An innovative safety-neutral slot overloading technique to improve airspace capacity utilisation

Innovative enhancements for CASA to optimise the network delay

Sergio RUIZ, Hamid KADOUR & Peter CHOROBA
EUROCONTROL Experimental Centre (EEC)
Outline

1. Enhanced CASA (ECASA): Introduction, Motivation & Objectives
2. Enhancement 1: Mitigation of Interacting Regulations (MIR)
   - The “interacting regulations” problem
   - MIR optimisation heuristic
3. Enhancement 2: Resourceful Overloading of Slots (ROS)
   - The “wasted capacity” problem
   - ROS optimisation heuristic
4. Early simulations results
5. Conclusions and next steps
Outline

1. Enhanced CASA (ECASA): Introduction, Motivation & Objectives

2. Enhancement 1: Mitigation of Interacting Regulations (MIR)
   - The “interacting regulations” problem
   - MIR optimisation heuristic

3. Enhancement 2: Resourceful Overloading of Slots (ROS)
   - The “wasted capacity” problem
   - ROS optimisation heuristic

4. Early simulations results

5. Conclusions and next steps
What airspace capacity is?

Nowadays, **airspace capacity** is (often) constrained by **operational capacity**, i.e., by the maximum number of flights that the ATCOs can manage safely with an acceptable & sustainable level of workload.

- Airspace capacity can potentially be limited by many different factors (e.g. physical capacity, weather, separation standards, CNS infrastructure, etc.).
- At airports usually the bottleneck is the runway throughput.
Computer-Assisted Slot Allocation (CASA)

Introduction to:
- Demand & Capacity Balancing with CASA
- Our graphical representation of the CASA slot sequences
- Key properties of CASA

In a regulation, ‘ATFM slots’ are allocated by CASA to time-separate (“smooth”) the traffic following the FPFS policy.

Potential bunch of flights (safety risk)

FPFS is considered fair because it preserves the original order.

FPFS minimises the delay in a single regulation.
Motivation & objectives of this research

**Motivation:**

With today’s congestion levels, CASA performance is largely affected by:

1) The *Interacting Regulations problem*
2) The *Wasted Capacity problem*

**Enhanced CASA (ECASA) is proposed with two enhancements:**

1) The **MIR** mechanism (*Mitigation of Interacting Regulations*)  
2) The **ROS** mechanism (*Resourceful Overloading of Slots*)

---

**Objectives:**

The final goals of ECASA are:

1) To reduce the **ATFCM network delay** and its impact on AUs
2) To make it **rapidly deployable** (min change & max value)
Outline

1. Enhanced CASA (ECASA): Introduction, Motivation & Objectives
2. Enhancement 1: Mitigation of Interacting Regulations (MIR)
   - The “interacting regulations” problem
   - MIR optimisation heuristic
3. Enhancement 2: Resourceful Overloading of Slots (ROS)
   - The “wasted capacity” problem
   - ROS optimisation heuristic
4. Early simulations results
5. Conclusions and next steps
The Interacting Regulations problem and the MIR mechanism

Before activation of R1 in TV1

Regulations without interactions

TV1 - Pre-R1: A,B,C,D,E,F,G,H,I,J...

TV2 - R2: K,L,M,N,O,P,Q,R,S,T,U

Delay: 2 4 6 8 10 8 6 4 2 0

Delay in R2 = 50 min

Flights F, G, H cross TV1 and TV2 but they are not regulated

After activation of R1 in TV1

Flights F, G, H are pushed by R1 and enter R2 (i.e. extra artificial demand in the R2 period)

Regulation R1 pushes traffic to R2

Delay in R1 = 90 min
Delay in R2 = 50 min
Total Delay = 140 min

Delay x2 in R2

Mitigation of Interacting Regulations (MIR)

Delay in R1 = 90 min
Delay in R2 = 104 min
Total Delay = 194 min

Delay x2 in R2

28% delay can be saved

Flights F, G, H are allocated differently in R1 and thus removed from R2

ECASA

Non-optimised
The size of the Interacting regulations problem: a common ECAC-wide problem

In a tightly connected and congested network the probability of multiple crossed-interactions is very high

Example: KEAST28N pushes traffic and generates hours of extra delay in 15 other regulations
The Mitigation of Interacting Regulations (MIR) mechanism

For more info about MIR:

In a nutshell, the MIR heuristic removes regulated flights from periods of congestion of other sectors.
Outline

1. Enhanced CASA (ECASA): Introduction, Motivation & Objectives
2. Enhancement 1: Mitigation of Interacting Regulations (MIR)
   - The “interacting regulations” problem
   - MIR optimisation heuristic
3. Enhancement 2: Resourceful Overloading of Slots (ROS)
   - The “wasted capacity” problem
   - ROS optimisation heuristic
4. Early simulations results
5. Conclusions and next steps
The “wasted capacity” problem

• CASA sequences often contain empty/unused slots (i.e. wasted capacity), due to different reasons, e.g.: lack of demand, missed slots, interactions between regulations...

• In the Technical Report ‘Analysis of Unused ATFM Slots’ (EUROCONTROL, 2000) it was estimated that around 21% of the delay could be due to unused slots.

The number of empty slots (capacity inefficiencies) increases with congestion.

The share of delay caused by unused slots could potentially be larger than 21%.
The Resourceful Overloading of Slots (ROS) mechanism

**Case 1:**

```
R1: __ __ __ __ E EX E F ...

Empty slot

B

R1: __ __ __ __ E EX E F ...

Used slot (compensating the nearby overload)

→ Better usage of spare capacity (slots) with no negative impact on ATC workload and important reduction of delay
```

**Case 2:**

```
R2: ... A B C EX D EX E F G H I ...

R2: ... A B C EX D EX F G H I ...

Used slot (compensating the nearby overload)

→ Idem, but using the empty slots in the middle of the sequences
```

**ROS mitigates the wasted capacity problem and reduces the total delay**

**Overloaded slots nearby empty slots is considered acceptable for ATC**
Outline

1. Enhanced CASA (ECASA): Introduction, Motivation & Objectives
2. Enhancement 1: Mitigation of Interacting Regulations (MIR)
   - The “interacting regulations” problem
   - MIR optimisation heuristic
3. Enhancement 2: Resourceful Overloading of Slots (ROS)
   - The “wasted capacity” problem
   - ROS optimisation heuristic
4. Early simulations results
5. Conclusions and next steps
Research methodology (with R-NEST)

ECAC data from AIRAC 1808 (mid Jul to mid Aug 2018)

ECASA performance has been analysed with these KPIs:
1. Delay in the network
2. Impact to AUs (#flights with delay >15 min.)
Regulations and delay in July-August 2018 (AIRAC 1808)

- **65%** more network delay vs 2017
- In en-route: **delay x2** vs 2017
- **337** regulations per day (max 450)
Fast Time Simulation results (with R-NEST)

Significantly less network delay compared to CASA
Fast Time Simulation results (with R-NEST)

Significantly less impact of delay
Recently updated results (not in the paper)

- We have added the *recorded dynamicity of the regulation scheme* (from oplog files)
- Results are highly sensitive to the inputs (reduction of benefits by 50%)
- Simulations with *recorded demand variability* (e.g. FPL updates) will be analysed soon (this could lead to important benefit reductions too)
Outline

1. Enhanced CASA (ECASA): Introduction, Motivation & Objectives
2. Enhancement 1: Mitigation of Interacting Regulations (MIR)
   - The “interacting regulations” problem
   - MIR optimisation heuristic
3. Enhancement 2: Resourceful Overloading of Slots (ROS)
   - The “wasted capacity” problem
   - ROS optimisation heuristic
4. Early simulations results
5. Conclusions and next steps
Conclusions and future work

• ECASA has 3 key features:
  ➔ Reconciliation of local constraints (i.e. to mitigate the Interacting Regulations problem)
  ➔ Better utilisation of slots (i.e. to mitigate the Wasted Capacity problem)
  ➔ Innovative approach (i.e. quick improvements using the current system and rules and requiring minimal developments)

• ECASA could contribute to:
  • Significantly reduce network delay and impact of delay.
  • Possibly increase ATCOs productivity (less ‘idle times’).
  • Equity and safety in principle remain neutral (to be further validated).

• Currently we are exploring the potential implementation of MIR in the Network Manager systems for real operations and will be followed by ROS.

• Future research will include new optimisation strategies for ECASA to further reduce delays.
Questions?
Implementation aspects

**ECASA follows an innovative approach (min change & max benefit)**

**ECASA-MIR algorithm:**

At each CASA True Revision Process (every 1 minute):

1) Run CASA as usual (CASA is the core)
2) Identify interacting flights generating unnecessary delay
3) Change the CASA priority of the flights identified

Note: Slot amendments are managed by CASA (in step 1)
Implementation aspects

**ECASA-ROS algorithm:**

At each CASA True Revision Process (every 1 minute):

1) Run CASA as usual (CASA is the core)

2) Identify unused slots & nearby slots that could be overloaded

3) Overload nearby slot & block the unused one

ECASA follows an **innovative approach** (min change & max benefit)