NETWORK DELAY MULTIPLIERS AND AIR TRAFFIC MANAGEMENT

Felix Mora-Camino[1], Georges Mykoniatis[1], Li Weigang[2], Oscar Diaz Olariaga[3]
[1]Laboratoire ENAC, Ecole Nationale de l'Aviation Civile, Toulouse, {felix.mora@enac.fr}
[2]TransLab, University of Brasilia, Brazil, {weigang@unb.br}
[3]Facultad de Ingeniería Civil, Universidad Santo Tomás, Bogotá, Colombia
{OscarDiazOlariaga@usantotomas.edu.co}

Keywords : *Air traffic, network delays, slot assignment, collaborative decision making.*

1 Introduction

Congestion in transportation systems is considered to be a limiting factor to economic growth. Many transportation systems are composed of a discrete set of companies working between a limited set of transportation terminals where endogenous congestion affects individual arrival and departure operations. This is particularly the case when considering a domestic network of airports linked together by an air transportation system. Collaborative Decision Making (CDM) has been developed recently to deal with the coordination of activities addressed to the processing of vehicles between their arrival and departure at an airport. In this paper, a Network Collaborative Decision Making approached is proposed to cope globally with the congestion of a distributed air transportation system. Network performance measures are developed for each airline, introducing equivalent delay multipliers for its flights while equity concepts, such as non-inferior solutions, between operators are considered at the level of each airport. Then slot allocation algorithms can be designed to manage with more equity and efficiency the arrival and departure capacity at the different airports of the considered air transportation network.

2 Slot allocation at airports

A slot can be defined as the authorization given by airport authorities to use all the facilities necessary to provide an air traffic service, on a concrete date and time, before a departure or after an arrival. In this section, for sake of brevity, only arrival traffic at airports is considered. Here it is assumed that the air traffic manager's objective is to maximize the available capacity by distributing the available slots among the flights as soon as it is possible to do it. This leads the initial flight schedule to be compressed by moving some flights forward in the schedule so they can occupy empty slots before theirs. These flights, at the same time, will free the slots they had been previously assigned so other flights might occupy them. Various compression algorithms have been developed by the air traffic management authorities. In general these algorithms work on an initial slot allocation and the earliest arrival time of flights. They allow not only to assign flights to slots, but also to redefine in some fair way the slot user-rights of the airlines.

3 Modelling flight schedules in airlines networks

In this section we introduce a mathematical representation of the flight schedule of an airline to be able to compute cumulative effects in network delays. Here the daily operation of an airline is seen as a set of tasks, the flights, performed successively or in parallel using resources such as aircraft and crews. Aircraft and crews are separately attached to flight pairings covering the whole set of daily flights. The succession of flights is constrained in different ways: Flight connections introduce sequential constraints between flights (these constraints are effective if there are passengers using these connections), shared aircraft and crew resource will also introduce constraints between flights. What will not be published is the information about the identity of aircraft and technical and commercial crews which correspond to the airline mobilized resource to perform the flights. In fact feasible pairings of aircraft and crews should be defined to give support to the realization of the flights.

4 Effective delay multiplier

In 1998 Beatty et al [3] introduced the concept of delay multiplier to evaluate the delay propagation in an airport network. Here, different delay multipliers can be defined for the delayed departure of a flight given the current operational situation of the airlines network: a sliding mean delay multiplier, a mean delay multiplier and a maximum delay multiplier. It appears that the importance of an additional delay to a flight *f* can be assessed in different ways using different indexes. One of them is the total induced delay, another one is the closeness to the maximum allowable delay beyond which an airline schedule is no more feasible. Then to get a unique delay index at a given time and place for a flight *f*, a new delay index is introduced, the *effective delay multiplier* (*EDM*) is introduced as an increasing function of the total induced delay and a decreasing function of the current maximum allowable delay.

5 Revised network slot allocation algorithm

The consideration of the effective delay multiplier as a mean of ranking concurrent arrival or departure flights within a slot allocation algorithm allows to take into account network effects of slot allocation either at arrival or departure. The effective delay multipliers of the flights are computed on line by the airlines over the subnetwork of flights they operate between the considered airports. Then arrival and departure slot allocation processes can be performed in a decentralized way at the airport level. The considered slot allocation algorithm is basically a compression algorithm where the effective delay multipliers of each arriving or departing flight allow to rank these concurrent flights in a way to manage airport traffic at the network level. The proposed compression algorithm develops then a greedy heuristic based on the effective delay multiplier attached to each flight. A numerical study relative to a medium size network is performed allowing to put into evidence the expected benefits.

6 Conclusion

In this study a Network Collaborative Decision Making approach has been considered to cope globally with the operation of a distributed air transportation system. Airlines network performance measures have been developed for arrival and departure traffic management at airports. Equity concepts, such as non-inferior solutions, between operators have been integrated in the decision scheme when considering airport slot allocation to flights. The proposed slot allocation process operates in a decentralized way by using effective delay multipliers computed by the airlines at the network level to assign priority levels at arriving or departing flights. This should allow to manage with more efficiency and equity the arrival and departure capacity at the different airports composing the air transport network.

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