Agent-based simulation framework for airport collaborative decision making

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***Abstract* — Airport Collaborative Decision Making is based on information sharing. A better use of resources can be attained when the different stakeholders at airport operations share their more accurate and updated information. One of the main difficulties when dealing with this information sharing concept is the number of stakeholders involved and their different interest and behaviour: aircraft operators, ground handling companies, airport authority, air traffic control and the Central Flow Management Unit. It is paramount to quantify the benefit of an airport collaborative decision making strategy in order to involve all these different organisations. Simulations are required to analyse the overall system and its emerging behaviour. This paper presents the development and initial testing of an agent-based framework, which allows this behavioural analysis to be done. The simulator explicitly represents the different stakeholders involved in the A-CDM and the interactions between them from milestone 1 to 7. This framework allows independent gradual development of local behaviours and optimisation, and a gradual increase on complexity and fidelity on the simulations.**

Keywords — Airport Collaborative Decission Making, agent-based modeling, simulation framework

ABBREVIATIONS

ABM	Agent based modelling
A-CDM	Airport collaborative decision-making
ACGT	Actual Commence of Ground Handling Time
AGHT	Actual Ground Handling Time
AIBT	Actual In Block Time
ALDT	Actual Landing Time
AO	Aircraft Operator
AOBT	Actual Off-Block Time
ARDT	Actual Ready Time (for Movement)
ASAT	Actual Start Up Approval Time
ASRT	Actual Start Up Request Time
ATC	Air Traffic Control
ATFM	Air Traffic Flow Management
ATM	Air Traffic Management
ATOT	Actual Take Off Time
CDM	Collaborative decision making
CFMU	Central Flow Management Unit
CTOT	Calculated Take Off Time
EIBT	Estimated In-Block Time
ELDT	Estimated Landing Time
EOBT	Estimated Off-Block Time
ETOT	Estimated Take Off Time
FIPA	Foundation for Intelligent Physical Agents
FIR	Flight Information Region
FPL	Filed Flight Plan
GH	Ground Handling
MTTT	Minimum Turn-round Time
IS	Information Sharing
JADE	Java Agent Development Framework
TOBT	Target Off-Block Time
TSAT	Target Start Up Approval Time

I. INTRODUCTION

Airport collaborative decision-making assists airport operations trying to make better decisions based on more accurate and timely information shared by all the actors involved (aircraft operators, ground handling companies, airport authorities, air traffic services, etc.). A-CDM aims at improving air traffic flow management at airports by reducing delays, enhancing the predictability of events and optimising the utilisation of resources [1].

A-CDM has been introduced in Europe during field trials at some airports and it is estimated that could provide a quick, cost-effective win-win situation for all partners, with substantial benefits achieved in a relatively low payback period [2]. Nevertheless, the actual effect on daily operations of the A-CDM implementation for a specific airport is hard to quantify. The number of actors involved and the amount of information to be exchanged is high and complex. Even if situational awareness can be created through defined A-CDM rules (milestones) and information sharing between the different actors, decision makers are often faced with unanticipated situations where *ad hoc* decisions are necessary. Thus, it is very difficult to predict the impact into the system that some of these decisions could produce in such a complex and dynamic environment. See for instance [3], where the authors apply cognitive engineering to evaluate pilot decisions during the turn-around process in an A-CDM context.

In this paper we propose to simulate A-CDM processes by using agent based modelling, allowing us to simulate the interactions of autonomous agents with the objective to assess their effects into the whole system. In complexity science or game theory, for instance, ABM is a very useful tool since it allows conceptualising real world processes with a great variety of implications, like socio-technical systems such as air traffic management or airport operations. Once the different *agents* are programed a simulation is launched and the behaviour of the system *emerges* from the lower-level individual agent processes. In such a way, it is possible to assess at system (high-)level the impact of different types of agent rules or behaviours that can map, for instance, human reasoning, low-level uncertainties, decision making processes, operational procedures, etc.

ABM has been used in the context of ATM in different fields. For example, in [4, 5] it is used to perform a thorough safety analysis of different ATM processes. In [6] the tactical and strategic layers of ATM are simulated using an ABM in order to assess the impact of some ATM strategies in the flight operations; while [7, 8] use ABM to model and study different ATFM strategies. Furthermore, [9] takes advantage of ABM to assist the design of air traffic control sectorisations.

In [10] an ABM system was developed to improve airside safety at the airport, focusing in particular to avoid runway incursions, but to the authors' knowledge no previous work has been performed to apply ABM to simulate the whole A-CDM process. In this paper, such a simulator is described and an initial architecture is presented, along with the different agents, their respective interrelations and the flow of information and messages. This architecture will set the bases of a high definition model of the A-CDM allowing the different stakeholders estimate the benefits of such strategy. Different behaviours and resources optimisation techniques can easily be assessed with a simulator like the one described in this paper.

The paper is organised as follows: Section II presents the bases of the A-CDM concept and the milestone approach that is under development in Europe. Section III contains the background on agent based modelling used for the simulator. The architecture of the simulator with the different agents and interactions are presented in Section IV. Section V is devoted to present some preliminary simulations with some explicit representation of agents' interactions. In Section VI future planned work is described and finally conclusions are summarised in Section VII.

II. A-CDM: A MILESTONE APPROACH

Since 1998, CDM procedures have led to shared decision making within the air navigation service provider and the airspace users in North America. The focus has been on the improvement of the assigned delay in ground delay programs, when cancellations and substitutions are present. When capacity demand imbalances are present CDM implies a cycle of feedback between the service provider and the airspace users. In this manner, a decentralized decision making process is implemented [11]. This idea of sharing information between the different stakeholders to obtain a decentralized optimization of the resources has been adopted in Europe to enhance airport operations in the so-called Airport CDM or A-CDM.

A. A-CDM rationale and expected benefits

The A-CDM is aimed at improving the overall efficiency of operations at European airports, especially regarding the aircraft turn-round and pre-departure sequencing process. The basic concept is that all partners involved in airport operations - ATC, CFMU, Airport, Aircraft Operator and Ground Handling - work together more efficiently and transparently by sharing key data, so that better decision making is possible, based on more accurate and timely information, with all airport partners having the same operational picture. This means that, in general, turn-around operations can be handled in a seamless and more efficient manner. Moreover, predictability is increased and corrective actions can be efficiently planned and implemented in case of disruptions.

The expected benefits are visible at a network level, with more accurate take-off information feeding into the air traffic flow and capacity management system run by EUROCONTROL's Network Management. The network will be able to use the available capacity more efficiently. More effective use of slots results in reduced delays, improved predictability of events during a flight and optimised use of resources at airports.

The A-CDM applications are organized into four different levels. First level focuses on Information Sharing and on the aircraft Turn-round Process. More advanced levels focus on aspects such as variable taxi time calculation or collaborative pre-departure sequence [12]. This paper concerns the first level of applications. Assuming a platform for information sharing among partners, A-CDM proposes a milestone approach to improve the aircraft turn-round process.

B. Information sharing

The A-CDM Information Sharing platform collects and distributes planning and flight progress information provided by the different partners. Information Sharing is in fact the "glue" that ties these partners together in their aim to efficiently coordinate airport activities, and forms the foundation for other Airport CDM Concept Elements.

C. The milestone approach

A sequence of 16 milestones in the aircraft turn-round process has been defined in [12]. These milestones define the different flight phases from the planning of the inbound flight, from the outstation, until the take-off of the flight at the subject airport. The list of the 16 milestones is indicative, some airports might need more milestones to include phases such as de-icing. When each individual milestone is completed the relevant information of the flight status is shared and distributed among the different stakeholders thought the Information Sharing platform, enabling them to appropriately respond to the event. Table I and figure 1 presents the list of these 16 milestones.

Several key time figures are affected by each of the milestones in such a way that when the next milestone is completed partners involved in that milestone collaborate to produce the best quality time estimate for some of these figures. The new estimates are shared and distributed so that other partners can optimize processes.

As an example, milestone 1 occurs three hours before the EOBT from the airport of origin, when CFMU activates the flight plan, communicating, among others, the ELDT. Then, the destination airport computes and communicates the EIBT by adding to the ELDT the best available estimate for the inbound taxi time. Some time later, when the aircraft takes off from outstation (milestone 3) the airport of origin communicates the ATOT, allowing the rest of partners to update with better quality estimations for the ELDT or the EIBT. These updated times allow, for instance, the Ground Handler to optimize or rearrange resources.

TABLE I. LIST OF MILESTONES IN A-CDM [12]

ID	Description	Time Reference
1	ATC Flight Plan activation	3 hours before EOBT
2	EOBT – 2 hours	2 hours before EOBT
3	Take off from outstation	ATOT from oustation
4	Local radar update	Varies according to airport
5	Final approach	Varies according to airport
6	Landing	ALDT
7	In-block	AIBT
8	Ground handling starts	ACGT
9	TOBT update prior to TSAT	Varies according to airport
10	TSAT issue	Varies according to airport
11	Boarding starts	Varies according to airport
12	Aircraft ready	ARDT
13	Start up request	ASRT
14	Start up approved	ASAT
15	Off-block	AOBT
16	Take off	ATOT

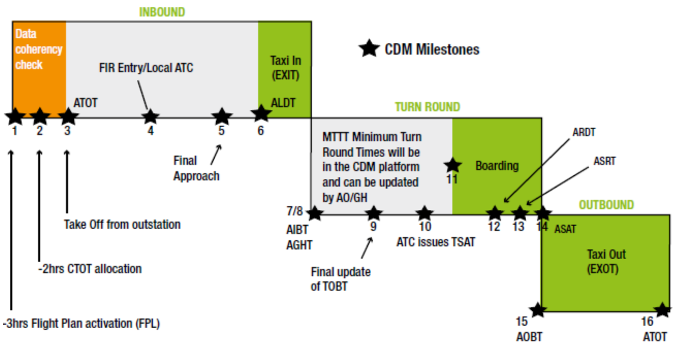

Figure 1. Phases of the A-CDM milestones [12]

This example shows the nature of the interactions among partners involved in the milestone approach and the potential for improvement as a result of key data sharing. Furthermore, it also anticipates the difficulty to predict and estimate accurately the impact of such a complex system, since a large number of aircrafts, companies, ground handlers, etc. may be operating simultaneously while dealing with a large number of events, including unanticipated situations. This is the main motivation for the development of an agent based simulator that will be described in the following sections.

III. AGENT BASED MODELING

An agent based architecture has been selected to model and simulate the interaction between the different actors involved in the A-CDM process.

A. *Suitability of ABM*

In an agent based architecture, each of the different actors involved in the A-CDM process is modelled independently. Each agent will be running autonomously and interacting to the different stimuli that receive. In the case of the A-CDM, each actor will be fed with the updated information coming from the different milestones and that will, in its turn, generate new information that will be shared among them. In its implementation at an airport, however, this sharing process might not be always as smooth as desired due to the behaviour of one of the involved actors or due to uncertainty in the data. This can be modelled in a natural manner using an agent based modelling technique.

One of the main goals of the simulator is to be able to capture the interaction between the different stakeholders involved in the A-CDM. It is of paramount importance to have an accurate representation of the information interchanged between the different actors to gain insight on the overall process. By having this accurate representation, it will be possible to analyse the effect of implementing a higher level of information sharing, along with different strategies followed by the actors.

With an agent based architecture these interactions become explicit. The suggested implementation allows the accuracy of the behaviour of the actors to increase gradually and it is even possible to analyse the effect of different strategies.

B. *Methodology*

In order to develop the system, a well-defined methodology, GAIA, has been selected [13]. This methodology helps in the definition of the number of agents needed, the functions they will have associated and the communication required between them.

The different models developed with GAIA methodology are presented in figure 2. The analysis of the problem is the first phase of the GAIA methodology. From this analysis the different roles and interactions are obtained. Each role will have associated a set of responsibilities and rights over the data. Finally, the different communication protocols and activities will be inferred.

Once the roles and interactions have been defined, the design of the agent system phase starts. In this phase, the different roles are grouped in agents obtaining as a result a set of agents and services, which are derived from the interactions among them.

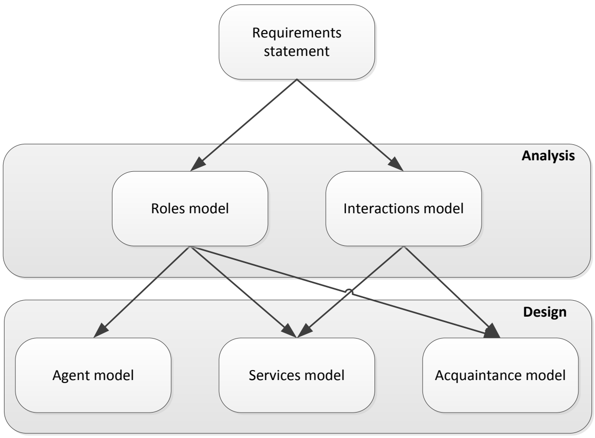

Figure 2. Relationships between GAIA's models [13]

JADE has been selected as the framework to implement the agents [14, 15]. JADE is a middleware designed to enable the development of agent oriented platforms. The communications within JADE follow the FIPA specifications. This ensures the interoperability between different agent based platforms.

IV. ABM APPLIED TO A-CDM

The application of ABM to A-CDM is relatively simple because ABM can capture the different stakeholders involved in the information sharing process in a seamless manner. Yet, in order to simulate realistic scenarios a detailed and comprehensive system architecture is required. This section describes this architecture, the realistic scenario generation, the description of the agents and the different roles and interactions.

A. Scenario generation

An analysis of traffic data is required in order to obtain realistic scenarios. Figure 3 depicts the different processes proposed to generate these scenarios, which are fed by Eurocontrol's DDR2 database.

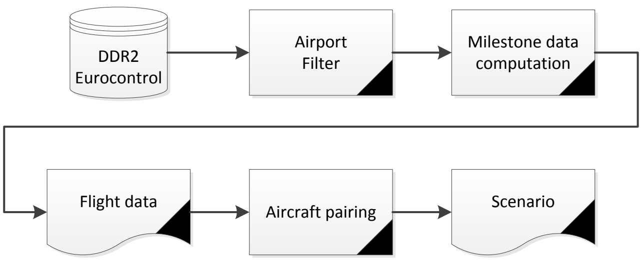

Figure 3. Computation of the required inputs for the ABM simulations

Firstly, the data of the flights operated in Europe in the desired time for the simulation, i.e. one day, is obtained from the DDR2 database. These flights are filtered by airport to limit the traffic to the one arrived or originated at the airport of study. The next step is to extract the information regarding the different milestones for each of the flights. For arrival flights: when the flight was ready to take-off at the origin airport, when it actually took off, if the flight had any controlled time of departure due to a regulation, when the flight was planned to entered in the FIR of the arrival airport and when it actually did it, the time when the aircraft started the final approach and the actual landing time. For flights taking-off form the airport under study, it is possible to obtain the take-off time from the DDR2. An important feature is that it is possible to differentiate between planned and actual traffic. These differences will be used in order to simulate realistic disruptions that might occur during one given day.

More information than just the traffic data obtained in the previous process is required to simulate the A-CDM. Particularly, the link between arrival and departure flights is needed in order to model the turn-around process at the airport. Thus, the arrival and departure flights plans should be associated with the actual aircraft. Unfortunately, DDR2 database does not have information regarding the aircraft registration (aircraft are always identified by means of their callsign) and therefore this link is not directly available.

The pairing stage depicted in figure 3 aims at solving this issue, by trying to correlate the arrival and departure times of all the aircraft of the same company. It takes into account the aircraft model and a user defined minimum turn-around time between flights. If there is more than one option fulfilling previous two constraints, then the pair of flights giving the minimum turn-around time is chosen. By doing this, the simulated traffic is not longer an actual representation of the operations of a given day, but it is still a realistic scenario of a possible day of operations at the airport and good enough for the purposes of this research.

The next step is to transform all the previous data into a simulator input for the milestone simulator. This milestone simulator will generate the different triggers of the different milestones for the A-CDM simulator.

B. Agents

GAIA methodology states that it is necessary to define roles and interactions in order to define the different agents and their services. However, for this particular problem, the number of agents matches the number of stakeholders involved in the A-CDM as defined by ACI and IATA: *CFMU*, *Airport*, *ATC*, *Aircraft Operators* and *Ground Handling* companies [16]. The agents listed previously represent the physical stakeholders involved in A-CDM, but other agents are also required to support the simulations: *Information Sharing*, *Simulator Input*, *Milestone Trigger*, *Simulation Output Database* and *Graphical Interface*. Figure 4 represents all the different agents and their relationships.

Information Sharing agent is responsible for storing and broadcasting the information about the different aircrafts. *Simulator Input* handles the scenario input data. *Milestone Trigger* is responsible of timing the simulation and starting every milestone in chronological order. *Simulation Output Database* saves the results of the simulation in a log file and *Graphical Interface* allows the user to follow the simulation while running monitoring the evolution of the aircraft parameters.

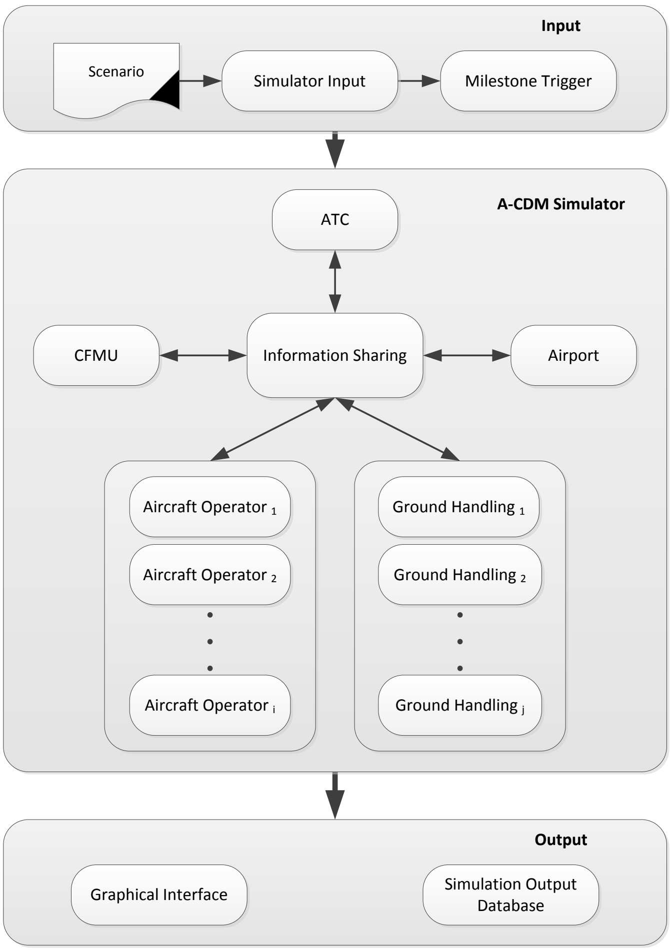

Figure 4. A-CDM simulator architecture

C. *Roles and interactions*

A deeper understanding of the different actors, their responsibility and their relationships is obtained after the analysis of roles and interactions. This model of roles allows us to establish the system functionalities. The capabilities of the different agents will be determined by the assignment of roles to agents. Table II presents this assignment between roles and agents. It is worth noticing that the simulator has been developed until milestone 7 and therefore some roles are expected to be added in the future.

After defining the different roles assigned to each agent and knowing the interaction between the roles, the communications needed between the agents can be established. These interactions and communications are depicted in figure 5. At a high level, six types of communications can be distinguished:

(1) Start simulation message to inform that the scenario has been processed and loaded
(2) Milestone Trigger messages to announce that an aircraft is in the next milestone
(3) Update Aircraft Data Information, that contains the flight times, with the data from the stakeholder
(4) Broadcast Aircraft Data Information
(5) Update graphical interface
(6) Update log file

TABLE II. ASSIGMENT OF ROLES TO AGENTS

	Agent	**Roles**
Input	Simulator Input	• Read and manage input data • Generate Flight Plan file • Generate Milestone trigger data file • Generate Flights-by-AO file • Initialize the simulation
Input	Milestone Trigger	• Read and manage the milestone trigger's file • Sort Milestone triggers temporally • Trigger milestones (message to proper agent) • Reorder the milestone triggers in case of a delay in a flight • Timing the simulation
A-CDM Simulator	CFMU	• Update internal table • Publish aircraft data update • Read and manage Flight Plans file • Apply airborne delays due to congestion in airspace • Definition of ETOT' and ELDT • Start Milestone 1 (Read FP and add aircraft to the Information Sharing) • Start Milestone 2 (Aircraft data update)
A-CDM Simulator	ATC	• Update internal table • Publish aircraft data update • Apply airborne delays due to airport congestion • Apply ground delays due to airport congestion • Start Milestone 3 (Aircraft data update) • Start Milestone 4 (Aircraft data update) • Start Milestone 5 (Aircraft data update) • Start Milestone 6 (Aircraft data update) • Start Milestone 7 (Aircraft data update)
A-CDM Simulator	Airport	• Update internal table • Publish aircraft data update • Calculation of Estimated Taxi In Time • Calculation of Estimated Taxi Out Time • Definition of EIBT and EOBT
A-CDM Simulator	Aircraft Operator	• Update internal table • Publish aircraft data update • Read and manage Flights-for-AO file (to work only with its own flights) • Link arrival Flight Plan with departure Flight Plan of an aircraft • Definition of ETOT
A-CDM Simulator	Ground Handling	• Update internal table • Publish aircraft data update • Store handling times database • Check turn-around process fits between EIBT and EOBT • Update EOBT if it is necessary
A-CDM Simulator	Information Sharing	• Update internal table • Broadcast aircraft data update (to A-CDM Agents) • Publish aircraft update (on Graphical Interface agent) • Check coherency on the timetable of an aircraft
Output	Graphical Interface	• Update table • Inform of Airborne and Airport flights • Stop the simulation at any point with a button
Output	Simulator Output Database	• Update messages in log file

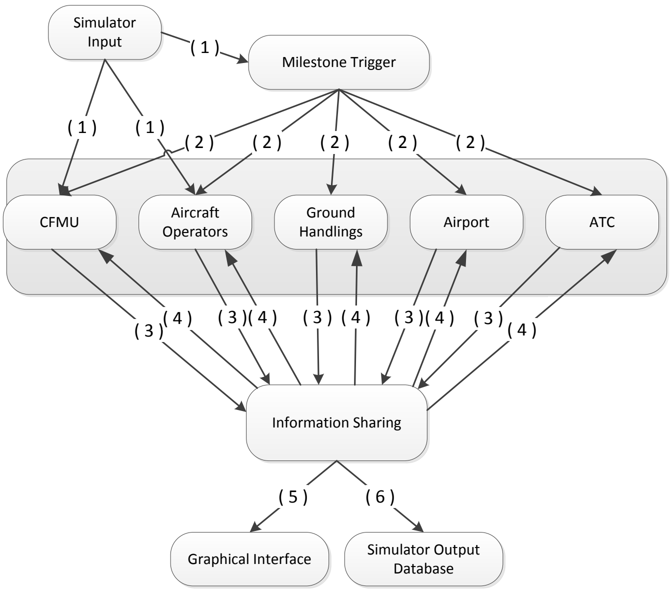

Figure 5. Communications model

The general process of a simulation is as follows: When starting the simulation, the *Simulator Input* reads the different parameters of the scenario and load that information into the *Milestone Trigger*, the *CFMU* and the *Aircraft Operator* (interaction type (1)). At every simulation step, the *Milestone Trigger* sends a message to the actor responsible for updating the information of the milestone that has just happened (message type (2)), i.e. if it is three hours before the ETOT of an aircraft (beginning of milestone 1), *CFMU* will be notified so it can update the FPL information.

The actor responsible for updating the fact that an aircraft has attained a milestone informs the *Information Sharing* (message type (3)). *Information Sharing* broadcast this update to all the agents in the system (message type (4)). The agents will react to this update by modifying some estimates of the flight. These estimates updates are send to *Information Sharing* who will again broadcast them, in an interchange of messages of type (3) and (4). In parallel, *Graphical Interface* and *Simulator Output Database* will record the simulation by receiving updates from *Information Sharing*, messages (5) and (6).

V. PRELIMINARY SIMULATIONS

The agents described in the previous section have been programed in JAVA under JADE. Therefore, it is possible to execute them in a distributed manner if desired.

JADE allows the monitoring of the different messages interchanged by the actors. Thus, the communications of the A-CDM during a given milestone can be easily depicted. Figure 6 and figure 7 show the messages sent by the different agents for a single aircraft and for one milestone, milestone 6 and milestone 1 respectively. In both cases the high number of communications involved is noteworthy.

In figures 6 and 7, each message is displayed with an arrow between two agents and the number above the arrow indicates the type of message (as explained on the previous section and depicted in figure 5). These messages have also a letter to identify them on the figures.

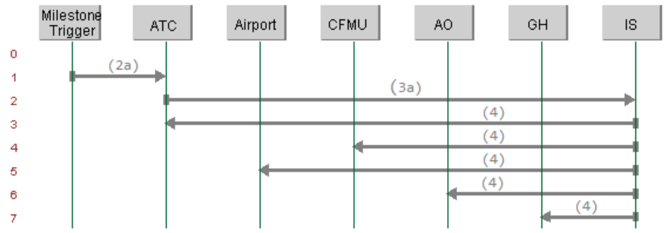

Figure 6. Time line of messages exchanges. Example of milestone 6

Figure 6 presents a simple communication example associated with the landing of an aircraft (milestone 6). *Milestone Trigger* starts the milestone with a message to *ATC* informing that the aircraft has just landed (message (2a)); *ATC* notifies the landing to the *IS* (3a), who broadcasts the actualization to all the stakeholders involved in the A-CDM (4).

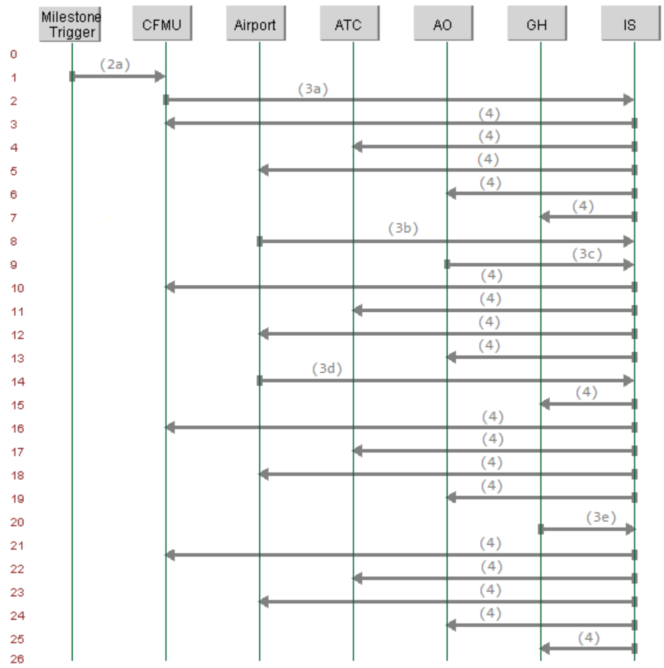

Figure 7. Time line of messages exchanges. Example of milestone 1

Figure 7 shows a more complex message interchange generated at the first milestone (3h before ETOT). In this situation a large number of messages are needed because it is the first time the aircraft is defined on the *Information Sharing*. This means that some agents will compute estimates for the aircraft turn-around times.

The process of the definition of all the times on aircraft's timetable on the first milestone is as follows: *Milestone Trigger* detects that there are three hours left before the ETOT from the origin airport of a flight, therefore, it triggers the first milestone by sending a message to *CFMU* (message (2a) in figure 7). *CFMU* receives the message from the *Milestone Trigger*, reacting to this message it reads the FPL and publishes this information by notifying the *IS* (3a). The *Information Sharing* receives the callsign, model, and the values of ETOT from the airport of origin and the ELDT at destination; *IS* stores these flight plan parameters and broadcasts them to all the stakeholders messages type (4).

With the information received by the *IS* some agents are able to update or define new times in the aircraft information. Firstly, there are two simultaneous calculations: *Airport* reads the ELDT on the message and defines the EIBT by adding an estimation of the taxi-in time; and once *Aircraft Operator* receives the callsign, it can relate the arrival flight with the departing one, thus the ETOT for the aircraft can be updated. These informations will be sent to the *IS*, messages (3b) and (3c) in figure 7 respectively, who will broadcast the information to all the stakeholders (4). Secondly, when *Airport* receives the ETOT, it is able to define the EOBT by subtracting an estimation of the taxi-out time, message (3d). Finally, when *Ground Handling* is informed about the EIBT and the EOBT, it is able to check that the MTTT for the aircraft model fits in the available time; if that is not the case, the *GH* can define a new EOBT that once published, message (3e), will be considered by the *Airport* to update the ETOT if necessary.

As explained before, the *Information Sharing* agent stores and broadcasts the available data after every update done by any agent. The 26 messages depicted on figure 7 are easily monitored by the JADE framework.

The developed simulator also tracks the evolution of the aircraft parameters during the simulation through a graphical agent. Figure 8 presents this graphical interface that shows the data from each aircraft, based on Information Sharing Model from EUROCONTROL [12].

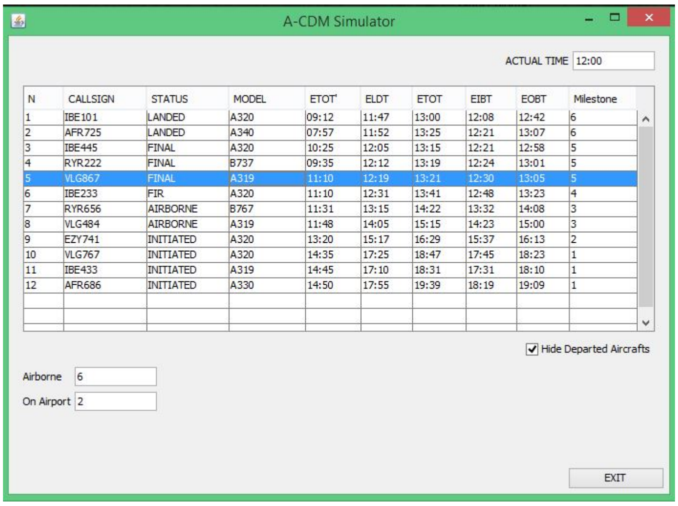

Figure 8. Informaton Sharing Graphical Interface

In this graphical interface all the aircraft and the simulation time (actual time) are represented. The numbers of aircraft airborne and at the airport are also displayed; in some cases some of the aircraft will be initiated in the simulation but being still at their airport of origin. Finally, on the table each aircraft is represented by a row with the information of the milestone where they are and the updated values of the flight: flight number, callsign, status, model, ETOT from origin airport, ELDT, ETOT, EIBT and EOBT.

VI. Future Work

At the moment of writing this paper, the A-CDM simulator was able to interchange messages between the different stakeholders for more than one aircraft at the same time. The messages required to simulate the processes form milestone 1 to milestone 7 have been implemented and tested. However, the update of the flight information is still done deterministically. Work is underway to gradually enhance the behaviour of the different actors. For example, the turn-around time used by the *Ground Handling* should vary as a function of the resources available and their disposition at the airport.

More detailed information, such as type and resources of handling companies or gate assignments, should be added in order to increase the accuracy of the actors' behaviour and of the processes involved at an airport. Different stakeholders, for example different airlines, such as legacy or low-cost carriers, with or without integrated handling, should also be modelled. Thus, more realistic scenarios will be simulated being able to test the communications and benefits of A-CDM.

It is also foreseen the introduction of stochastic events in order to reflect a more realistic simulation. Therefore, some of the events will be computed based on statistical distributions instead of being fixed parameters. This stochasticity is currently under development. A first approach will be to add some delay to the flight data obtained from the DDR2 database, i.e. en-route delay, for instance.

Finally, the process described in Section IV.A to generate the realistic scenarios from Eurocontrol DDR2 database needs to be completely implemented, including the flight plan pairing.

VII. Conclusions

Collaborative decision making is considered an efficient manner to involve the different stakeholders at an airport, in order to optimise resources while improving predictability and reaction to unforeseen events. Information sharing is the core of this distributed optimisation technique. Involving the stakeholders and quantifying the benefits of such strategy is of paramount importance. A simulation environment, showing the advantages of such an implementation would help to obtain this commitment. Moreover, this simulation engine could be used to assess the different processes, interactions and dependencies and evaluate the impact in the whole set of operations.

This paper sets the ground for a complete A-CDM simulator. The current state of the simulator is a very convenient framework to develop more complex actors' behaviours and to simulate different strategies for resources optimisation or delay mitigation. A seamless representation of the different actors, their behaviours and their internal optimisation is allowed by the simulator's architecture presented in this paper.

The simulator explicitly represents the interactions between actors from milestone 1 to milestone 7. This helps to obtain a higher commitment of the different stakeholders with the A-CDM, as they can visualise the information required and shared, and the benefits obtained. The expected benefits of a full implementation of the A-CDM milestone approach can be assessed from those simulations. A further development of the simulator would allow the simulation of the higher A-CDM phases to be implemented and tested [12].

Other strategies, rather than just the A-CDM milestone approach [12, 16], could be easily adapted and implemented in the simulator described in this paper. Thus, new strategies or policies in line with SESAR and NextGen programmes, such as the one described in [17] where new mechanisms for airport slot allocation are investigated, could be implemented to test and assess the eventual benefits and their impact on the operations.

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