black edges on Figure 1), while the rest of the edges represent a stay at an airport (the blue edges on Figure 1). The graph also contains a source and a sink, linked to the first and the last time steps for every airport.

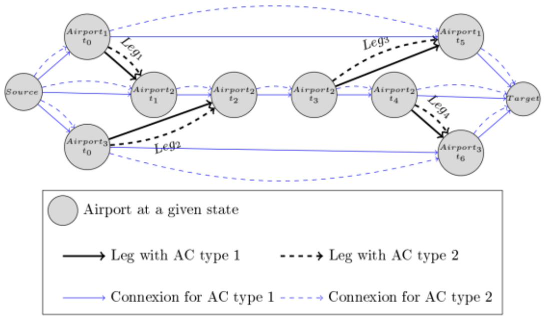

FIG. 1: An example of a network with two types of aircraft

In the fleet assignment problem, the edges representing the scheduled flights legs are duplicated for each possible aircraft type. Each of these edges are valued with the corresponding profitability, and the goal is to choose one edge amongst the parallel ones while maximizing the overall profitability. A frontal mixed integer linear program is solved to get the fleet assignment result.

In the rotation problem, one time space network is created per aircraft type. The minimum flow is computed on this network. An iterative shortest path procedure is then applied to extract efficiently feasible successions of assigned scheduled flight legs. These successions are called rotations, and the result gives the minimum number of aircraft used, without economic considerations.

With this time space network approach, the fleet assignment result can directly processed to extract the rotations. Indeed, both problems are intricate in the way that the fleet assignment model, by essence, gives the number of aircraft for each aircraft type needed to be used for the rotations. Furthermore, the shortest path method is very efficient to extract rotations. Results are given within seconds whatever the size of the network is, even for the biggest airlines.

Conclusions and follow-up

This approach is in line with a full bottom up approach of strategic network planning, also considering route identification, scheduling and tail assignment with maintenance planning. The methodology used here allows to have fast results for strategic network assignment and rotations, which logics are still operationally valid.

The next identified steps would be then be to develop an embedded model with scheduling [3] and to intricate more constraints relative the maintenance and the crew rotations as a strategic level. To be more realistic, trajectory optimization models developed within Airbus' Airline Sciences team would also be integrated to compute realistic flights and their economics. Also, a realistic estimation of time on the ground provided by Air Traffic Management studies would increase the accuracy of the rotations.

References

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