ON THE FEASIBILITY OF TRAFFIC SYNCHRONIZATION IN CENTRAL EUROPEAN UPPER AIRSPACE

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Abstract

One general hypothesis for future Air Traffic Management (ATM) is that traffic in a flow shall be better organized to increase its performance in terms of capacity and delays savings. This hypothesis suggests a shift from current ATM concept, which is non-synchronized, to a synchronized system with synchronized distance separation between all aircraft evolving in a flow in order to be able to cope with future air traffic demand. This paper presents one first step towards the evaluation of operational feasibility of this concept in Central European Upper Airspace\(^1\): the improvement of controllers’ productivity through adequate task sharing in the traffic synchronization activity. Task sharing is necessary in this case because synchronization time can span over several sectors in Europe. A simple synchronization model is proposed, taking into account (i) the time duration needed to transform the non-synchronized in-bound flows into synchronized ones, and (ii) the variations of conflict situations.

Introduction

The worldwide growth in air traffic after 2003 is characterized by a tangible recovery in daily traffic (2.8% for the whole year). The summer 2004 records an even much higher growth of 5.3% \(^1\) From 2004 onwards, traffic growth in the whole European Civil Aviation Conference (ECAC) area is expected to be approximately 3-4% per year \(^2\), meaning that in 2020 the ATM system shall accommodate about twice as many aircraft as of today. This estimation leads to a serious problem, especially in the enlarged European Union where the citizens become more and more mobile. As a consequence, either air route network has to be extended to accommodate increased air traffic flows, or traffic in flows shall be better regulated with fewer extensions to current route network.

Several studies have been launched recently in Europe and USA aiming to support the future vision of synchronized ATM system with the ultimate goal to fill the gap between the predictive and the adaptive components of ATM systems. The predictive component could be illustrated, taking the case of Europe, by the slot allocation planning performed by Central Flow Management Unit (CFMU) while the adaptive component can be illustrated by the local tactical actions performed by the controllers \(^3\) \(^4\) \(^5\). Several organizational changes have been proposed such as Multi Sector Planner \(^6\), Super Sector \(^7\), Shift \(^8\), and Traffic Organization \(^9\). Some other studies on traffic organization have investigated the potential of flow synchronization; however they focus mainly on speed control and/or solely on the terminal areas \(^10\) \(^11\).

All above investigations are based upon the hypotheses that when traffic is synchronized, better efficiency for the overall air traffic management system could be reached thanks to the focus on the management and monitoring of traffic flow instead of individual flights. Airport throughput could also be improved since the sequencing is supposed to be organized a priori at the synchronization of flights into a flow. There have been different definitions of synchronization but all above investigations agree that the cooperation between all components of ATM system, (i.e., airlines, control centers, flow management, and airports) is a principal requirement. Our research uses the assumption that traffic synchronization is the flow-wide improvement in performance in terms of synchronized distance separation between all aircraft evolving in a flow. In other words, coordination between control sectors is a necessity since the distance required to synchronize a given traffic could span across several sectors, given the small sizes of sectors in core European airspace.

Among previous studies, the FAM project at EEC has explicitly considered the same assumption. However, none of the above investigations has seriously considered controllers’ acceptability, and in particular for the task of monitoring aircraft’s speed adjustment and assigning flight level to achieve synchronized flows. That may span over several

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\(^1\) this work is funded by the CEATS Research, Development and Simulation Centre (CRDS), Budapest, Hungary.
sectors, and therefore requires collaborative work between controllers. The work presented in this paper is framed within a PhD research that investigates the acceptability of controllers in the collaborative context.

Towards traffic synchronization

Airspace

To achieve traffic synchronization, a given traffic shall be transformed from a non-synchronized state to an ordered traffic. This transformation is necessary for the traffic in-bound from non-synchronized areas, and requires in-depth analysis of its feasibility.

The Central European airspace (CEATS-Central European Air Traffic Services) is chosen for this research because of the characteristics of its traffic: moderate growth (cf. Figure 2) and high percentage of over-flown traffic.

Other reasons for which the CEATS airspace is chosen for this research include:

- Firstly, CEATS Functional Airspace Block is an area with more efficient airspace structure and more effective performance crossing the national boundaries of countries concerned. It will operate large area with more optimized route network and sectorization;
- Secondly, better inter-sector coordination using uniform systems; and
- Finally, the mean route length in the upper airspace is usually twice as long as the 200 km of the lower airspace. Some CEATS ACCs with a large proportion of traffic overlying, the upper/lower mean route length ration can be four.

We expect that the chosen airspace offers high potential for performance improvement with synchronized ATM concept.

Route Network

The synchronized traffic structure involves a part of standardization in the crowded areas where the control system applies the same rules to each aircraft flying in a flow. This structure is the first layer of safety where potential conflicts are removed. Each synchronized flow has its own level & speed; the flow speed fixes the speed of the flights.

Flow consists of aircraft with a common part of the flight path, or part of it spreading on more than one flight level. Adjusting the flow of traffic into given airspace, along a given route or bound for a given aerodrome, so as to ensure the most effective utilization of the airspace is very complex. To simplify this complexity the research pays attention on aircraft speed assignment for given flight level: one speed per one flight level.

The discovery of ‘interesting flows’ depends on both daily traffic distribution and frequency of the aircraft arrivals to CEATS Airspace Block. Initial investigations showed 4-5 main flows (cf. Figure 3), where daily distribution is very high. These flows are indeed relevant for further investigations. Nevertheless we still have to look closer on the frequency, to find the aircraft making journey from CEATS entry point to the exit point and to record the route performed.

Next step is to normalize the counts to remove shorter journeys counted as parts of longer ones and consider only ‘significant counts’ over ‘significant

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2 The activities of CEATS are centered towards improving the operation in this area, where Air Traffic Services are currently provided by different Area Control Centers in Vienna, Budapest, Bratislava, Ljubljana, Zagreb and Padua, and to be replaced by a unique common control center in Vienna, called CEATS Upper Area Control Center (CUAC), planned to start its operation in 2008 [12].

3 The figures for Italy apply to the whole country, not only to the Padua ACC [ref. CEATS Business Plan]
number of points’. In this way, we expect to uncover other interesting flows.

![Figure 3. Daily loading of selected segments](image)

**Envelopes of Aircraft Performance**

Even there is a large percentage of aircraft on a particular flight level that use similar speed, flight data analysis (will be presented later in this paper) shows that the potential speed ranges for the purposes of synchronization are fairly evenly distributed between selected flight levels.

Aircraft’s performance envelope plays a major role in the ability of the aircraft to reach synchronized flight level assigned to the aircraft according to the speed it flies.

**Transition time**

The flow isolates a part of the traffic on particular flight level selected according to predefined rules.

The reserved level & speed are a compromise between the preferred flight level and the preferred speed, and are depending on the characteristics of the airspace and its traffic distribution. Moreover, the aircraft performance (ceiling level) is also a limiting factor for joining the flow.

To build synchronized traffic, the transition time to evolve from non-synchronized inbound to a more organized traffic is necessary. For example, supposing that FL 360 and 370 have been selected for synchronization with predefined speed range 446-450 NM/h. Both flight levels are currently used by different aircraft with different performances. The aircraft falling into these predefined speed ranges must be rerouted from different flight levels to join the synchronized flow once they cross the CEATS boundary. All the other traffic has to be rerouted to another flight levels.

The Target Flow is defined by:
- the Assigned Flight level ($A_T$)
- the Target Speed ($V_T$) (desired speed of the flow)

**Transition time:** $t = f(V, A)$

Where each aircraft $i$ is defined by:

**Actual speed $V_i(t)$**

**Actual Flight Level $A_i(t)$**

The goal is to change:

- $V_i(t) \rightarrow V_T$
- $A_i(t) \rightarrow A_T$

The transition time ($T_t$) differs for each flight and depends on traffic density and the availability of the selected flight level (cf. Figure 4). In particular, to evolve without delay or conflict from a non-synchronized flow to a synchronized one is of high importance in the monitoring of expeditious and safe air traffic flow.

![Figure 4: Transition time](image)

The question is: How much time is needed to transform non-synchronized traffic into a synchronized one? Is it feasible within the boundaries of one sector or more sectors must be involved?

Three different scenarios are considered:

- $T_t \leq 1$ sector $\rightarrow$ no coordination is needed
- $T_t \leq 2$ sectors $\rightarrow$ coordination between 2 sectors
- $T_t > 2$ sectors $\rightarrow$ coordination between $n$ sectors

The synchronization process starts once the aircraft crosses the border of CEATS airspace block.
The controllers use current practices to smoothen the flow in order to deliver more organized traffic into next sector. If it’s not feasible within the boundaries of the first sector, the second sector follows the same procedures to achieve flow-wide improvement and so on so forth. The coordination and traffic organization to achieve synchronized flow is the task of the controllers.

In order to simplify the investigation, other issues such as non-nominal weather conditions, military traffic are initially disregarded.

Traffic analysis

The purpose of Central European Air Traffic Services (CEATS) Fast-Time Simulation No. 4 (FTS4 with the latest route network and airspace structure of CEATS airspace) is to further evaluate proposals for the new sectorisation of the CEATS airspace: to obtain updated workload and capacity figures for the CEATS referenced sectorisation [13]. This simulation was performed with the Reorganized ATC Mathematical Simulator (RAMS Plus™) - a fast-time simulation tool commonly used at CEATS Research, Development and Simulation Centre (CRDS). Our modeling approach uses the data obtained with FTS4 as baselines for our comparative study to be described further in this paper.

Before running the fast-time simulation the question of how to organize the inbound traffic is raised. One 24-hours traffic sample (June 28, 2002) is used during the course of this study, increased by 36% (as estimated for the start of CUAC’s initial operations in 2008). In this sample, more than 7 thousand flights are considered of which 5241 are in upper airspace (above FL285).

Since the CEATS area of operation is above FL285 only the flights crossing this flight level are taken into account for synchronization.

Initial investigation shows that the most used airspace at CEATS is between FL330 – FL370 (cf. Figure 5). This distribution only describes the potential airspace to be synchronized and doesn’t preclude any information about speed distribution.

In order to make a comparison, adequate aircraft performance data are necessary, especially true air speed during the cruising phase of flight. Those data were taken from the Aircraft Performance Summary Tables for BADA [14] document. For each aircraft type, the performance tables specify the true air speed, rate of climb/descent and fuel consumption for each phase of the flight. The first analysis showed 96 different speeds, where in many cases only slight speed deviations were discovered. Thereat, the aircraft were grouped according to the speed ranges (up to 400 NM/h +/- 5 NM/h; above 400 NM/h +/- 2.5 NM/h) having at the end 31 aircraft groups (cf. Figure 6).

![CEATS Traffic versus Speed](image)

**Figure 6: CEATS speed ranges**

Figure 7 depicts the CEATS traffic distribution according to the 10 most preferred speed ranges during the cruise phase of flight. Those 10 speed ranges represents 89.8% of the whole traffic and could be potentially taken into account for the purposes of this research.
The initial analyses showed that the speed range 446-450 NM/h is used by 1500 aircraft representing 29% of the traffic followed by 857 aircraft (16.5%) with the speed at intervals 456-460 NM/h and 685 aircraft (13.2%) with the speed between 426-430 NM/h.

From the figures above it can be seen what flight levels are preferred by the aircraft and what are the most preferred speed ranges that could be further taken into consideration. Nevertheless the answer on the following question: What speed than should be assigned to what Flight Level?, could not be answered yet. Another comparison of speed distribution on flight levels was needed (cf. Figure 8).

**Table 1. Percentage of selected speed ranges on even Flight Levels**

<table>
<thead>
<tr>
<th>Flight Level (*100 Feet)</th>
<th>Speed range (NM/h): number of aircraft (% on FL)</th>
</tr>
</thead>
<tbody>
<tr>
<td>340</td>
<td>426-430: 211 (33.3%) or 451-455: 172 (27%)</td>
</tr>
<tr>
<td>360</td>
<td>446-450: 336 (40.1%)</td>
</tr>
<tr>
<td></td>
<td>456-460: 248 (29.6%)</td>
</tr>
<tr>
<td>380</td>
<td>446-450: 265 (63%)</td>
</tr>
</tbody>
</table>

With similar computation, the most potential Flight level to build synchronized flow is the FL370 when considering the amount of the traffic or FL330 and FL350 when considering the percentage of traffic using similar speed (cf. Figure 10).
Further step - task sharing

We expect that to build synchronized flow, inter-sector coordination is needed and may induce an increase of the task load in comparison with the maintenance of already organized flow. Our hypothesis lies upon the acceptability of controllers involving in this coordination task.

Experimentation is set up to empirically validate our hypothesis. Currently in fast-time model simulations the measurement of workload is derived from the mathematical calculation of the total working times recorded for each ATC task category (Flight data management, Co-ordinations, Conflict search, Routine R/T, Radar). This main categorization in CEATS studies and each category consists of ATC task set. These tasks are assigned to defined actors, i.e. planning and/or executive controller.

Presently, the task list in use consists of 15 tasks with given duration times. To reduce the discrepancy in workload calculated by fast-time simulations and real-time simulations, another set of tasks has been designed [15]. This task list contains 31 tasks with new time durations and the actors who resolve the tasks. The results obtained using a different task list showed the significant influence of task list and/or task duration on workload calculation.

The plan is to use both tasks lists in the synchronized fast-time simulation (SFTS) and to observe which gives more beneficial results and supports the synchronization proposal more effectively.

To consider the impacts of synchronization, several measures will be examined and comparison between FTS4 and SFTS will be made. These measures include:

- **Conflicts.** The number of conflicts (vertical, horizontal) will be considered.
- **Task load.** Both task lists will be recorded and task load will be measured.
- **Sector Capacity.** Number of the aircraft in a sector during certain period of time will be considered.
- **Over-flown time** (sector, FAB).

Conclusions

The natural place for synchronization is in an area where the traffic demand is too high for the actual capacity. When we envision the future, crowded areas might become normal. This study is framed within a PhD research that investigates the acceptability of controllers in the collaborative context, and in particular for the task of monitoring aircraft’s speed adjustment and assigning flight level to achieve synchronized flows.

The Central European airspace (CEATS-Central European Air Traffic Services airspace) is chosen for this research because of high percentage of over-flown traffic and its traffic characteristics with moderate growth.

Initial investigation showed that 89.8% of the CEATS traffic prefers 10 different speed ranges out of proposed 36. The most preferred speed range 446-450 NM/h is used by 1500 aircraft representing 29% of the traffic, followed by 857 aircraft (16.5%) with the speed between 456-460 NM/h and 685 aircraft (13.2%) with the speed between 426-430 NM/h. These three speed ranges show high potential to be assigned to the inbound traffic for synchronization purposes.

Even a large percentage of aircraft on particular flight level prefer similar speed as those on FL370 or FL380, it is not clear yet if they can be used for synchronization objectives. Another indicator that may solve this problem is aircraft performance, and

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<tr>
<td>370</td>
<td>446-450: 426 (45.8%) or 456-460: 301 (32.4%)</td>
</tr>
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</table>
in particular the one concerning aircraft maximum flight level.

An important consideration is the ability to validate the model by comparing calculated values with available values under actual conditions (in this case, last updated data from FTS4). The simple synchronization model proposed here is static and initially does not take into account that the traffic is dynamic. Next step would be to focus on mathematical model that takes the traffic’s dynamics into consideration.

Another additional measurement could be done considering the needs of airlines, the extra costs they have to pay (e.g. extra flight paths and fuel consumptions) in the synchronization process.

In case there is enough time, the future work would be to set a Human in the loop experiment focusing on specific part of the airspace where the fast-time simulation identifies large number of conflicts (e.g. boundaries of CEATS airspace). But this will be defined later.

Acknowledgement

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Keywords

Traffic flow synchronization, human factors, en-route speed control, task sharing, future concept.

Biography

Lenka Dravecka is a Ph.D. candidate at Eurocontrol CEATS Research, Development and Simulation Centre, Budapest, Hungary, under the supervision of Prof. Vu Duong from Eurocontrol Experimental Centre (EEC). She holds a Master Degree in Civil Aviation Engineering from the University of Zilina (Slovakia).