Commonalities between networking in multiplayer computer games and negotiation processes in a future multi-layered Air Traffic Management (ATM) system

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ABSTRACT

First, this paper describes a future layered Air Traffic Management (ATM) system centred in the execution phase of flights. The layered ATM model is based on the work currently performed by SESAR [1] and takes into account the availability of accurate and updated flight information 'seen by all' across the European airspace. This shared information of each flight will be referred as Reference Business Trajectory (RBT). In the layered ATM system, exchanges of information will involve several actors (human or automatic), which will have varying time horizons, areas of responsibility and tasks.

Second, the paper will identify the need to define the negotiation processes required to agree revisions to the RBT in the layered ATM system.

Third, the final objective of the paper is to bring to the attention of researchers and engineers the communalities between multi-player games and Collaborative Decision Making processes (CDM) in a layered ATM system.

Author Keywords

Networking; negotiation; multiplayer; air traffic management; collaborative decision making.

ACM Classification Keywords

H.4.3.; K.6.4

General Terms

Human Factors.

INTRODUCTION: CURRENT ATC SITUATION: "SINGLE PLAYER MODE"

Nowadays, during the execution phase of IFR flights, pilots and sector controllers carry out mostly both the reaction to unforeseen circumstances and routine optimization processes.

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These actions are usually initiated by the need to intervene to restore an operational performance indicator which is predicted to degrade below an acceptable limit.

Generally speaking, a sector controller is trained to detect the need to intervene, mainly by observation of the surveillance picture and the crosscheck of displayed (or printed) Flight Plan information. This process is called monitoring.

The same sector controller is also trained to select a solution to solve the detected issue by comparison of the different alternatives taking into account short term and long term effect according to their available information. This process is called analysis.

Finally, the same sector controller will implement the selected solution giving the aircrew the adequate clearances at the right time or coordinate the action with a neighbouring upstream or downstream sector controller. This process is called implementation.

In normal circumstances the sector controller is the only active player monitoring, analyzing and implementing the selected solutions to avoid any loss of separation in the sector, while the pilot has to follow the clearances communicated by the controller and only in few occasions there is a negotiation to find the best solution or the pilot selects and implements a solution alone (i.e. see and avoid, TCAS RA alert,…etc).

The limitations of the current Air Traffic Management (ATM) system make it impossible to design tools to assist sector controllers in the monitoring, analysis and implementation of solutions that work effectively across airspace boundaries or take into account long term impact of their actions. Furthermore, sector controllers can only handle a very limited number of indicators, normally separation, conformance and sequence arrangement and can only control a limited number of aircraft, denoted as "sector capacity".

Therefore a smoothing mechanism to avoid ATC overloads and to maximize the use of the airspace is required. This 'mechanism' is known as Air Traffic Flow and Capacity Management (ATFCM). The ATFCM prepares the scenario (flight plans) to balance air traffic demand with system capacity.

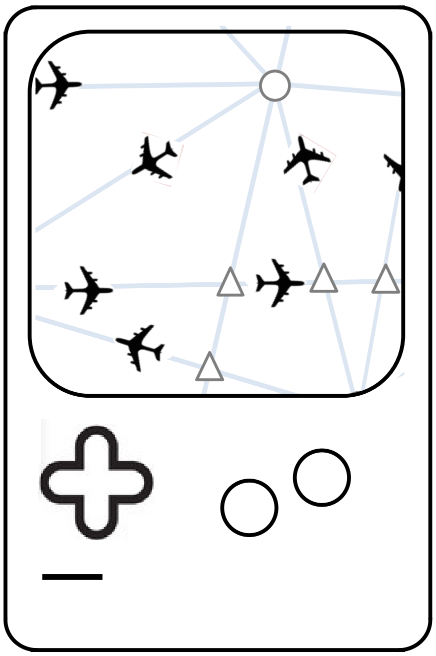

Figure 1. Current situation: Single Player mode.

FUTURE ATM SYSTEM

The SESAR (Single European Sky ATM Research) programme aims at accommodating the growth in air traffic, to optimize the use of airspace, to reduce delays, and to improve the overall safety performance of the European ATM system. The five key features of the SESAR Master Plan to achieve the ATM paradigm shift are [1]:

• Moving from airspace towards 4D trajectory-based operations, such that each aircraft follows its preferred route and arrives at its desired time of arrival; the so-called Reference Business Trajectory (RBT);

• Dynamic airspace management, facilitated by a central network, to enhance coordination between aviation authorities;

• New and innovative technologies for more precise navigation and surveillance in order to optimize airspace and airport capacity;

• Moving towards a network centric approach, underpinned by a System Wide Information System (SWIM), such that all parties involved have access to relevant and most up-to-date flight information;

• Allocate a central role for the human, but supported by a high degree of automation to reduce workload, optimize airspace capacity, and maintain a sufficient level of safety in complex, high-traffic, and time-critical situations.

By developing these five key features SESAR aims to accomplish a:

- 10-fold increase in safety,
- 3-fold increase in capacity, and
- 50 percent reduction in ATM costs per flight.

Key to the SESAR Concept is the ‘trajectory-based operation based upon a 4D Trajectory’ and the ’Business/Mission Trajectory’ principle in which the airspace users, air navigation service providers and airport operators define together, through a collaborative process, the optimal flight path from gate-to-gate.

In order to fully meet the safety and other performance targets of the future ATM System several parading shifts are required. As indicated on Figure 2 SESAR will help to create these paradigm shifts.

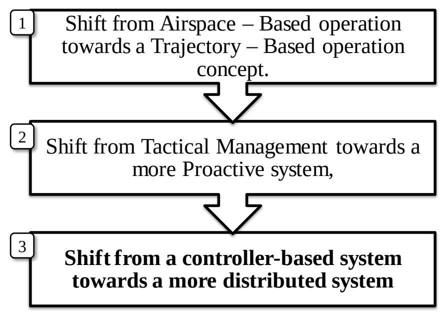

Figure 2. Contribution of SESAR to create a paradigm shift

The SESAR concept is based on the sharing of the Business Trajectory between all stakeholders – Airspace Users, Air Navigation Service Providers, Airports, Network Management and others. During the planning phase this is the Shared Business Trajectory (SBT), which is based on the airspace user’s preferred profile. During the execution phase of flight this is the Reference Business Trajectory (RBT) which will be maintained according to the airspace user’s needs, subject to the minimum constraint necessary for ATM purposes.

The performance of many ATM processes and tools will be enhanced by coordination achieved through use of the Business Trajectory, including Conformance Monitoring, Conflict Detection & Resolution Tools, Arrival & Departure Management Tools, Demand and Capacity Balancing and Network Management. It is important that the services associated with the Business Trajectory support all ATM actors.

The Business Trajectory for a flight should form a single reference point to which all ATM actors can refer. During the execution phase, the RBT will be shared between all ATM actors concerned with the flight and will be ‘revised’ when necessary through negotiation between agreed actors, principally the Airspace User and affected Air Traffic Control Centres (ATCCs).

The communication for these negotiations should be built on the air-ground and SWIM (ground-ground) capabilities:

- Ground Communications: Data communication between ground systems needs to be based on SWIM- the ATM intranet- principles. EUROCAE ED-133[2] provides an existing standard for Flight Interoperability for such SWIM communications and defines the Flight Object (FO) as the data structure for sharing information about a given flight.
- Air-Ground Communications: The exchange of RBT information with the aircraft can be supported by the airborne systems in development by SESAR (CPDLC, ADS-C).

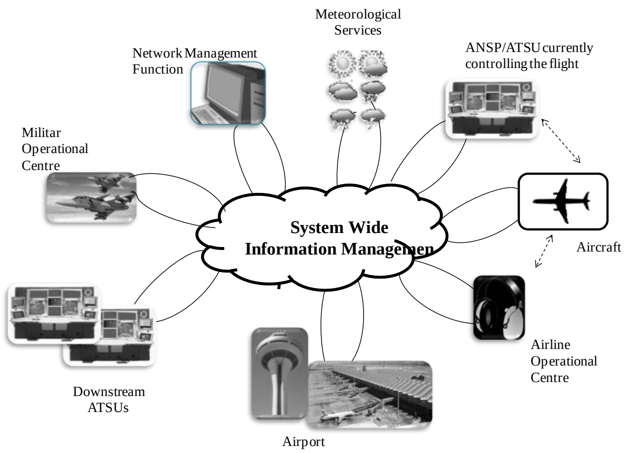

Figure 3. Conceptual Model for the Trajectory Management Framework.

A NEW LAYERED ATM MODEL: "MULTI-PLAYER MODE"

If an RBT is available and seen by all it is possible to conceive a different operating method than the current ATM system.

Exchanges of information will involve new actors (human or automatic) and trajectory services provided or consumed through the network. It is recognized that trajectory services and actors [1] will have varying time horizons and varying accuracy requirements.

However there is a need to describe in more detail the 'mechanisms' by which actors (ATC, Network Management, Flight Crew, Airline Operation Centre) will negotiate revisions to the RBT.

For example, an actor (possibly a sector controller or any actor with a wider scope in terms of look-ahead or area of responsibility) with the assistance of appropriate tools can monitor an assigned set of indicators. The goal of this process is as in the current situation: to identify issues or hotspots that need to be analyzed.

The same or another actor with a wider scope would analyze possible alternatives to solve the hotspot. Additional information could be requested in the process, as it would be available in the system either provided by the airspace user or by other ground actors. In the end, a course of action would be selected.

Again, the same or another actor would take care of the implementation of the selected solution, which could imply a formal change of the agreement both on the ground and with the airspace user.

The availability of flight information in the form of an RBT would make it possible to perform monitoring, analysis, negotiation and implementation of solutions in wider time and airspace scopes and with the concourse of selected actors (human or automatic) in the so called Collaborative Decision Making processes (CDM) processes.

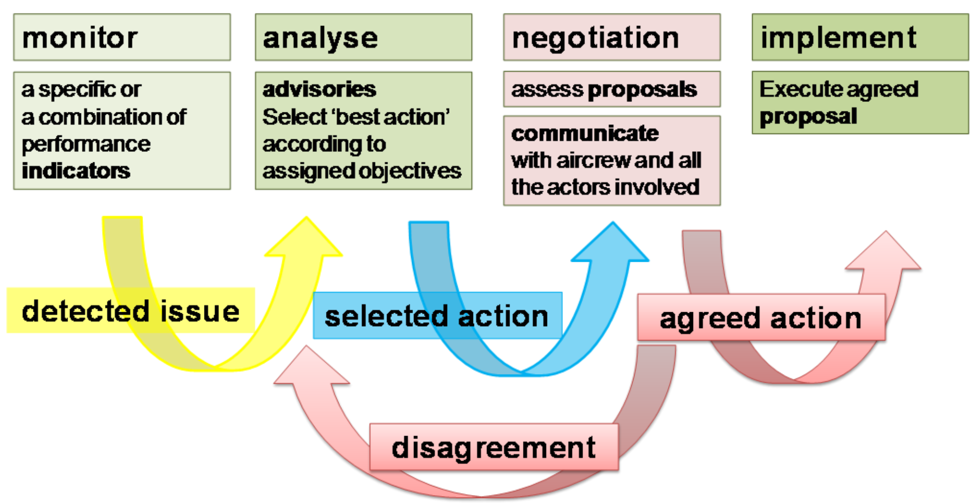

Figure 4. Identification of cascaded actions in ATM during flight execution.

A simple Role model

A very simple three dimensional model can represent the concept of role in this future ATM environment for the execution phase of flights.

Along one dimension it can be represented the different look-ahead time horizons, from the very tactical (some minutes into the future) to the very strategic (some hours).

Along the second dimension we can represent the different airspace scopes, spanning from the smaller: the sector and growing in discrete steps: the metasector, the sector cluster (or family), the ATSU airspace, the FAB airspace and finally the entire European region.

Along the third dimension we can represent all operational performance indicators that belong to any operational objective of any actor. We should think of their related metrics which might be used by automation in the determination of hotspots and management of solutions. Here just some examples proposed for clarification:

- separation: distance between predictions,
- conformity: distance between measure and prediction,
- synchronization: eligibility for insertion in a queue
- demand&capacity balancing: absolute/relative difference between D&C
- complexity: cumulative count of separation, synchronization,… issues
- quality of service: difference between user's objectives and achievements
- environmental impact: cumulative measure of effects (CO2, noise,…)
- any other measurable indicator of operational interest

The multiple intersections of these three dimensions give different combinations of operational performance objectives, airspace and look-ahead horizon of interest to a particular current or future role/actor (human or automatic).

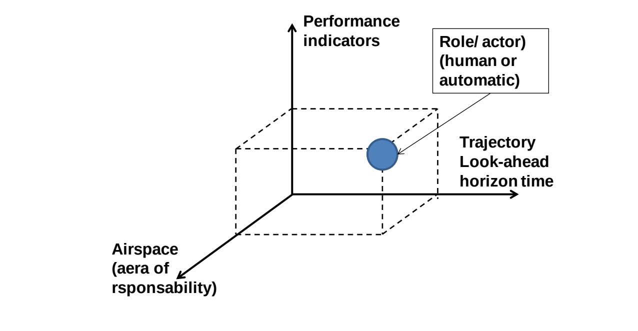

Figure 5. Identification of roles as combinations of airspace, look-ahead time and operational objectives (performance indicators

Actors and Layers in Trajectory Management Negotiation

Based on the definition of operational role as a combination of airspace and time interest over measurable operational objectives we can represent the entire ATM system as a stratified succession of layers where the different roles can be allocated.

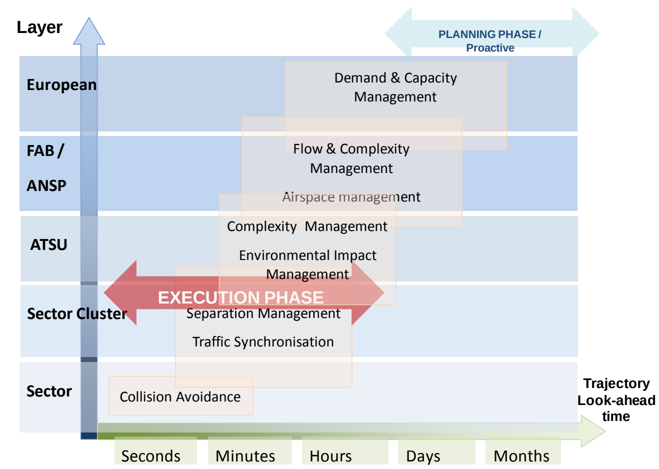

Figure 6. Stratified layers along airspaces crossed by an RBT

Specialised Actors at each Layer will use Tools to perform assigned Tasks adequate to their Planning Layer:

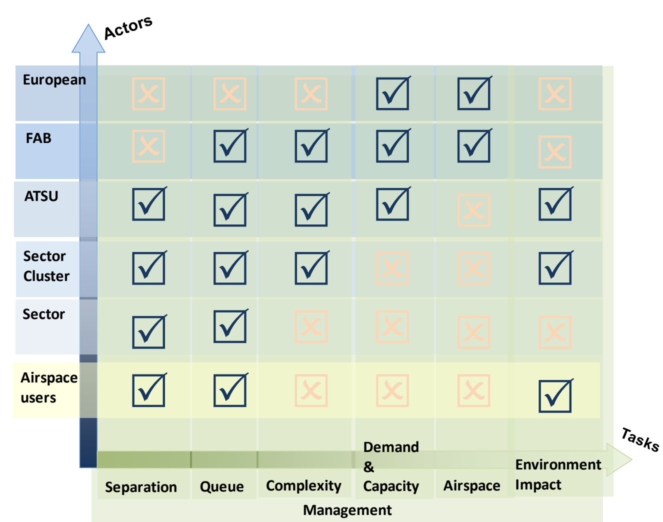

Figure 7. Tasks vs. Actors / Roles

Note that a specific flight will be simultaneously in the scope of different actors at different layers with different look-ahead time horizons and interested in different operational objectives.

The model can be alternatively seen from the roles perspective. The different actors interested in the flight will be located along and across the layers. This is represented in the next figure.

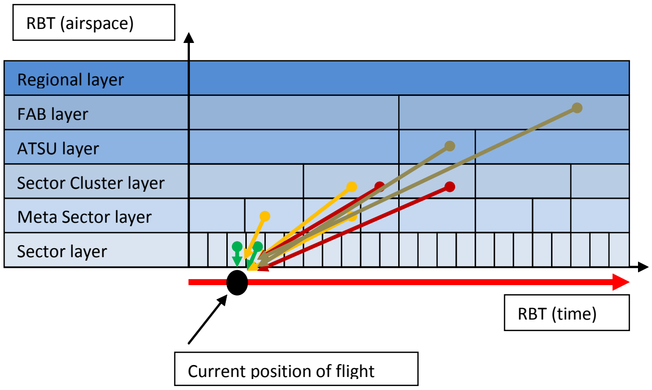

Figure 8. Actors simultaneously interested in a specific RBT at a given time. The different colours of the arrows indicate different operational objectives

As an example and based on the figure we could identify several actors taking the same RBT into account. Two sector controllers with very short look-ahead horizon would be interested in separation and conformity aspects. Two or three multi-sector planners would be looking at separation, synchronisation or workload balancing with different look-ahead horizons. Two or three cluster managers would be looking at D&C balancing and complexity issues with further ahead time horizon. On top, at ATSU or FAB level managers would be dealing with operational performance indicators with a vast look-ahead horizon in cooperation with airport managers and ATFCM managers, as many of their eligible in-scope flights might still be on the ground.

There is a critical need to define what is the role of the various actors (ATCO, Network Management, Flight Crew, and AOC) in agreeing revisions to the RBT – e.g. what are the negotiation processes.

Some principles for the negotiation processes are:

- avoid complex and potentially irresolvable negotiations.
- the number of actors involved in negotiating changes to the RBT should be minimised.
- as the ultimate owner of the RBT, any revision to the RBT should be agreed with the Airspace User.

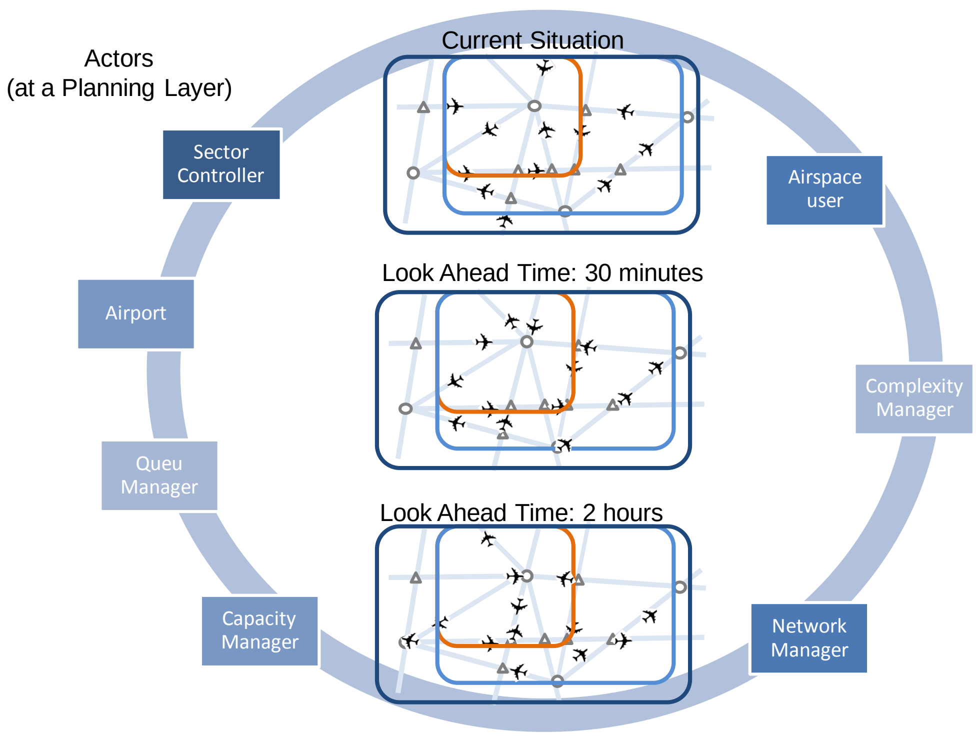

Figure 9. Actor vs. Area of Responsibility vs. Look Ahead vs. Task

COMMONALITIES BETWEEN NEGOTIATION PROCESSES BETWEEN MULTIPLE ACTORS AND MULTI-PLAYER GAMES

A layered ATM model implies that every action proposed by an actor to revise an RBT will have to be agreed by several other actors (human or automated players) using Collaborative Decision Making (CDM) processes

These CDM processes in the future ATM system will have several common issues with multiple-player games:

- are network delay-sensitive;
- are more complex that "single player modes", due to the unpredictability of the result of the negotiations;
- required similar communication architectures;
- required interest management algorithms;
- actors in the negotiation can be human or automated players;

A review of the literature shows that research on these topics is extensive in the video game industry (some examples are [3,4,5,6,7, 9]), while the ATM research community has only recently started to research on CDM processes in a net-centric service oriented architecture (for example [10,11]).

In addition it is recognized that the communication which will take place in the CDM processes is also under-explored and only few efforts have been done to use multi-player games to assess the study the communicative structures between multiple participants in a negotiation [12].

CONCLUSION

The current documents published by SESAR provide a high-level description of a new layered ATM system in which CDM processes represent one of the main paradigm shifts.

The improvement in safety, capacity and efficiency aimed by SESAR will be facilitating to some extent by the introduction of new actors monitoring, analysing and implementing solutions during the executing phase. However, there is not available yet a detailed description of the actors and how these CDM processes will be performed to revise a RBT, taking into account each actor could have different solutions and that the consequences of a delay could lead to an incident or even an accident.

In this paper we have provided a low level description of the future ATM layered model and we have identified some principles for the negotiation processes. Based on this description and principles we have identified some common issue between networking in multiple-player games and CDM processes in the future ATM system.

The next steps of this research will focus on furthering our understanding of the CDM processes and on how to apply the identified video games technology to these processes.

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