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EUROCONTROL EXPERIMENTAL CENTRE

ISA PROJECT
(IPv6 - Satellite - ATMode for ATN)
AIR TRAFFIC REQUIREMENTS

EEC Note No. 28/98

Project COM-1-E2

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Abstract:

The new applications FREER, CDM, European FDPS, … represent the basic modules for a new High-Density CNS/ATM concept. In order to determine the required bandwidths it is essential to evaluate the different messages forwarded on the communication channels Ground/Ground, Air/Ground and Air/Air.

Up to now, no comprehensive document seems to be available which defines clearly the requirements for ATS, AOC, AAC and APC. The aim of this study is to identify the new applications for these services in order to estimate the various bandwidths required.

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1. Introduction

The new applications FREER, CDM, European FDPS, … represent the basic modules for a new High-Density CNS/ATM concept. In order to determine the required bandwidths it is essential to evaluate the different messages forwarded on the communication channels Ground/Ground, Air/Ground and Air/Air.

This study tries to distinguish from a gate-to-gate point of view the different types of information exchanges during a given flight. All aspects are considered which are essential 85for aeronautical data transmissions (Data-Link) like Quality of Service, Priority, Availability, Security, Mobility and group-addressing (multicast).

The aim of FREER (Free-Route) [Ref. 1] is to examine the feasibility of an ATM concept according to which ATC functions could be transferred to the cockpit by the use of ADS-B and Data-Link technologies. This concept is therefore based on a reliable and efficient Data-Link which will enable the cockpit to have the same global view of the air traffic as the controller.

The CDM project (Collaborative Decision Making - EEC task) is dealing with the ground part and concerns the relationships between the airlines (AO), the CFMU (flow management), the airports and the control centres (ATCC) in order to improve the information flow for the benefit of flight plan preparation and negotiation.
This project should allow a more efficient management of the airport slot allocation.

For the airlines, the interest is above all economical. For example, trajectory optimization will allow a better use of the airspace, decreased delays, fuel savings and an improved management of the air fleet.

It is also necessary to take into account the rapid evolution of the Internet, the use of mobile telephones on-board (GSM, UMTS) and the wish of all airline companies to offer an ever-improving service to the passengers.

Decreasing communication costs, decreasing cost for optical cabling, improvements of infrared interfaces for laptops, technology evolutions in hardware and protocols (switches, routers, ATMode, IPv6, ...) are all driving factors for the development of new concepts. These evolutions are compatible with the communication techniques made available by the new satellite generations (GEO-LEO).

Presently, different projects (EOLIA, PETAL II, ...) are involved in the evaluation of the various Data-Links of the CNS/ATM package 1. They will permit to evaluate the feasibility of an efficient Data-Link. The results should allow an optimization of the control procedures and the cooperation of the pilots in the air traffic management.

However, a major uncertainty exists with respect to the capability of these different transmission modes (Mode-S, Satcom, VDL mode2/mode 4) to offer sufficient bandwidth and flexibility for the implementation of the new concepts.

FREER represents the most demanding application in terms of advanced communication techniques, but the other applications like CDM, the airlines operational communications (AOC) and the passenger services are equally concerned. Hence, new solutions based on modern telecom and network technologies (satellite, ATMode, IPv6, ...) have to be thought of.

Up to now, no comprehensive document seems to be available which defines clearly the requirements for ATS, AOC, AAC and APC. The aim of this study is to identify the new applications for these services in order to estimate the various bandwidths required.

1.1. References

[1]: FREER-1 Requirements Document, Version 2.0 - 04/96

[2]: PD/3 Data Link Communications Requirements Document for the Trajectory Negotiation Application, Version 1.3 Draft – PHARE 11/97

[3]: The Improvement of Meteorological Data for Air Traffic Management Purposes, D. 85 June 97

[4]: COM.ET2.ST15 : Analyse Options for Initial A/G Data Networks – Phase 3 Report – Tentative Implementation Plan by Horizon 2000-2005 Core Report Document 12/97 EATCHIP programme

1.2. Web sites

AudioLAN	http://www.eurocontrol.fr/projects
Expérimentations - ATMode	http://www.eurocontrol.fr/projects
FREER	http://www.eurocontrol.fr/projects
IPv6	http://www.process.com/ipv6
ISA	http://www.eurocontrol.fr/projects

1.3. Acronyms

AAC	Airlines Administrative Communications
ACARS	Aircraft Communications Addressing and Reporting System
ACL	ATC clearance
ACM	CPDLC – Frequency change
ACTS	Advanced Communications Technologies and Services
ADAP	Automated Downlink of Airborne Parameters
ADS	Automatic Dependent Surveillance
ADS-B	ADS Broadcast
ADS-C	ADS Contrat (Point to Point)
AIS/NOTAM	FIS - Aeronautical Information Services / Notice to Airmen
AMSS	Aeronautical Mobile Satellite System
AOC	Airlines Operational Communications
APC	Aeronautical Passenger Communications
ASAS	Aircraft Separation Assurance System
ATC	Air Traffic Control
ATCC	Air Traffic Control Centre
ATIS	FIS - Automatic Terminal Information Services
ATM	Air Traffic Management
ATMode	Asynchronous Transfer Mode
ATN-OSI	Aeronautical Telecommunication Network - OSI protocol
ATS	Air Traffic Services
B-ISDN	Broadband-Integrated Services Digital Network
CAP	ADAP - Controller Access Parameters
CDM	Collaborative Decision Making
CIC	CPDLC - Clearance and Information Communications
CFMU	Central Flow Management Unit
CNS/ATM	Communication Navigation Surveillance, Air Traffic Management
COIAS	Converge IPv6-Satellite-ATMode
COTS	Commercial off-the-shelf
CPDLC	Controller-to-Pilot Data-Link Communication
DCL	Departure Clearance
DGNSS	Differential Global Navigation Satellite System

DLIC	Datalink Initiation Capability
DSC	CPDLC - Down Stream Clearance
DYNAV	Dynamic Route Availability
EATCHIP	European Air Traffic Control Harmonisation and Integration Programme
EC	European Commission
EEC	Eurocontrol Experimental Centre
EFIS	Electronic Flight Instrument System
EFR	Extended Flight Rules
EOLIA	European pre-Operational data LInk Applications
ESCAPE	Eurocontrol's Simulation Capability and Platform for Experimentation
ETA	Estimated Time of Arrival
FANS	Future Air Navigation System
FDPS	Flight Data Processing System
FIS	Flight Information Services
FLIPCY	Flight Plan Consistency
FMC	Flight Management Computer
FMS	Flight Management System
FREER	Free-Route Experimental Encounter Resolution
GEO	Geostationary Earth Orbit
GSM	Global System for Mobile communications
INRIA	Institut Nationale de la Recherche en Informatique et Automatisme
IP	Internet Protocol
IPng/IPv6	Internet Protocol next generation/Internet Protocol version 6
ISA	Ipv6-Satellite-Atm project
LEO	Low Earth Orbit
MCS	Multi-aircraft Cockpit Simulator
PD3	PHARE demonstrator 3
PHARE	Programme for Harmonised ATM Research in EUROCONTROL
OCM	Oceanic Clearance Message
PPD	ADAP – Pilot Preferences Downlink
PETAL II	Preliminary Eurocontrol Test of Air/ground Datalink, phase II
QoS	Quality of Service
RVR	FIS – Runway Visual Range
SAP	ADAP – System Access Parameters / flight and meteo
SIGMET	FIS – Significant Meteorological Information
TFTS	Terrestrial Flight Telecommunications System
TMA	Terminal Management Area
TN	Trajectory Negotiation
UCL	University College of London
UKMO	United Kingdom Meteorological Office
UMTS	Universal Mobile Telecommunication System
VDL	VHF Data-Link

2. Aeronautical services

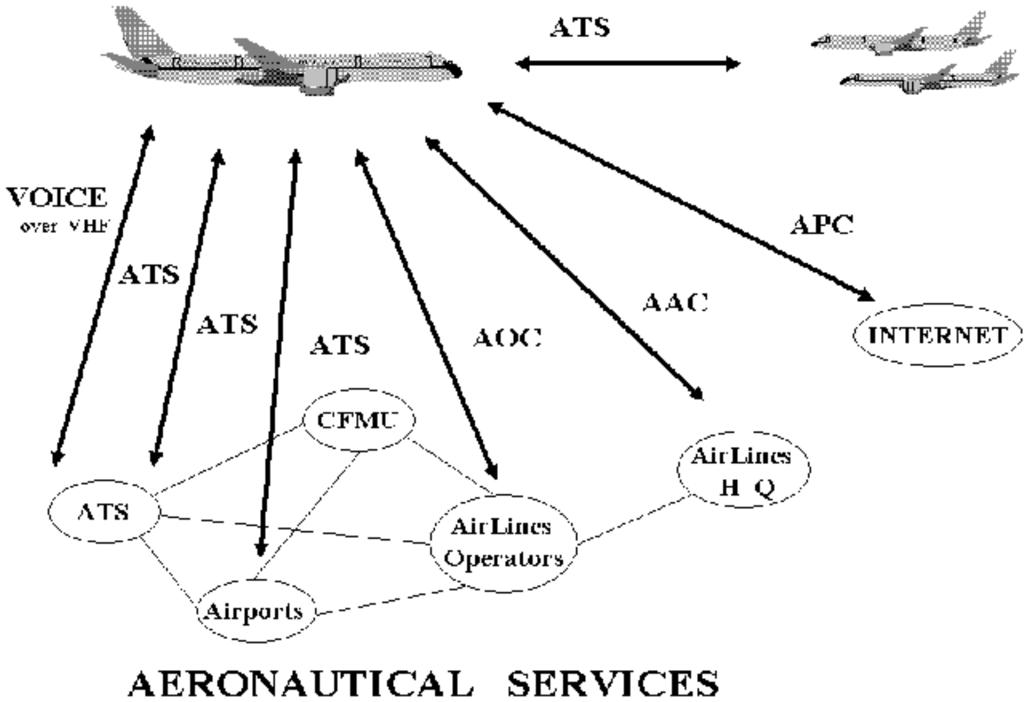


Figure 1

Figure 1 represents the different information flows to evaluate, each flow corresponding to :

- a type of service grouping several applications,
- a priority level.

Five communication services types have been identified :

- Voice over VHF is today the basic dialogue mode used by controllers and pilots for air traffic control operations (ATS voice communication). In the future, voice transmission will be part of a distinct digital flow allowing for a higher security level (today everybody can receive and understand aircraft VHF channels).

- Air Traffic Services (ATS) communications, which serve flight management and take place between the cockpit and ground-based personnel or systems operating under the control of national Civil Aviation Authorities). These communications may also take place between two cockpits in case of Air-to-Air applications.

- Airlines Operational Communications (AOC), dedicated to flight operation, maintenance and engineering activities handled by crew members in connection with airline ground-based personnels or systems.

- Aeronautical Administrative Communications (AAC), which serve cabin-management and in-flight passenger service support purposes.

- Aeronautical Passenger Communications (APC), dedicated to passengers in the cabin.

2.1. Priorities Definition

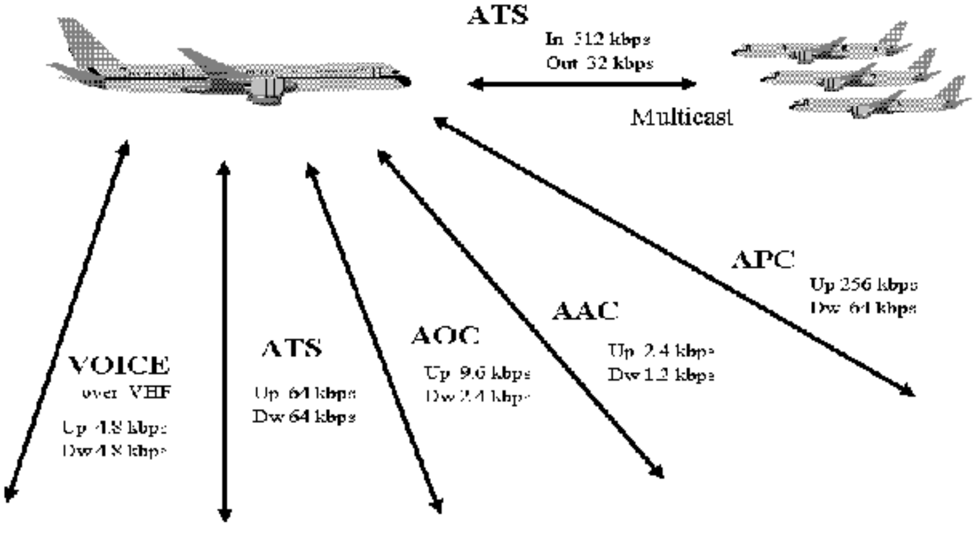
Certain communication services of those presented here are essential because they are linked to the safety of aircraft and passengers (e.g. ATS) while other services serve only for the passengers' entertainment. Therefore, a priority level is allocated to each of these services :

- The highest priority is given to Voice over VHF which is the main dialogue mode for the Air Traffic Control management.
- Priority number 2 is given to the Data-Links reserved for ATS applications Air/Ground and Air/Air.
- Priorities number 3 and 4 are allocated to AOC (Airlines Operational Communications between aircrafts and airline companies) and AAC (Airlines Administrative Communications between aircrafts and airline company head offices).
- Aeronautical Passenger Communications (APC : telephone, fax, data, Internet, ...) have the lowest priority and are only allowed during the en-route flight phase, when the other applications (ATS, AOC or AAC) are inactive.

Priority	Services
1	Voice over VHF
2	ATS
3	AOC
4	AAC
5	APC

Table 1 – Priority levels

2.2. Required Bandwidth Evaluation



AERONAUTICAL BANDWIDTH - GENERAL CASE

Firstly, the various applications of the different services ATS, AOC, AAC and APC have been listed. Then, all data exchanges generated by each application had to be identified and quantified in order to establish an order of magnitude for the bandwidth required by each communication service.

2.2.1. VHF bandwidth

The Up and Down bandwidth of the actual VHF channel has been estimated at 4.8 Kbps on the basis of the AudioLAN project (see url= http://www.eurocontrol.fr/projects...).

The digital voice data flow must be constant and the latency time less than 100 ms in order to avoid poor audio quality (disrupted audio, sound echo, ...).

2.2.2. ATS bandwidth

Concerning the ATS domain, we have concentrated our work on applications which should be operational in the years 2010/2015, namely :

- The FREE Concept [Ref. 1].

  Two aspects have been considered : FREER 1 or the autonomous mode and ASAS 2015 or the Air/Ground coordination mode which corresponds to the FREER 2 concept.

  In FREER 1, ATC functions are totally transferred to the cockpit for low traffic density zones where ground infrastructure is poor or not existing.

  In ASAS 2015, ATC functions are partially transferred to the aircraft for high-density zones where air traffic flow is anticipated over long periods of time with the help of ground infrastructures. In this mode, pilots will finally dispose of the same information as the controllers.

- The trajectory negotiation [Ref. 2].

- The NowCast meteo model [Ref. 3].

  The meteorological aspect seems rather poorly developed. However, studies have been carried out with Meteo France and UKMO under an EATCHIP programme called “ NowCast ”. The principle of Nowcast consists in updating a ground 4D-meteo database (position, altitude, time) with data collected by the aircrafts. The updated meteo information could then be fed to all aircraft to allow a better trajectory prediction (vision 3½ or 4D) and thus procure a considerable profit for the air operations (flight safety, longer life-time for the aircraft, ...).

- The CPDLC applications (Controller Pilot Data-Link Communication), dealing with frequency change (ACM) and the different authorizations or clearances (departure DCL, oceanic DSC/OCM) [Ref. 4].

- The ADAP applications (Automated Downlink of Airborne Parameters) comprising the Controller Access Parameters (CAP) for the prediction display; the flight system parameters (SAP-Flight) for the enhanced surveillance, conflict detection and medium term planning; the meteo parameters (SAP-Meteo) for the improvement of flight operations and trajectory predictions [Ref. 4].

- The FIS applications (Flight Information Services) regrouping meteo messages (SIGMET, NOTAM) as well as flight plan conformity [Ref. 4].

- And the ADS-B applications.

The table in Appendix 1 lists the various ATS applications and the messages linked to these applications which have been identified during the study.

Concerning the evaluation of the required ATS bandwidth, it is necessary to distinguish the Air/Ground and the Air/Air flow. This distinction is linked to the notion of group-addressing or multicast required for the Air-to-Air dialogue in the context of the FREER project.

- With reference to the table in Appendix 1, the Up and Down bandwidths of the Air/Ground ATS data flow are estimated to 64 Kbps. This estimation is based on the requirement to transmit a constraint list (uplink) or a trajectory (downlink) of a maximum size of 3,000 bytes within a maximum 1.5 s time interval corresponding to the data validity. This example generates a data flow of 16 Kbps to which one must add the transmission of other higher-volume messages like the NowCast data.

  It is obvious that the estimation of a mean data flow (between 50 and 100 bps) encountered during our various studies of the ATC-generated data is only meaningful if one does not consider the time of data validity. In the present case, we should arrive at a mean data flow of a hundred bits per second. 240 s could be required to transmit a trajectory, thus occupying the full bandwidth. Big problem : the data validity is 1.5 s.

- The study of the Air-to-Air dialogue has led to the notion of cluster. A cluster can be defined as a group of aircraft in a given space around a particular aircraft where some of group might run into conflict with respect to the latter one. Behind the notion of cluster, one finds the group-addressing or multicast aspect (IPv6) which is important for the Air-to-Air dialogue in a defined airspace. A generally admitted hypothesis for the evaluation of the required Air-to-Air bandwidth corresponds to a maximum of 30 aircrafts within a cluster, at the horizon of 2015.

  In FREER 1, the aircraft is transmitting its position and flight intent information to all aircraft within its cluster. In the context of ASAS 2015, the aircraft must transmit position and trajectory to all surrounding aircrafts in order to anticipate possible conflicts and to give to pilots and controllers the same air traffic picture.

  The Air-to-Air bandwidth requirements are estimated on the basis of the ASAS 2015 application corresponding to a high-density continental traffic and resulting in a superior bandwidth to FREER 1.

  The Air-to-Air bandwidth can be evaluated in two distinct ways :

  - The Air-to-Air “ Out ” data flow of an aircraft is evaluated to 32 Kbps knowing that it must transmit 3000-byte trajectories within 1.5 s, i.e. 16 Kbps (cf. Appendix 1). As to the “ In ” data flow, the aircraft could receive in the worst case simultaneously 29 aircraft trajectories, i.e. 29 times 16 Kbps, to which one must add 29 position reports. The “ In ” flow is evaluated to 512 Kbps.

  - One way to reduce the “ In ” bandwidth could consist in defining within the original cluster another cluster combining only the possible conflicting aircrafts. Within the original cluster, aircrafts communicate only their position reports. Only the members of the conflict cluster do transmit their trajectories, thus limiting the important data flow to this airspace. A deterministic conflict detection algorithm allows such a modeling. The maximum traffic within a conflict cluster has been estimated to 4 aircrafts, hence reducing the Air-to-Air “ In ” bandwidth by about 85 percent of the preceding case.

    The “ Out ” flow remains unchanged. As to the “ In ” flow, the aircraft would receive in the worst case simultaneously trajectories from 3 conflicting aircrafts, i.e. 3*16 Kbps to which one must add position reports from 29 aircraft. The “ In ” flow is evaluated to 64 Kbps.

Questions to ask : how does a cluster form itself ? Can one allocate clusters dynamically ? Who does manage it ? What should be the allocated cluster airspace and how many aircrafts at maximum should it contain ?

The multicast notion can also be envisaged on the level of the airline companies in order to address the whole fleet. In this case, group addressing is fixed and well defined.

2.2.3. AOC bandwidth

The airline services (AOC and AAC) have been grouped in two distinct data flows with two different priorities.

The AOC communications depend basically on the strategies defined by the airline companies for the operational procedures. Hence, messages are specific to the airline needs and can be different from one company to the other. It seems that these informations are sufficiently commercially important (e.g. take-off power) so that airline companies do not like to divulge them too precisely.

Generally speaking, the AOC services are dedicated to flight plan management, air traffic operations and maintenance activities.

The table in Appendix 2 gives an idea of certain AOC messages used by Lufthansa. The AOC service is remarkable by its asymmetrical data flow. The amount of information sent to the aircraft is more important than the one sent to the ground. The important “ Up ” flow during the pre-flight phase is due to the loading of the Flight Management Computer (FMC/FMS) database. During the en-route phase, the high “ Up ” flow is due to the size of the flight plan messages and the “ Down " flow is due to size and frequency of the maintenance messages fed from the Central Maintenance Computer (CMC) and the motor monitoring messages fed from the Aircraft Condition Monitoring System (ACMS).

Presently, the AOC messages are running through the ACARS system at 2.4 Kbps. The airline companies wish to enhance considerably this service in view of a better fleet management and an optimisation of their aircraft. Taking account of the new functions (grey-shaded in Appendix 2), the “ Up ” flow is estimated to 9.6 Kbps and the “ Down ” flow to 2.4 Kpbs.

2.2.4. AAC bandwidth

The AAC communications are used during the flight phase for the cockpit management and for the passenger services support.

AAC messages are for example : Pax Seatplan, Flight log, Connecting gate, Aircraft crew rotation, Airshow, etc...
The table of Appendix 2 gives an idea of some AAC messages used by Lufthansa. This service presents an asymmetric data flow : the “ Up ” flow is higher than the “ Down ” flow.

Just like the AOC messages, the AAC messages are equally passed through the ACARS system with a rate of 2.4 Kbps. The “ Up ” flow is estimated to 2.4 Kbps and the “ Down ” flow to 1.2 Kpbs.

2.2.5. APC bandwidth

The passenger part foretells a great number of applications linked to the multimedia evolution. Indeed, the multimedia world boils over with imagination highly attractive for the passenger who has for the time being a purely passive role during the flight. The passenger demands more entertainment and calls for the possibility to keep contact with his company by E-mail, to connect to Internet and even to use telephone service via Internet (cf. AudioLAN) without paying for the TFTS communication cost.

Downloading of certain applications (Video-on-Demand) during the parking phase on ground would allow to save rare and expensive air-services bandwidth.

As to the Internet part, the Eurocontrol Experimental Centre in Brétigny seems to be a good example. The Centre is employing about 400 people who make all use of an Internet connection from their working office via a 256 Kbps access provider link. This configuration seems fully adequate for the needs of a commercial aircraft. This type of service presents also an asymmetrical data flow. The requests are smaller than the replies. So, the “ Up ” flow is evaluated to 256 Kbps and the “ Down ” flow to 64 Kpbs.

3. COIAS Project - Air Traffic Requirements

3.1. Project Objectives

Eurocontrol has expressed to European Commission its great interest to participate in Advanced Communications Technologies and Services (ACTS) projects dealing with IPv6, ATMode, satellite and UMTS at the user level. In this way, the EEC is joining a consortium (Dassault Electronique, British Telecom, CISCO, Eutelsat, UCL, INRIA, Helas Space, Secunet) of the task-AC321, EC DGXIII for a project named COIAS.

The COIAS project aims to investigate the integration of ATMode and satellite telecommunication technologies with the new generation Internet technology - IPv6 (expanded and hierarchical addressing, Quality of Service, security, routing, multicast and mobility features). The project will experiment the necessary mechanisms required to couple IPv6 with both ATMode and satellite protocols, providing both security and facilities to potential users.

The COIAS project shall validate the integration of ATS, AOC, passenger applications and network components, and shall address, among others, the problem of the operational environment, from both the user and application level.

It is proposed to use the large simulations facilities of the Eurocontrol Experimental Centre which represents real and advanced Air Traffic Control and Air Navigation systems to experiment and validate at application level these emergent network and telecom technologies. EEC participation will validate the integration of the ATC applications and network components, and will address, among others, the problem of operationally requesting, from the user or the application level.

EEC should provide applications and infrastructure for the experimental platform which needs to have Air-Air, Air-Ground, Ground-Ground links, multi-peer communications, security, mobility, multimedia, QoS and hierarchical addressing : FREER, MCS, ESCAPE, AudioLAN, FASTER-Collaborative Decision Making…

Through its pilot experiments, the project shall also demonstrate to large user communities that these services are operational and ready to be integrated into their day-to-day work schemes.

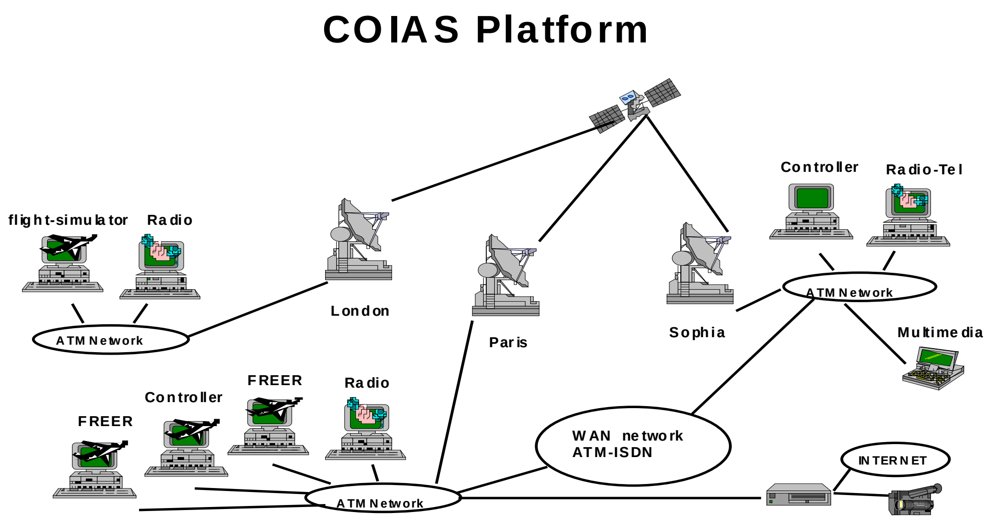


Figure 3 : COIAS platform configuration

3.2. Priorities Definition

Priorités	Services
1	Voice over VHF
2	ATS
3	AOC and AAC
4	APC

Table 2 – Priority levels

3.3. Bandwidth Evaluation

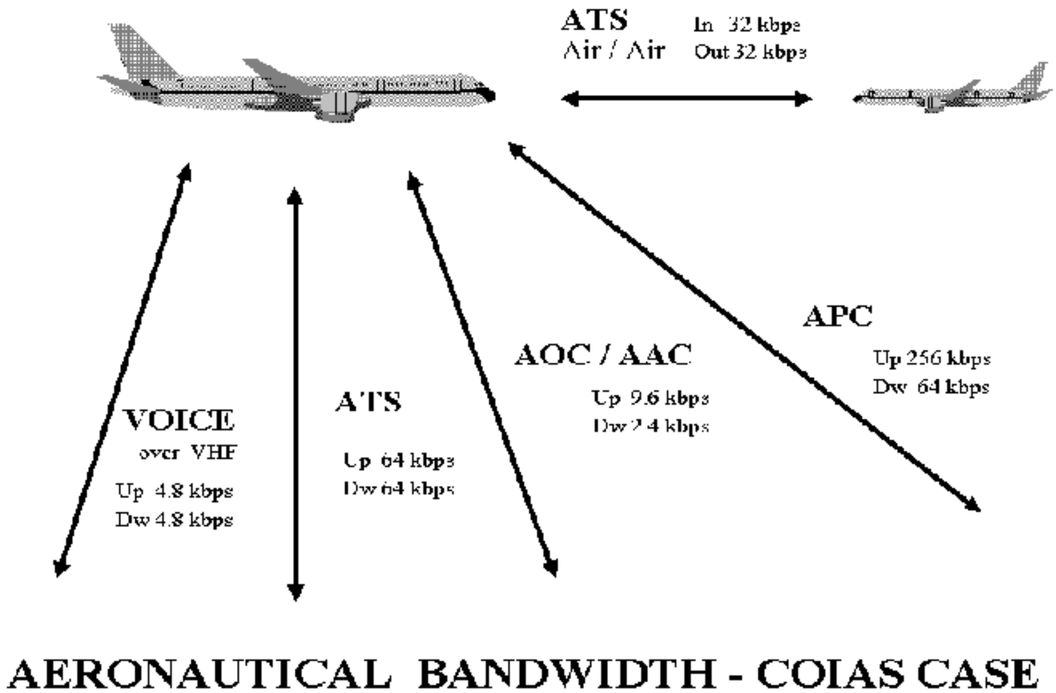


Figure 4

The bandwidths required for the COIAS project have been estimated from the results obtained in Chapter 2.2. Only two differences should be pointed out :

- The COAIS project will dispose of 2 FREER simulators, thus restricting the Air-to-Air ATS bandwidth to two aircrafts.

- The proper airline services (AOC and AAC) have been regrouped in a unique data flow with a unique priority.

3.3.1. VHF bandwidth

The Up and Down VHF bandwidth is estimated at 4.8 Kbps.

3.3.2. ATS bandwidth

The ATS Air/Ground and Air/Air flows have been separated for the same reasons as indicated in the preceding chapter.

- The ATS bandwidths Air/Ground Up and Down are estimated at 64 Kbps.
- As to the Air/Air flow, the COIAS project will dispose of 2 FREER simulators. The " In " and " Out " flow of each aircraft/simulator are estimated at 32 Kbps.

3.3.3. AOC-AAC bandwidth

These two services have been regrouped in a unique flow. The estimated bandwidth for the services corresponds to the AOC evaluation reported in the previous chapter. The " Up " flow is estimated at 9.6 Kbps and the " Down " flow to 2.4 Kpbs.

3.3.4. APC bandwidth

The " Up " rate is estimated at 256 Kbps, the " Down " rate at 64 Kbps.

4. Conclusion

This study about the identification of the different information flows Air/ground and Air/Air has clearly shown that the presently used Data-Link and telecom techniques are not suitable for new applications like FREER.

❑ The important latencies encountered during the ADS-Europe trials reveal a new phenomenon linked to real-time nature of the transmitted data (period of time during which the data remains valid).

In addition to latency problems, the required channel capacity must take into account that some new applications generate high volume messages (e.g. trajectory negotiation). In other words, should an aircraft which transmits a 5 Kbit message occupy a 500 bps or a 64 Kbps bandwidth ?

The evaluation of the correct and optimized bandwidth requires necessarily a data flow model taking into account message volume, life time, repetition rate, priority level, available resources and mechanisms of ATMode and IPv6.

❑ It is obviously unreasonable to reserve during the whole flight a given satellite resource. This resource being rare and expensive, why not foresee a dynamic bandwidth allocation ?

With respect to this allocation, the en-route and other flight phases (take-off, ascent, descent and landing / TMA) have opposite constraints :

- The en-route phase requires a bandwidth on-demand due to the high volume but occasional transmissions (meteorological request, trajectory negotiation, ...).

- The other phases correspond more to a constant data volume linked to a frequent sector change. During these flight phases, the data delivery is urgent, and therefore the allocation of a permanent channel would be appropriate.

⇒ All these considerations appear to be more important than the mean bandwidth studies envisaged by the next trials. Under these circumstances, ATMode and IPv6 should supply all the options of flexibility, addressability, mobility, security (safety) and dynamic bandwidth allocation.

The present study of “ Air Traffic Requirements ” which was initially meant to list the various data flows, has revealed surprising findings. The notion of aircraft cluster and the Nowcast meteo model belongs to these new elements.

❑ The study has underlined the problem of cluster management which is linked to the notion of group-addressing or multicast. Those aspects are essential for the Air/Air dialogue particularly in the context of conflict resolution.

Several questions are pending with respect to cluster definition, dynamic cluster allocation, the way an aircraft should be recognised by a cluster, etc... Many questions which can be the subject of follow-up studies.

⇒ In the absence of documentation and a precise definition of requirements for ATS, AOC, AAC and APC, any estimation of necessary bandwidths can only be approximate. Nevertheless, the rough estimates given are coherent with the actual requirements of the new applications and the possible medium term of evolutions.

The implementation of these services should now allow to thoroughly examine the ATMode technology and to fully utilize all resources provided by the IPv6 designers.

Many thanks to Eric HOFFMAN (FREER), Jean-Pierre NICOLAON (FREER) and Georges MYKONIATIS (CDM) for the valuable contribution they have supplied for the requirements definition.

Appendix 1: ATS applications horizon 2010/2015

Applications		Message length / data bytes	Average period between Messages	Maximum transit delay	Comments
FREER (ASAS)					
Position Report / State Vector	air/air	20	5 s	0.5 s	ADS-B
Flight Intents	air/air	100 3000	30 s 5 min	1.5 s 1.5 s	FREER 1 : TCPs (e.g. 4) + reference to destination ASAS 2015 : detection -> trajectory (same information for pilot and controller)
Status Detection (EFR)	air/air	100	random	1.5 s	depends on conflicts - autonomous airborne mode (FREER 1)
Control Delegation	up	> 3000	5 min	< 1.5 s	Horizon 2010/2015 - conflict resolution - ground-air co-ordinated mode (ASAS 2015) No-go zones (Multi Sector Planner) from Free-flight controller Tactical delegation : voice and datalink -> EFIS display
PD3					
Trajectory Negotiation	up dw	3000 3000	5 min 5 min	1.5 s 1.5 s	Constraint list - multi sector planning/tactical controller Trajectory (FMS 3½D)
CPDLC/ACM	*up*	*215*	*4 min*	*5 s*	*Frequency change (en-route/7min, approach/1min)*
NowCast	up dw	10 000 50	15 min? 5 min?	15 s 15 s	Meteo model based on volumes/cubes (aircraft always in the tube?) cube [alt,pressure,temp,wind speed,cloud covering,...] Pilot on-request Meteo smoothing
CPDLC					**Controller Pilot Data Link Communication**
CPDLC / ACM	up	215 (up=158 / dw=57)	4 min	5 s	Frequency change (en-route/7min, approach/1min)
CPDLC / CIC (ACL)	up dw	292 292 (up=146 / dw=146)	5 min 5 min	1.5 s 1.5 s	Clearance and Information Communications (ACL = ATC Clearances)
CPDLC / DCL	up up	425 (up=274 / dw=151) 475 (up=299 / dw=176)	1/flight 1/flight	15 s 15 s	Departure Clearance Revised Clearance
CPDLC / DSC (OCM)	up	235 (up=178 / dw=57)	2/flight	10 s	Downstream Clearance (Oceanic Clearance Message) 1 Oceanic initial + 1 Revised Clearance (or CIC?)
ADAP					**Automated Downlink of Airborne Parameters**
ADAP / CAP	dw	20	70/flight	1.5 s	Controller Access Parameters (prediction display)
ADAP / SAP-Flight ADAP / PPD	dw dw	20 20	70/flight 70/flight	5 s 5 s	System Access Parameters-Flight Pilot Preferences Downlink (enhanced surveillance / conflict detection and medium term planning)
ADAP / SAP-Meteo	dw	36	3 min	< 2 min	Short term meteo forecast to improve aircraft operation and trajectory prediction

ATS applications horizon 2010/2015 - suite

Applications		Message length / data bytes	Average period between Messages	Maximum transit delay	Comments
FIS					**Flight Information Services**
D-FIS / D-OTIS / ATIS	up	180 (up=154 / dw=26)	3/flight	15 s	Automatic Terminal Information Services
D-FIS / AIS-NOTAM	up	292 (up=254 / dw=38)	3/flight	15 s	Aeronautical Information Services / Notice to Airmen
D-FIS / D-RVR	up	100 (up=62 / dw=38)	3/flight	15 s	Runway Visual Range
D-FIS / D-SIGMET	up	292 (up=254 / dw=38)	3/flight	15 s	Significant Meteorological Information
DLIC	up/dw	274 (up=138 / dw=136)	1/flight	15 s	Datalink Initiation Capability (new name for Context Management - CMA)
FLIPCY	up/dw	1084 (up=542 / dw=542)	2/flight	10 s	Flight Plan Consistency (new name for Flight Plan Conformance - PLN)
DYNAV	up	555 (up=530 / dw=25)	5/flight	1.5 s	Dynamic route availability (better route proposed) MSP tactical flow planning
Push-back	up/dw	60 (up=32 / dw=28)	1/flight	15 s	Simple request/response pattern - dialogue between pilot and airlines or airports
Taxi	up	180 (up=152 / dw=28)	1/flight	10 s	
Others					
ADS-C oceanic (basic) ADS-C continental		200 50	5 min 4 s	15 s < 0.5 s	Automatic Dependent Surveillance - Point to Point
ADS-B		20	12s - 5s - 1s	1.2s - 0.5s - 0.1s	ADS Broadcast
DGNSS		100/200	10 s	1 s	Differential GPS

Appendix 2: AOC and AAC messages example

AOC and AAC Messages

Flight phases	Message	Message Type	Downlink size (bytes)	Uplink size (bytes)	Frequence	Comments
Pre-flight	FMC Performance init	AOC		1250	1	Flight Management Computer/System (FMS)
	Weight and Balance	AOC	19	100	1	
Take-off	FMC Route Data init	AOC		1250	1	
	FMC Cruise Wind init	AOC		1250	1	
	FMC Alternate Dest init	AOC		1250	1	
	Loadsheet	AOC	19	100	1	Document containing the Aircraft-Centre of Gravity
	ETT	AOC	30		1	Estimated Total Time
	OUT Message	AOC	27		1	Aircraft ready for taxiway
	OFF Message	AOC	118		1	Take-off - the aircraft left the runway
Ascent	Refueling Report	AOC	27		1	
En-route	airshow message	AAC	19	200	5	
	Pax Seat Plan	AAC	30	4000	2	
	Flight Plan	AOC	41	5000	0.5	
	CMC-CFDIU Message	AOC	800		2	Maintenance messages from Central Maintenance Computer- Central Fault Display Interface Unit
	ACMS Report	AOC	400		4	Engine monitoring messages from Aircraft Condition Monitoring System
	ETA Change	AOC	30		1	
Descent	Aircraft Crew Rotation	AAC	50	1200	0.1	
	ETA - 20	AOC	30		1	Estimated Time of Arrival
	ETA - 7	AOC	30		1	
Landing	ON Message	AOC	27		1	Aircraft landing
Taxi	IN Message	AOC	27		1	Gate arrival