CEC TEN-T ATM Task UK/96/94

ACCESS

ATN Compliant Communications

European Strategy Study

Define Network Topology - Routing Architecture

Definition of the European ATN Routing Architecture

OPTION 1

Document Reference	: ACCESS/STNA/203/WPR/009
Author	: STNA
Revision Number	: Issue 2.0
Date	: 5 March 1998
Filename	: S009I2-0.DOC

DOCUMENT CONTROL LOG

Revision Number	Date	Description of Change
Issue 1.0	21/01/98	First Issue
Issue 2.0	05/03/98	Updated to include minor comments.

EXECUTIVE SUMMARY

The Organisations involved in the ground deployment of the European ATN can be classified in 2 overlapping categories:

- The ATN Users (ATS Organisations, Aircraft operators, Military organisations, Airport operators and Meteorological organisations) are the organisations running applications that will be source and/or destination of ATN data traffic.
- The ATN Service Providers (International Aeronautical communication Service Providers (or other public/private telecommunications network operators), ATS Organisations and Airport Operators) will provide full (or part of the) set of ATN services to (a group of) ATN users.

The European ATN will encompass the network(s) of these multiple different organisations; its routing organisation will hence be firstly constrained by the existence of the multiple administrative boundaries.

At national level, within each European country, the ATS Organisation is expected to co-ordinate and maintain control, directly or indirectly, over the ATN communication provision strategy. In most cases, the national ATSO is expected to be the go between other organisations in the country for ATSC information exchange while ensuring that all other aeronautical communications are not unduly restricted and can be provided to the maximum extent possible through common airborne and ground equipment. In different countries, however, different schemes will be followed and certain CAAs may consider third party telecom service providers (ground-ground or air-ground) as a suitable alternative to ATS-dedicated private (i.e. CAA managed) networks.

At international Level, institutional arrangements for communication service provision will mainly involve national ATSOs, supra-national ATSOs and IACSPs.

This document aims at proposing a routing organisation for the European ATN in the geographical area and the timeframe considered in the ACCESS project, and at describing a technically feasible deployment scenario meeting the identified technical and organisational constraints. This report is considered as a first possible option for the European ATN architecture. A second option is being developed, following a different approach. Evaluation and validation of both options will be performed later. Further analysis and simulations will then allow to validate the assumptions, provide the basis for a comparative assessment of the different architectural options and support the actual design decisions by quantitative figures.

In this document, the routing organisation is firstly considered in a global geographical scope covering the whole European Region as well as the ATN interconnection of the European Region with other Regions in the world. The design decisions are primarily driven by the criteria to minimise the route management load in the ATN routers. The rational for this criteria is that the ATN can only work if the ATN routers are in a position to absorb and process the routing traffic in real time and converge quickly to valid routing decisions. The route update rate to be supported by the ATN routers is hence perceived as one of the main constraining factors.

The European ATN is proposed to consist of one global ATN Island hierarchically subdivided into 3 sub-regions:

1. The Western ATN subIsland, which covers the oceanic area and most of the core area, and consists of the following countries: United Kingdom, the Benelux Countries, France, Germany, Switzerland, Ireland, Spain and Portugal

2. The Eastern ATN subIsland, which covers a part of the core area, and mostly peripheral area, and consists of the following countries: Austria, Italy, Greece, former Czechoslovakia, Hungary, Romania, Croatia, Slovenia, Bulgaria, Turkey, Cyprus, Malta

3. The Northern ATN SubIsland, which covers Scandinavia and countries around the Baltic Sea: Norway, Sweden, Denmark, Finland, Latvia, Lithuania, Poland

This global European ATN Island should be completed by an independent separate European « Home » Routing Domain Confederation (RDC) formed by the Airlines and their service providers and hosting the home Routing Domains of the European Airlines.

The Western, Eastern and Northern ATN subIslands should be organised according to the following principles:

- The subIsland's backbone architecture should consist of backbone routers interconnected with a central route server.

- In European geographical areas, where an international ATC Wide Area Network is available, Boundary Intermediate Systems of local administration should establish an IDRP connection with the central backbone route server

- In European geographical areas, where access to an international ATC WAN is not available, Boundary Intermediate Systems of local administration should establish an IDRP connection with a backbone router.

The ATSOs might be reluctant to offer their ATS-dedicated ATN networks to serve as transit network for AOC traffic; IACSPs could consequently be prime actors of the AOC data forwarding task. IACSPs (with aircraft operators) are assumed to participate in the implementation of the ATN, at the following 3 levels:

1. At national level, for the provision of general ATN services (e.g. AOC, AAC communication) complementing the services provided by the national ATSO. Depending on the national strategy of the ATSO, IACSPs may be contracted for the provision of ATN services meeting local ATS communication requirements.

2. At subregional/regional level, IACSPs may deploy an ATN infrastructure meeting airlines communication requirements, and completing potentially the regional ATS communication service by offering alternate/backup ATN routes to the aircraft.

3. At inter-regional level, IACSPs and airlines are assumed to look after the implementation and interconnection of Home Routing Domains and to consequently participate in the routing and forwarding of inter -island data traffic to/from aircraft.

It is assumed that IACSPs and airlines will implement the ATN infrastructure suitable at each level for meeting the particular requirements. The Routing Organisation for this ATN infrastructure is out of the scope of this study.

IACSPs and ATS Organisations are assumed to be interconnected at backbone level and at the level of the individual A/G routers permitting both ATSC and AOC traffic exchange with aircraft.

On the basis of all these general routing organisation principles and of the outcomes of ACCESS WP 202 (Define geographic area & services), WP 204 (Ground/Ground Subnetworks) and WP 205 (Air/ground Subnetworks), the document proposes the routing architecture and the deployment scenario for a target European ATN in the geographical area considered in the ACCESS project.

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1.1 Scope

The 'ATN Compliant Communications European Strategy Study' (ACCESS) project that is being run under the European Commission's programme for financial aid in the field of Trans-European Transport Network (TEN-T), ATM Task UK/96/94, aims at defining the initial architecture of the ATN in EUROPE (i.e. selection of the initial applications, definitions of the initial network topology, definition of the routing organisations and of the addressing plan, etc. ..), and will propose initial solutions as regards to the security, safety/certification, network management, institutional, and other issues as well as a transition plan.

Part 1 of Access project focuses on ATN Implementation with the objectives of proposing a network architecture, solutions for network implementation issues and a plan for transition from the existing network infrastructure to the proposed ATN infrastructure.

Part 2 of the ACCESS project covers the ATSMHS Interoperability/Validation testing.

This report presents the first option for the Routing Architecture of the European ATN. It has been developed in the scope of Work Package 203 (entitled « Define network topology - routing architecture ») and represents one part of the ACCESS interim deliverable 1 in Part 1. A second option is proposed in another document.

1.2 Geographical Area and time frame considered by the ACCESS project

The geographical area considered in ACCESS consists of the following countries: UK, Ireland, Benelux, Germany, France, Italy, Spain and Portugal. These States were chosen for the following reasons:

- **They have a direct connection to the CFMU and/or are involved in the control of North Atlantic traffic.** States connected directly to the CFMU - in 1997 - were selected because this enables the major ground/ground data flows in Europe to be included in the study. North Atlantic Region States were selected, as this Region is likely to provide the first operational implementation of ATN services.
- **The study is representative of both Oceanic and Continental ATC**. Including the NAT Region and European States allows routing and architecture issues between boundary Regions to be studied.

With regard to the definition of the routing organisation of the ATN in Europe, it has however been considered that limiting the study to those states was too restrictive and that there was a need to first consider the problem in a more global geographical scope, covering the whole European Region as well as the ATN interconnection of the European Region with other Regions in the world. In a first step, the geographical scope of this work package will therefore been broadened to the whole Europe. In a second step, and from the proposed overall pictures of the European ATN topology will be derived the proposed specific ATN routing organisation within the ACCESS geographical area.

With respect to the considered timeframe, it is assumed that an initial European ATN will be deployed and be operationally used during the period 2000-2005. This initial European ATN is considered in the time as the first brick to a global and mature target European ATN that would answer the most of ground-ground and air/ground ATN communication requirements currently identified. This target European ATN is assumed to be deployed in years 2005-2010 where new data link services and new communication networks will be set in operation and additional ground facilities will be equipped.

The initial ATN of year 2005 must consist of the first elements on an expandable ATN infrastructure that will actually allow, in some further implementation steps, the building of the target European ATN of the year 2010. The initial European ATN is therefore viewed as a transition step toward the target infrastructure.

As a practical approach for the definition of the initial European ATN, it is considered that ACCESS must first focus on the definition of the target European ATN and that the initial implementation will be derived in the scope of the ACCESS transition planning Work Package (WP240).

Following this approach, the scope of this document has not been limited to the initial period of the ATN deployment and proposes a routing organisation for the target European ATN. The ACCESS Work Package 240 will later on in the ACCESS project define more precisely what the initial European ATN could be, based on some guidelines given here.

1.3 Purpose of the Document

The purpose of this work package is to define the routing framework of the target European ATN, i.e. the definition of routing domains (backbone RD(s), and other RDs), routing domain confederations, routing policies, the location and types of routers, etc.

This task is closely related to WP_204 (ground/ground subnetworks) and WP_205 (air/ground subnetworks). The result of these 3 tasks will define the overall topology of the target European ATN.

This document develops a first proposal for the routing organisation of the European ATN. A second option for the European ATN routing architecture is developed in another document, following a different approach.

1.4 Document Structure

This document is structured as follows :

Chapter 2 identifies the organisation types that will potentially deploy ATN systems on the ground and will hence participate in the European ATN topology.

Chapter 3 provides a global European ATN Routing Organisation scheme, identifying the boundaries of the organisation that will implement ATN systems, and proposing in accordance, with the ATN ICS SARPs, a division of the European ATN into ATN Islands, and Routing Domain Confederations (RDCs).

Chapter 4 proposes the routing organisation of the target ATN in the geographical area considered in the ACCESS project, and describes a technically feasible deployment scenario meeting the identified technical and organisational constraints.

1.5 References

ACCESS Reference	Title
[CEC1]	COPICAT - Users Requirements and Expectations - Edition 1.1, CEC DGXIII, February 1997
[CEC2]	COPICAT - Economic and Technical Assessment of ATN Deployment in Europe - Executive Summary - Edition 1.1 - 29/11/96
[CEC3]	COPICAT - Technical Aspects - Edition 1.1 - 10/02/97

ACCESS Reference	Title
[CEC4]	COPICAT - Economic Assessment & Proposed ATN Organisation - Edition 1.1 - 10/02/97
[CEC5]	PRESTATN Phase 1 Report - ATN Requirements Assessment, Version 1.1, February 1996
[EAT1]	Application Requirements for Data Communications Services, Edition 1.0, Eurocontrol, December 1995
[EAT7]	ENOC - European Network Operating Concept - Draft 3.1 - December 1994
[EAT18]	European Air Traffic Management System (EATMS) - User Requirements Document (URD) - Edition 0.D
[EUR2]	IDRP Convergence Modelling Study: Final Report - Version 1 - 15/03/1996
[EUR3]	ATN Islands and Homes IDRP Convergence Modelling Study: Final Report - Issue 2.1 - 8/01/1997
[IAT1]	Datalink Task Force Report - Issue 0.1 - 4 February 1997
[ICA8]	ATN SARPs - Sub-Volume 5 - Internet Communications Service
[ICA9]	Guidance Material for the ATN Internet Communications Service SARPs - Issue 2.0
[ISO1]	ISO/IEC 10747 - Protocol for Exchange of Inter-Domain Routing Information among Intermediate Systems to Support Forwarding of ISO/IEC 8473 PDUs

2. European ATN Administrative domains

2.1 Introduction

The objective of this paper is to define a scaleable architecture for the target European ATN, in accordance with the ATN ICS SARPs.

The European ATN will encompass the network(s) of multiple different organisations; its routing organisation will hence be firstly constrained by the existence of the multiple administrative boundaries.

This chapter identifies the organisation types that will potentially deploy ATN systems on the ground and will hence participate in the European ATN topology. It discusses the possible role of the different organisations in the building and use of the European ATN.

In the discussion of the position, involvement or strategy of the different organisations regarding the building and the organisation of the ATN in Europe, it must be noted that all statements/assumptions related to the different organisations reflects only the feeling of the ACCESS participants, gained during discussions or review of documents. This chapter is mostly based on the following 4 sources: [EAT7], [CEC1], [CEC5] and [IAT1].

2.2 Identification of Organisation types

2.2.1 General

The Organisations involved in the ground deployment of the European ATN can be classified in 2 overlapping categories:

1. The ATN Users: these are the organisations running applications that will be source and/or destination of ATN data traffic. The following ground user groups have been identified as having ATN communications requirements:
   - ATS Organisations
   - Aircraft operators
   - Military organisations
   - Airport operators
   - Meteorological organisations
2. The ATN Service Providers which will provide full (or part of the) set of ATN services to (a group of) ATN users. Three groups of organisations are assumed to provide ATN services in the European Area:
   - The International Aeronautical communication Service Providers (or other public/private telecommunications network operators)
   - The ATS Organisations
   - The Airport operators

The list of users and providers distinctly overlap. This means that ATN users and ATN Service Providers are partly identical. However, different entities within these groups will be responsible for the provision of ATN services on the one hand, e.g. telecommunications support departments, and will use these services on the other hand, e.g. controllers.

2.2.2 ATS Organisations (ATSOs)

ATS Organisations are concerned with the safe transport of aircraft and passengers throughout a specified area of coverage. In many European States, the provider of civil Air Traffic Services is part of the National Civil Aviation Administration (CAA). However, there is now a trend to create separate business-oriented corporations, responsible to the CAA, for the management provision and financial viability of the Air Traffic Services.

A different ATS Organisation operates in each of the following ECAC states: Austria, Belgium, Bulgaria, Croatia, Cyprus, Czech Republic, Denmark, Estonia, Finland, France, Germany, Greece, Hungary, Ireland, Italy, Latvia, Lithuania, Luxembourg, Malta, Netherlands, Norway, Poland, Portugal, Romania, Slovakia, Slovenia, Spain, Sweden, Switzerland, Turkey, UK. Eurocontrol is another different ATS Organisation.

In each country, depending on the airspace it is responsible of, and of the volume of aeronautical traffic in this airspace, the ATSO deploys different ATS service units which can be categorised in:

- ATC Centres (including Tower, Approach, Area and Oceanic Control)
- Airspace Management Units
- CFMU, Flow Management Units and Flow Management Positions
- AIS Units
- Meteorological Offices

Users of ATN services will be deployed in each of these service units and will consist of ATS applications running on or interfaced to ground ATN End Systems

As a result of existing responsibility and liability regulations for ATS provision, national ATSOs own not only End Systems, but also network and subnetwork facilities. ATS Organisations are expected to keep control of their proprietary resources in the future and by this will act as service providers within their domain of the ATN.

With respect to ATN communications ATSOs may operate:

- Ground Based ATS host computers being ATN End Systems
- ground and air/ground ATN routers
- Mode S interrogators and GDLP
- VHF ground stations
- ground subnetwork, e.g. RENAR, CAPSIN,...

2.2.3 Aircraft operators

Together with the ATS Organisations, and the International Aeronautical Communication Service Providers, the Aircraft Operators are expected to be the first actors on the deployment of the European ATN.

The main European Airlines already using the ACARS system should be concerned by the initial ATN deployment in Europe and are expected to implement ATN End Systems in the Airports that serve as their centre of operation.

The following table shows the European Airlines operating AOC applications over ACARS today:

Airline	Centre of Operation
British Airways	London Heathrow, Gatwick
Lufthansa	Frankfurt am Main
Air France	Paris-CDG Paris-Orly
KLM	Amsterdam
SAS	Copenhagen, Stockholm, Oslo
Alitalia	Rome, Milan
Swissair	Zurich
Iberia	Madrid, Barcelona
Sabena	Brussels
Aer Lingus	Dublin
Finnair	Helsinki
Austrian Airlines	Vienna
TAP - Air Portugal	Lisbon, Porto
Virgin	London Heathrow
Lauda Air	Vienna
Cargolux	Luxemburg
Hapag Llyod	Hannover
LTU	Dusseldorf

Aircraft operators are involved in four principal areas of communications:

- Air Traffic Services Communications (ATSC)
- Aeronautical Operational/Administrative Communications (AOC/AAC)
- Aeronautical Passenger Communications (APC)
- intra- and inter-airline communications

ATSC comprises Air/Ground communications between ATC facilities and the aircraft for Air Traffic Services (ATS), and Ground/Ground communications between the airline's ground facilities and ATC (e.g. CFMU) for strategic and tactical planning in the pre-flight phase. The Ground/Ground communication for strategic and tactical planning is limited to some few exchanges concerning airspace/slot allocations and is assumed to have minor impact on the design of the European ATN due to its low data volume and rare transactions as compared to ATS Air/Ground communications.

Ground/Ground communications between an airline's facilities and other airlines are used for a variety of services and applications, e.g. computer reservation systems. Although this type of communication may be included in the ATN in the future, no requirements for the near-term deployment of the ATN for these services are identified.

The likely ground communication architecture for an airline in the near future is based on the present one which consists of an AOC/AAC application server centralised at its centre of operation. It is assumed that, due to economic considerations, airlines will set up similar arrangements for ATN service provision as in place today for non-ATN communications, i.e. it is assumed that one or more commercial service providers will provide ATN services to the airlines in Europe. This means that:

- airlines will operate their own ground subnetworks in those areas where volume of traffic justifies the operational costs of a private ground network.

- one or several commercial aeronautical communication service providers will provide ATN service in Europe on behalf of the airlines community in those areas with a volume of traffic insufficient to justify the operational costs of individual private networks.

2.2.4 Military organisations

The main basic assumption is that military structures will not use the ATN for their own operational needs due to the specific nature of their organisation and their confidentiality requirements. The military will continue to use their own, completely separate, communication infrastructure either on the ground or for Air/Ground communications. There are 3 areas however where an operational interface will be needed on the ground: radar data distribution, tactical co-ordination between civil and military controllers and exchange of flight plans. This interface is expected to consist in each country of a secure application gateway provided by the military and connected to the ATN network of the national ATSO. These gateways will be seen either as extra ATN End Systems or ATN router to the national ATSO ATN network, and will be part of the national ATN addressing plan, the back-end of these gateways being a "military-only" area.

2.2.5 Airport operators

Airports are operated by private and/or governmental organisations. Airport operators are responsible for the availability of runways, taxiways and for the assignment of gates. Availability information and gate assignment information is communicated to ATC and it can be assumed that the main airports will implement information server on ATN End Systems and will use the ATN for communication with ATC.

For data communication between ground-based communication systems and aircraft parked at the gate or at rest on the apron, airport operators are assumed to establish and operate Gatelink subnetworks. Gatelink is intended for use of updating onboard databases, entertainment systems at the airport, and real time two-way data communications for ATSC, AOC, AAC and APC. In this respect, the Airport Operators will position themselves as provider of ATN service (by offering interconnection with their Air/Ground BIS) or of ATN subnetwork service (by offering interconnection with the Gatelink subnetwork).

Intra and Inter airport operator communication is assumed to be outside the scope of the ATN.

2.2.6 Meteorological Organisations

Meteorological data originate at meteorological authorities (World and Regional Area Forecast Centres, WAFC, RAFC) and distributed among these using dedicated networks. They are made available to the aeronautical meteorological offices. The aeronautical Meteorological Service gathers meteorological information, processes and analyses this information and provides the results to users like ATC, airlines and pilots. Aeronautical Met databases are available in a number of European Countries. They provide access to standard format information (METAR, TAF, SIGMET and SPECI). Each of these databases is currently connected to several neighbouring ones by means of the AFTN network.

In the future, MET users will be users of ATN End Systems. Consequently, it is likely that Met databases be also integrated in ATN End Systems.

In Europe, the aeronautical meteorological services are administered by the national meteorological authority or by the national ATS Organisation, depending on the country. Hence, in some European countries, the ATN End Systems that will integrate the Met database may be under the administrative authority of the national meteorological organisation.

2.2.7 International Aeronautical Communication Service Providers

International Aeronautical Communication Service Providers (IACSPs) are organisations and entities which will provide ATN communication services to the aeronautical community on a world-wide basis. Within this class fall, amongst others, ARINC, SITA, and some other co-operative initiatives such as the Satellite Aircom Consortium, or the Skyphone Consortium.

2.2.7.1 Background

The networks of public telecommunications operators are often well designed to support services in their national territory. From practical experience the interconnection agreements in place, between public operators, for world wide communication network do not necessarily fulfil airlines requirements for world-wide and dependable service through a well identified interface. Furthermore, all previously identified ATN users do not operate in isolation from the Agencies providing ATS services. Therefore, the establishment of internetworking and/or gateways services is required to maintain connectivity between the networks supporting airlines requirements and the networks supporting Civil Aviation requirements. In this context, the aeronautical users have the choice either to operate proprietary networks, or to establish local, regional or world-wide co-operative operating agreements offering the end-to-end services required at a reasonable cost.

For the above reasons the ICAO had provided guidelines and a framework for the development and operation of International Aeronautical Communications Services (IACS) and has acknowledged the merits of using an IACS Provider such as ARINC and SITA.

2.2.7.2 Existing Aeronautical Communications Service Providers

The following organisations and consortia are currently offering aeronautical communications services in the European region on a commercial basis:

- SITA
- Satellite Aircom Consortium
- ARINC
- Skyphone Consortium
- Inmarsat Signatories

These service providers offer several end-to-end communications services between airborne and ground based users through a combination of terrestrial and mobile networks.

In the future other public or private telecommunications network operators could position themselves as potential ATN service or ATN subnetwork service providers, and compete for subscribers on the basis of price, quality and range of services offered.

2.2.7.3 Provision of ATN Services by the IACSPs

Today, the potential role of International Aeronautical Communication Service Providers (mainly of SITA in the current situation) as carrier of operational ATC traffic is still in debate from a variety of standpoints (technical dependability, cost/benefit, institutional), yet most CAAs consider third party telecom service providers (ground-ground or air-ground) as a suitable alternative to ATS-dedicated private (i.e. CAA managed) networks.

The extent of the participation of the IACSPs in the future European ATN will depend on the arrangement of communication service provision that will have been agreed with ATSOs and Airlines.

But in any case, it is likely that the IACSPs will be organisations involved in the European ATN, and will implement:

- Ground-Ground and Air/Ground ATN Routers
- ATN Network Management End Systems.
- Ground subnetwork, e.g. X.25 WANs

- VHF ground stations
- VHF subnetworks
- satellite subnetworks
- satellite GESs

2.3 Inter-Organisation information flows

The information flows between organisations are usually categorised in the following different traffic types:

- Air Traffic Services Communications (ATSC) traffic
- Aeronautical Operational Communications (AOC) traffic
- Aeronautical Administrative Communications (AAC) traffic
- Aeronautical Passenger Communications (APC) traffic
- System Management traffic

Figure 1 gives an overview of the main information flows identified between the different potential users of the European ATN. The identified ATN users are the organisations that are potential source/destination of ATN traffic. The International Aeronautical Communication Service Providers are not identified as users (but providers only) of the ATN service and are consequently not represented on the figure.

Note: This figure is intended to illustrate and help the understanding of the discussion, but is not to be considered as an exhaustive pictures of all information flows.

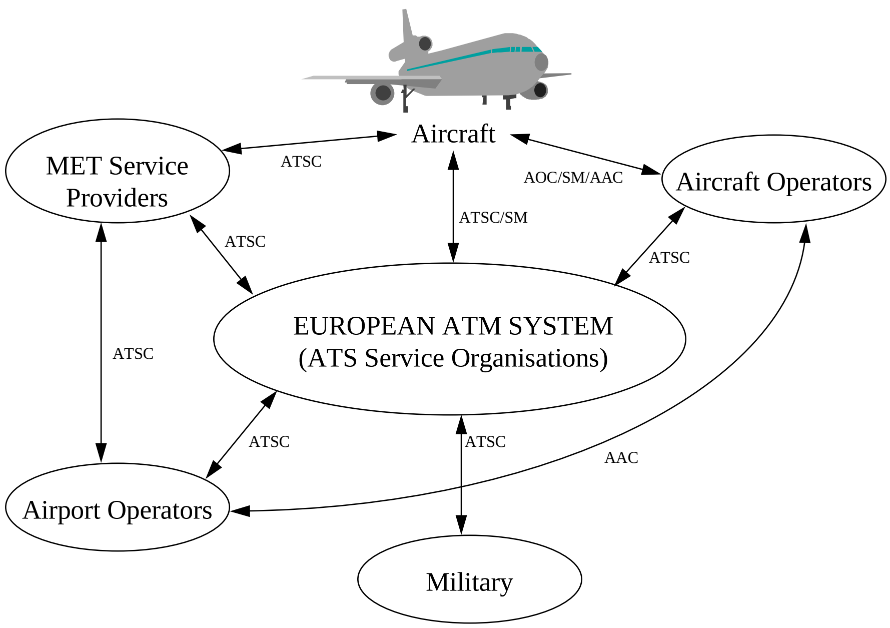


Figure 1: Main ATN traffic flows between ATN End Users

Independently of their role as user of the European ATN, organisations may be candidate or not for supporting the transit of ATN traffic between different other organisations. On the role of the different organisations type in the internet transit of information, the following assumptions are made:

- Military Organisations and Met Service Providers will not provide relaying service of information to other organisations.
- Airport Operators may provide relaying service of ATSC, SM, AOC, APC and AAC information exchanged between other organisations and the aircraft at the airport
- Aircraft Operators will not provide relaying service of information to other organisations.
- ATS Organisations will provide the Airport operators, military organisation, Met Service providers of their own country with ATSC routes to other organisations and to the Aircraft. They may additionally provide relaying service of AOC and SM information exchanged between the Aircraft Operators and Aircraft.
- International Aeronautical Communication Service Providers will be candidate for the transfer of any ATN traffic between organisations and between organisations and aircraft. They will provide the complement of ATN relaying services that are not provided by the ATSOs.

The following table summarises the assumptions made on the role of the different organisations type in the internet transit of information:

Organisation type	acceptable traffic in transit
ATS Organisation	ATSC possibly AAC, AOC and SM
Aircraft Operators	none
Military Organisation	none
Airport Operators	ATSC/AOC/SM/APC traffic toward/from the aircraft at the airport AAC
Meteorological Service Providers	none
International Aeronautical Communication Service Providers	AOC/SM/APC ATSC depending on arrangements with ATS Organisations

2.4 Organisations Interconnection schemes

2.4.1 General

Institutional arrangements for ATN communication between organisations should provide the maximum flexibility, ensure the ability to protect safety communications from harmful interference, and guarantee timely delivery of safety communications. The ATS Organisations are expected to co-ordinate and maintain control, directly or indirectly, over the ATN communication without unduly restricting the airlines requirements for communication. Within any arrangement of communication service provision, it should be ensured that all aeronautical communication (ATSC, AOC, AAC, APC and SM) can be provided to the maximum extent possible through common airborne and ground equipment.

With respect to communication service provision, in Europe, the following generalised scenarios can be identified:

1. Scenario 1: The ATSOs, by sharing some of their facilities, provides all the physical elements to ground and air-ground communication.

2. Scenario 2: International Aeronautical Communication Service Providers provide a comprehensive range of aviation communication services (ground BIS, Air/Ground BIS, ground subnetworks Air/Ground subnetwork managed for and on behalf of the customer), through contracting for or establishing communications facilities. There are 2 variants of this scenario: the service provider can have individual contracts with ATSOs and airlines for their individual communication needs, or airlines can have a contract for all services including ATS communications.

3. Scenario 3: Combination of the 2 above scenarios where:

    - Some European national ATSOs will provide all the physical elements to ground and air-ground communication.

    - Some European national ATSOs will delegate the provision of the ATN communication services to an IACSP.

    - Some European national ATSOs will implement parts of the physical ground and air-ground communication and will delegate the provision of other parts of the ground and air-ground communications to an IACSP.

2.4.2 Interconnection of the military organisations to the European ATN

As identified in section 2.2.4 Military air defence units require remote access to both surveillance and flight data. The method of providing interoperability is at the discretion of individual countries. A number provide co-location of military and civil ATS organisations. It is assumed that the military organisation will access the European ATN by direct interconnection with their national ATS Organisation.

Secure gateways should be used to provide interoperability between ATN End-Systems and military operated End Systems. It is assumed that the military End Systems are located on a secure network operated and managed by the military for operational purposes.

The ATN side of the Gateway should act as an ATN End System of the national ATSO, located within the routing organisation of the national ATSO and as such should appear in the national ATSO ATN addressing plan. The ATSO should be responsible for management of the ATN side. The military organisation should be responsible for the management of the non-ATN side and of the security implications.

2.4.3 Interconnection of the Meteorological Service Providers to the European ATN

As identified in section 2.2.6, MET databases could, in the future, be integrated in ATN End Systems. The method of providing interoperability with these databases is at the discretion of individual countries. It is assumed that the Meteorological organisation will access the European ATN by direct interconnection with their national ATS Organisation. The meteorological End Systems should act as ATN End Systems of the national ATSO, located within the routing organisation of the national ATSO and as such should appear in the national ATSO ATN addressing plan.

2.4.4 Interconnection of the Airport Operators to the European ATN

As identified in section 2.2.5, airport operators are potentially:

- information service providers accessible through the ATN (providing information on the state of the airport and runways to ATS Organisations. In this respect, Airport Operators could implement information servers on ATN End Systems.

- ATN Communication Service Provider by providing relaying service of ATSC, SM, AAC, APC and AOC information exchanged between other organisations and the aircraft parked at a gate of the airport. In this respect, Airport Operator could implement « A/G » BIS attached to the Gatelink subnetwork

- ATN subnetwork service provider by operating one or more ATN subnetwork (e.g. Gatelink)

In the main Airports, serving as centre of operation for an Airline, it is assumed that such an ATN infrastructure will effectively be deployed. The Airport operator End System(s) and the A/G BIS attached to the Gatelink subnetworks would then form an ATN Routing Domain locally interconnected with the ATC systems of the national ATSO on one hand and with ATN Systems in the centre of operation of the airline, on the other hand.

In smaller airports, it is assumed that possible available Gatelink subnetworks will be connected to an A/G BIS provided by the ATSO . The possible Airport Operator ATN End Systems should then act as ATN End Systems of the national ATSO, located within the routing organisation of the national ATSO and as such should appear in the national ATSO ATN addressing plan.

2.4.5 Interconnection of Aircraft Operators to the European ATN

As identified in section 2.2.3 the main European Airlines already using the ACARS system should be concerned by the initial ATN deployment in Europe and are expected to implement ATN End Systems in the Airports that serve as their centre of operation.

The set of ATN Systems of an Aircraft Operator in its centre of operation will form a Routing Domain that is expected to be interconnected with the local ATSO and/or IACSPs, depending on the adopted national strategy among the ones identified in section 2.4.1.

2.4.6 Interconnection of ATS Organisations to the European ATN

As identified in section 2.2.2, ATS Organisations are expected, depending on the airspace they are responsible of, and of the volume of aeronautical traffic in this airspace, to deploy ATN Systems in its different ATS service units such as the ATC Centres, the Airspace Management Units, the Flow Management Units, the AIS Units and the Meteorological Offices.

According to the previous subsections, ATSOs are expected to be directly interconnected with or to encompass, the ATN systems of the military, meteorological, and Airport operators organisations in their country. They are also assumed to be interconnected at national airports with the ATN systems in the centre of operation of airlines.

ATSOs are not assumed on the other hand to be directly interconnected with military, meteorological, and airport operator organisations of other countries.

The interconnection of ATSOs with IACSPs is addressed in section 2.4.1 and depend on the national strategy for the provision of ATN services.

The direct interconnection of ATSOs with other European ATSOs is another issue. For trans-national ATSC communications, direct bilateral agreement for interconnecting ATN routers is assumed to be the simplest possibility, as it is in line with current practices by which a CAA already feeds its radar or flight plan data to another one, each actor being responsible of its own equipment (several bilateral links of this kind already exist). On the other hand, it is both institutionally and technically unlikely that national ATSOs could offer their ATS-dedicated ATN networks to serve as transit network for AOC or long distance ATSC traffic (i.e. ATSC traffic between non-adjacent ATSOs). Highly multi-national communications could rather be provided for both AOC and ATSC through a common backbone architecture.

2.4.7 Interconnection of the International Aeronautical Communication Service Providers to the European ATN

The participation of the International Aeronautical Communication Service Providers in the European ATN depends on the national CAAs strategy for the provision of ATN services. This issue has been partially addressed in section 2.4.1.

2.5 Conclusion

Institutional arrangements for ATN communication between organisations will govern the European ATN Routing organisation. This principle does not follow from the ATN SARPs (which are primarily technical in nature) but from the structure of and the relationships between future users and providers of ATN services in Europe. Groups of organisations have established ways of working among themselves and this should, for reasons of efficiency, be considered in the routing architecture. [1]

[1] This is the case, for example, with airlines which however also have special relationships with their national ATSO. It is also true of meteorological offices, the military and airport companies.

At national level, within each European country, the ATS Organisation is expected to co-ordinate and maintain control, directly or indirectly, over the ATN communication provision strategy. Different schemes will be followed in different countries depending on the participation in the ATN traffic routing that will be left by the CAA to third party International Aeronautical Communication Service Providers. In most cases, the national ATSO is expected to be the go between other organisations in the country for ATSC information exchange while ensuring that all other aeronautical communications are not unduly restricted and can be provided to the maximum extent possible through common airborne and ground equipment.

Figure 2 attempts to illustrate different scenarios where different ATN communication service provision institutional arrangement are set up in different countries.

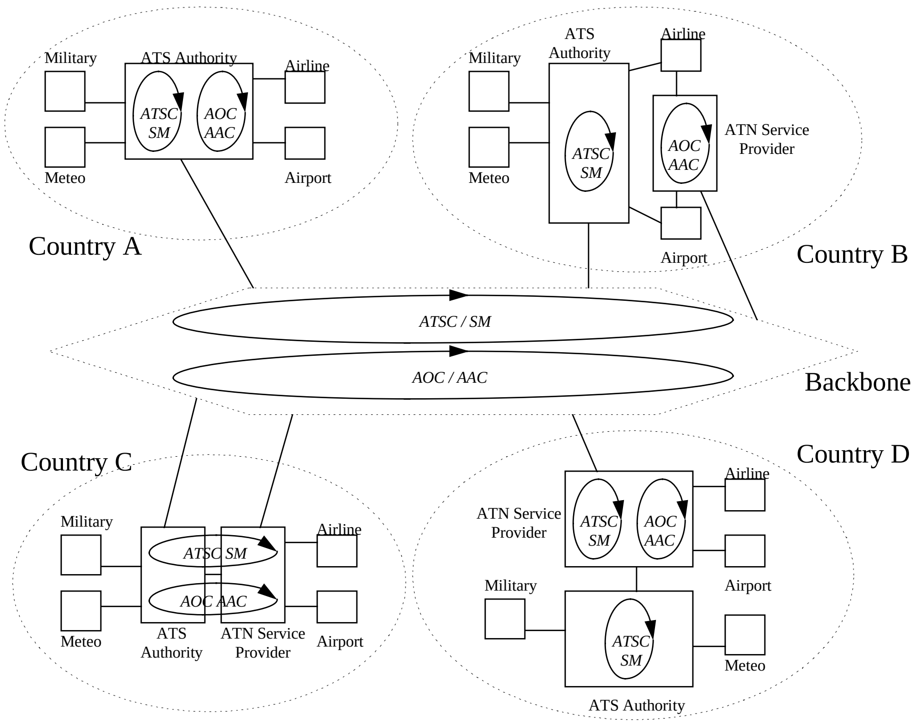


Figure 2: ATN communication service provision arrangement scenarios

Institutional arrangements for communication service provision at European and world-wide international Level will mainly involve national ATSOs, supra-national ATSOs and IACSPs.

ATSOs have traditionally operated their own national data networking infrastructures and have only interacted with other ATSOs via « narrow », well-defined interfaces. It is proposed that this working principle be maintained in the transition to the ATN.
These facts are utilised in a pragmatic way in the definition of the routing architecture in this document. The means provided for this by the ATN SARPs are Routing Domains, Routing Domain Confederations and Routing Policies.

3. Overall Routing Organisation Scheme

The aim of this chapter is to provide a global European ATN Routing Organisation scheme, identifying the boundaries of the organisations that will implement ATN systems, and proposing in accordance, with the ATN ICS SARPs [ICA8], a division of the European ATN into ATN Islands, Routing Domain Confederations (RDCs) and Routing Domains (RDs).

This chapter requires from the reader some knowledge of the ATN routing concepts. Although an overview of these concepts is provided in section 3.1, readers are invited to find a more explicit description in the Guidance Material for the ATN ICS SARPs ([ICA9]).

3.1 General ATN Routing Concepts

3.1.1 General

The European ATN will comprise a co-ordinated set of heterogeneous networks with a common end-to-end service provided by the ISO 8473 ConnectionLess Network Protocol (CLNP). The European ATN will also consist of systems; End Systems (ESs) which are the applications processors hosting end user applications; and Intermediate Systems (ISs) that are the routers, switching CLNP packets through the internet from source ES to destination ES. The procedures for routing across heterogeneous subnetworks have to be independent of the subnetworks if they are to provide a general purpose solution for routing across many different subnetworks, and ISO has developed a suitable routing framework, to support dynamic routing in a heterogeneous networking environment . The ATN Routing Concepts rely on this routing framework.

3.1.2 Administrative Domains

An Administrative Domain is simply the set of all systems and subnetworks operated by a single organisation. Where organisations structure themselves hierarchically, then the hierarchy can be reflected in a similar hierarchical nesting of Administrative Domains.

However, it may not always be possible for all systems under the control of one operator (or owner) to trust each other, or different routing procedures may need to be applied to different systems under one operator, or they may not even need to be interconnected. For such reasons, the OSI Routing Framework introduced the notion of Routing Domain.

3.1.3 Routing Domains

Administrative Domains may be divided into several Routing Domains, all operated by a single organisation or administrative authority.

An RD groups End and Intermediate Systems and is typically under the control of a single operator (or owner), reflecting a requirement for a common element of trust between systems within the same RD.

ATN administrative Domains may be organised into more than one Routing Domains for the following Reasons:

1. Security and/or Safety Considerations may demand the partitioning of the Administrative Domain into distinct Routing Domains, so that each such Routing Domain can insulate itself from malfunction or security weakness in another, through the application of a specified Routing Policy.

2. Efficiency and/or cost considerations may demand the use of the Inter-Domain-Routing Protocol (IDRP) rather than the ISO/IEC Intra-Domain Routing Protocol (IS-IS), over wide area communications link.

3. Network design requirements may demand the implementation of different routing algorithms based on different criteria, in different parts of the Administrative Domain: the routers in a given Routing Domain must all implement the same routing algorithm based on the same route selection criteria.

4. IDRP requires that all routers, which participate in inter-domain routing (i.e. the Boundary Intermediate Systems (BIS)) and belong to the same routing domain, establish a full mesh connectivity with each other for purpose of exchanging routing information acquired from other routing domains. In large and dense routing domains, the number of intra-domain connections that needs to be maintained by each BIS can be significant, and may induce routing instability problem. Due to the great number of connections that would be needed to maintain a full mesh direct peering between all BISs of a large Routing Domain, and to the potential derived routing instability problems, it might be desirable to split Large Routing Domains into several smaller RDs.

3.1.4 Routing Domain Confederations

The use of the ISO 10747 Inter Domain Routing Protocol (IDRP) also introduces the concept of the Routing Domain Confederation (RDC) which gives routing almost infinite scaleability. RDCs are simply groupings of Routing Domains. A Routing Domain may be a member of zero, one or more RDCs, and hence RDCs may overlap, may be nested, and may be disjoint. RDCs are first a short hand way of referring to communities of Routing Domains, but are at their most powerful when they are closely related to NSAP Address management and when combined with IDRP's features for *route information reduction* and *route aggregation*.

The importance of RD and RDC formation, is due to the problems of maintaining dynamic route stability in large networks. If dynamic changes are not suppressed outside of a local scope, the network may be permanently unstable. At the boundaries of Routing Domains, the on-line personal status of systems or even whole routing areas is not individually advertised. Likewise, at the boundaries of RDCs, the on-line personal status of whole Routing Domains may be not individually advertised, provided that a common address prefix exists to collectively refer to all addresses of RDs in the confederation. Then, for instance one single route to a European RDC can replace the set of routes to each individual RD in Europe.

Routing Domains may be members of RDCs for the following reasons:

1. For Administrative or other reasons, the RDs within a single Administrative Domain need to appear as a single entity for interconnection with another Administrative Domain

2. Due to marketing or other business arrangements, RDs in multiple Administrative Domains need to appear as a single entity for interconnection with another Administrative Domain

3. For ATN scaleability reasons, RDs in multiple Administrative Domains may need to form a single RDC at the boundary of which can be reduced the details on the routes as well as the number of routes advertised to other domains.

4. For traffic containment reasons: one characteristic of the IDRP Routing is that the traffic exchanged between 2 RDs of a same RDC cannot cross the RDC boundaries: data packets cannot exit and then re-enter an RDC. The use of RDC may then be a way for organisations exchanging traffic to ensure that the information will not be inappropriately routed through the network of other organisations.

3.1.5 ATN Island RDC

In order to support efficient communication to mobile systems, the ATN SARPs have introduced additional mechanisms, built on two concepts: the ATN Island and the « Home » domain.

The ATN island concept is one of the mechanisms for containing the impact of the aircraft mobility on the routing traffic and which hence permits mobility within a scaleable routing architecture. An ATN

Island is simply an ATN region comprising a number of Routing Domains, some of which support air/ground datalinks. The ATN Island exists for the exclusive purpose of supporting routing to mobiles. Its first benefit is that an ATN Island does not propagate by default to other Islands the local route to the aircraft that it may know. Route to the aircraft are only advertised outside an ATN Island toward the « Home » RD domain of the aircraft (the « Home » domain concept is explained in section 3.1.7 below). This rule contains the impact of the mobility of an aircraft to the ATN Island with which the aircraft is currently in contact, and to the other ATN Islands which may potentially be on the ground path toward the « Home » Routing Domain of the Aircraft. The second main benefit of the ATN Island, is to focus the overhead of handling the potentially large number of routes to aircraft on the few specialised routers which form the ATN Island Backbone RDC (see below).

3.1.6 ATN Island Backbone RDC

Within each ATN Island, at least one Routing Domain forms the Island's backbone. This may be only one RD or may actually be an RDC comprising all backbone Routing Domains in the same ATN Island. Within the ATN Island, the Backbone RDC provides all other Routing Domains within the Island with a default route to *all aircraft*; and all Routing Domains within the Island provides the backbone with each individual known route to an aircraft. Within the backbone RDC, all routers must exchange all routes to aircraft, which are advertised to them; they are then able to act as default routers to any aircraft currently in communication with the ATN Island. Off the backbone, a Routing Domain with an air/ground Datalink needs only the capacity to handle the aircraft supported by its Datalink and there is a similar impact on Routing Domains that are Transit Routing Domains providing a route between the backbone and an air/ground Datalink equipped Routing Domain. For all other Routing Domains on the Island, thanks to the backbone, there is no impact on routing overhead due to aircraft. In the absence of a backbone, all routers within the Island would need to be explicitly informed with a separate route to each aircraft.

3.1.7 The Home Routing Domains

Aircraft for which inter-Island communications are required must have a « Home » domain. The role of the « Home » Domain is to advertise a default route to all aircraft belonging to an airline, or the General Aviation aircraft of a given country of registration. This default route is advertised to all other ATN Island's backbone routers.

The backbone routers of an ATN Island have a simple policy rule to implement for each explicit route to an aircraft that they have available. If the aircraft has a « Home », then the actual route to the aircraft is advertised toward/to the « Home ». Otherwise the explicit route is not advertised outside of the Island.

The « Home » is therefore always kept aware of routes to all of « its » aircraft. As it is also providing the default route to such aircraft, routers in any Islands that have packets to route to one of that « home's » aircraft and do not know a direct route to that particular aircraft, will by default send those packets to the « home », where the actual route to the aircraft is known, and where the packet can consequently be successfully routed to the destination aircraft.

3.2 Organisation of the European ATN into ATN Islands

3.2.1 General

This section discusses the organisation of the European ATN into ATN Islands

3.2.2 Factor constraining the formation of Islands

For developing a scaleable routing architecture for the ATN in Europe, it is necessary to consider the factors that limit the effective size of an Island

Within the ATN Island, the backbone RDC is always informed about routes to all aircraft currently reachable via datalinks available to the Island's Routing Domains and hence acts as default route providers for packets addressed to airborne systems, by providing one default route to all aircraft.

Because the backbone routers need to know all routes to aircraft currently in communication with the ATN Island, their capacity places a limit on the number of aircraft that can be handled by an ATN Island and hence on the effective size of the Island.

Each route known to a router occupies a certain amount of data storage and, while data store can be a limiting factor on the total number of routes handled, the number of routes updates that a router can handle is more than likely to be the main limiting factor.

In the ground environment, routes updates will usually only occur when changes occur in the local region of the Internet. Typically the introduction of a new Routing Domain or interconnection, or the removal or loss of one of these will cause a change. However, the frequency of update is unlikely to be high.

However, with mobiles, the situation is very different. Aircraft are constantly on the move, changing their point of attachment to the ATN , and hence generating routing updates. The impact of these updates needs to be minimised if the number of aircraft that can be handled by an ATN Island is to be maximised.

3.2.2.1 Problem statement

Let us consider a single ATN Island, as the Island I in Figure 3 below, and the routing traffic within this Island.

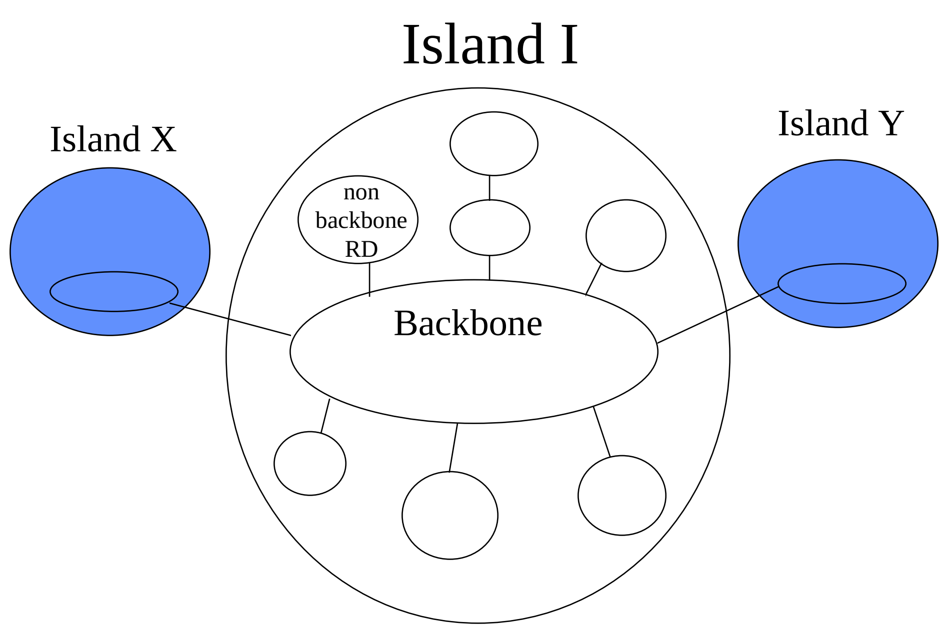


Figure 3: Generic Island Interconnection Model

Routers in the backbone know the routes to:

1. all aircraft currently reachable via datalinks available in I
2. all aircraft homed in I
3. all aircraft homed in X and currently reachable via Datalink in Island Y
4. all aircraft homed in Y and currently reachable via Datalink in Island X

5. all Home Routing Domains within and outside Island I
6. all fixed RDs within the Island I
7. all other Islands

Among all these routes to be known by ATN backbone routers, the routes to Home RDs (5), to fixed RDs within the Island (6) and to other Islands (7) are fixed and therefore stable. Apart from transitory states, these routes do not induce routing traffic in the backbone and consequently do not put major constraint in the routing organisation.

Hence, the main factors limiting the size of the Island pertain to the routes to aircraft currently reachable via datalinks available in the local Island (1), to the routes to aircraft homed in the local Island and currently reachable via datalinks outside the local Island (2), and to Inter-Islands transit routing traffic (3 and 4).

As concerns the first category (1), the following events trigger an update of the routes known by the backbone routers:

a) an aircraft takes off in the Island I and consequently enters in contact with a first A/G BIS of the Island.

b) an aircraft lands in the Island I and consequently stops all direct ATN communication with the Island .

c) an aircraft leaves the Island I and consequently looses contact with A/G BISs of the Island

d) an aircraft enters the Island I and consequently enters in contact with a first A/G BIS of the Island.

e) the details (security, QoS, hop count, path attribute), known by the backbone, on the route to the aircraft changes. This may occur when the aircraft enters in contact with a new A/G BIS in the Island or looses one contact with an A/G BIS of the Island.

With regard to the routing traffic in the backbone corresponding to the routes to aircraft homed in the local Island and currently reachable via datalinks outside the local Island (2), the following events trigger an update of the routes known by the backbone routers:

a) an aircraft homed in I takes off in another Island and consequently enters in contact with an A/G BIS of this Island.

b) an aircraft homed in I lands in another Island and consequently stops all ATN communication.

c) the details (security, QoS, hop count, path attribute), known by the backbone, on the route to the aircraft changes. This may occur when the aircraft leaves an Island, or enters a new Island, and possibly on the occurrence of other minor events such as the change of connectivity with A/G BISs in the crossed Island.

The inter-island transit routing traffic (3 and 4) is similar in nature to the traffic to local homes (2) and differ only by the fact that homes are located in other Islands to which the local Island offers transit services.

3.2.2.2 Minimising the routing traffic due to the aircraft flying in the Island

The routing update rate to be supported by the backbone routers of an Island can be seen as the product of the number N_{iac} of aircraft in direct communication with the Island by the average number of route updates generated by each aircraft per unit of time (r_c).

$$R = N_{iac} * r_c.$$

The obvious way to limit the update rate to be supported by routers in the Island's Backbone is to limit the size of the Island: the smaller an Island, the lesser are the number of Aircraft landing, taking off and flying in the Island. Splitting a region into several Islands allows therefore to distribute the routing traffic among the Islands. This is illustrated in the Figure 4 below:

The Figure 4 represents the route updates resulting from a flight between 2 points of the same Island: the 8 route updates generated during the flight are reported to the backbone of Island 1 only; no route update resulting from this flight has to be processed by the Backbone of Island 2. In the same way, flights entirely contained within Island 2, would not result in any load for the backbone of Island 1.

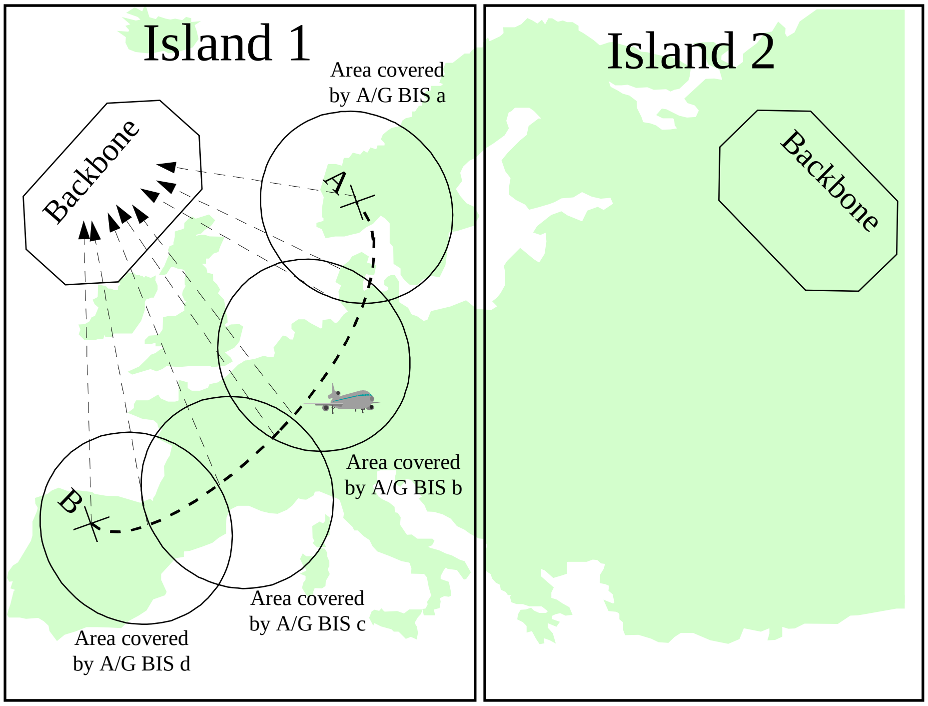


Figure 4: Minimising the route update rate by distribution over multiple Islands

The Figure 5 represents the route updates resulting from a flight from a point in Island 1 to a point in Island 2. The flight results in 4 route updates sent to the backbone of Island 1, plus 4 route updates sent to the backbone of Island 2. Each backbone has therefore to handle a part of the routing traffic resulting from the flight.

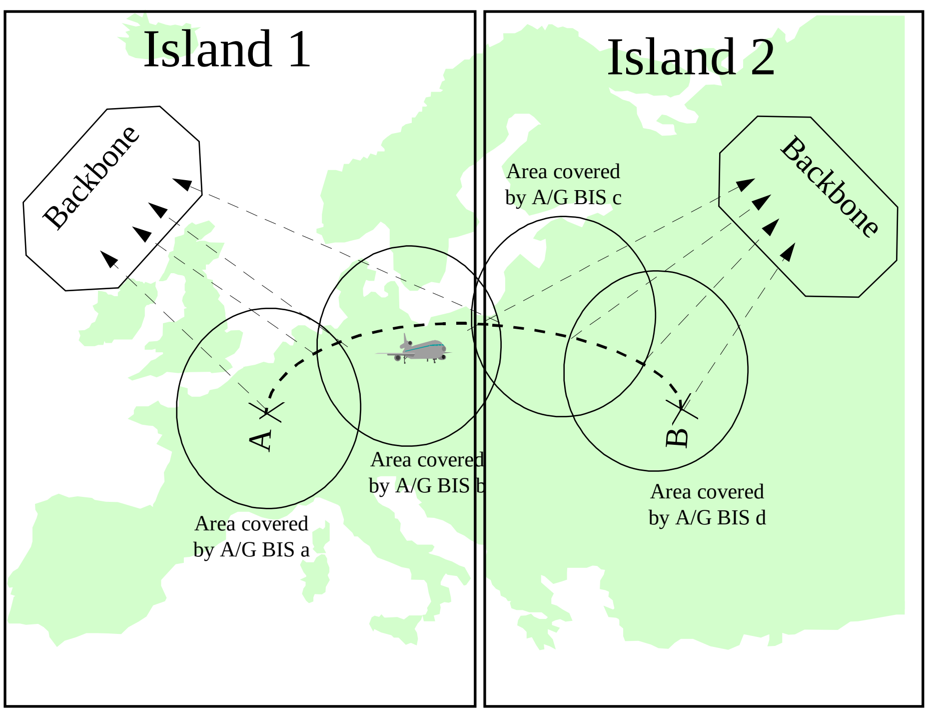


Figure 5: Minimising the route update rate by distribution over multiple Islands

By extrapolating the 2 examples above with several hundreds of aircraft and assuming the aeronautical traffic is well distributed among the Islands, it is easy to see that the multi-islands organisation prevents the concentration of the routing traffic concerning all the mobiles in the region on the same set of routers, and hence decreases the routing traffic load to be supported by each backbone routers.

The other way to reduce the route update rate in a backbone is to reduce the average number of route updates generated by each aircraft per unit of time (r_c).

A first solution is to minimise the number of times each aircraft needs to change its connectivity with A/G routers. Such an approach leads to minimise on the ground the number of routers with A/G connectivity, and to maximise the coverage that each of these A/G routers has under its responsibility. This could be achieved using large RF coverage (e.g. using satellite subnetwork) or by maximising the number of ground stations with limited coverage (e.g. VDL or Mode S) connected to a single A/G router. An extreme scenario would be to have all VDL, Mode S and Satellite ground stations connected to the same, single and unique A/G router. This approach is however assumed to be valid only to a certain extent and to be constrained by technical limits and safety, operational and institutional issues. With respect to the technical constraints, it is assumed that A/G routers will have an upper limit in the number of concurrently connected aircraft and this limit will force the A/G routers multiplicity. With regard to the safety, it may be considered that the requirement for double or triple A/G router coverage will be expressed, leading to double or triple the number of A/G routers otherwise required. As concerns operational and institutional issues, countries or even ACCs in countries may be willing some autonomy in the ATN data link service provision and implement their A/G routers for the coverage of their own airspace, rather than relying on the coverage of adjacent countries or ACCs. Assuming that the number of A/G routers cannot fall bellow a given amount, other ways for the reduction of r_c are therefore of interest to investigate.

Another way to reduce r_c is to limit the number of connectivity changes that are effectively reported to the backbone. For this purpose, the Routing Domains and Routing Domain Confederations outside the backbone and with air/ground connectivity, should be designed in a way which allows to hide minor changes on the routes to the aircraft to the backbone. By grouping the off-backbone Routing Domains and RDC in a number of large off-backbone sub-Island RDCs which would mainly report the landing, taking of, entrance, and exit of aircraft in their area and would hide to the backbone the details of the changes of connectivity with A/G BISs, the route update rate per flight can be significantly reduced. This approach is illustrated in the Figure 6 below

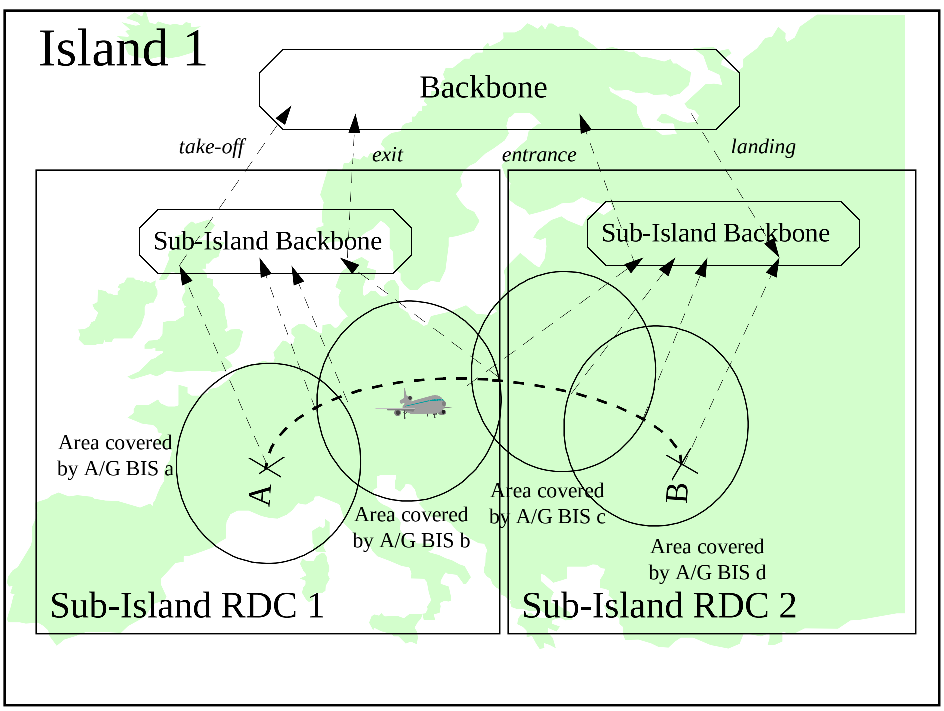


Figure 6: Minimising the route update rate with a hierarchical organisation

This approach introduces a concept of hierarchy of Islands, and backbones, with sub-Islands and sub-backbones knowing the details of the routes to the aircraft in their area, and a unique top level Island

and backbone simply knowing for each aircraft in the region a general route through one or several of the sub-Islands.

For the Island's backbone, the hierarchical model appears to be optimal when the number of inter-subIslands flights is minimised: indeed the flights entirely contained inside a SubIsland result in only 2 route updates (i.e. landing (or entry in Europe) and take-off (or exit of Europe)) being reported to the top level backbone. When such an approach is retained, the SubIsland boundaries must therefore be chosen so as to entirely encompass the maximum of aircraft routes while minimising the number of routes crossing SubIslands boundaries.

The hierarchical model can be generalised to more than 2 levels, and it can be imagined that subIslands are themselves organised into several third level RDCs (as illustrated in Figure 7 below), in turn split in 4th level RDCs, etc.... the lowest possible level being constituted of single Routing Domains with A/G connectivity. Each level allows to hide to the upper level the route changes occurring as a result of having the aircraft crossing lower level boundaries.

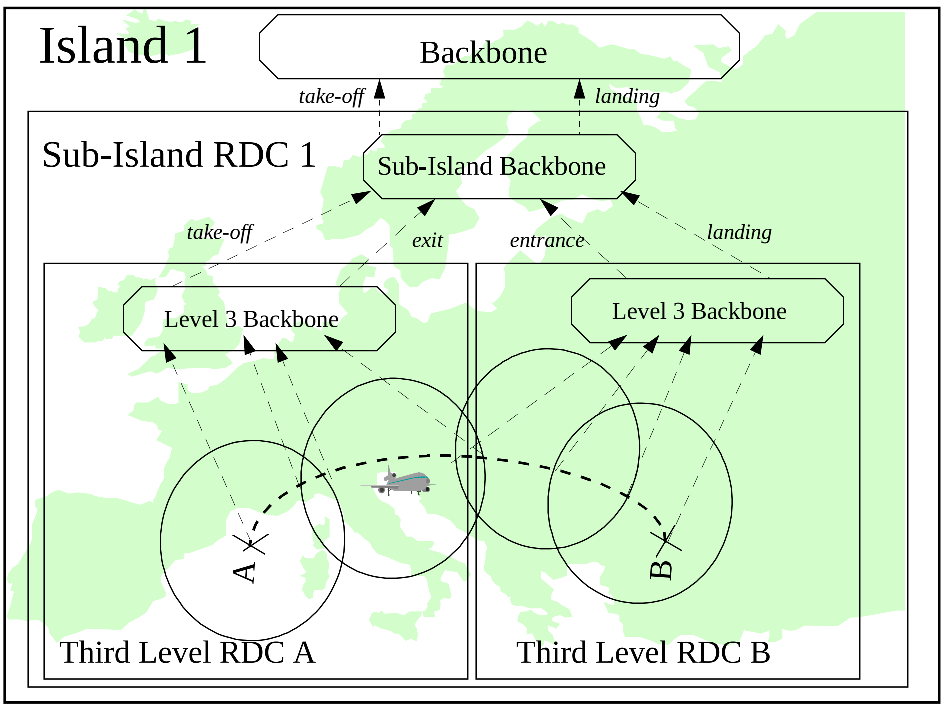


Figure 7: Minimising the route update rate with a hierarchical organisation

3.2.2.3 Minimising the routing traffic due to aircraft outside the local Island

With regard to the routing traffic in the backbone corresponding to the routes to aircraft homed in the local Island and currently reachable via datalinks outside the local Island, the routing update rate to be supported by the backbone routers of an Island can be seen as the sum for each Home RD that the Island contains, of the products of the number N_{eac} of aircraft of the related company currently flying outside the Island, by the average number of route updates generated by each of those aircraft per unit of time (r_e).

$$R = \sum (N_{eac} * r_e)$$

There are therefore 3 ways to decrease this traffic: (1) by reducing N_{eac} , (2) by reducing r_e , and (3) by reducing the number of Homes in the Island.

The only way to reduce the number N_{eac} of aircraft of the related company currently flying outside the Island is to extend the size of the Island so as to encompass more routes of the airline's aircraft. However, there is nothing to win in making larger the Islands for the only purpose of reducing the routing traffic due to external aircraft since this traffic would then become traffic resulting from aircraft flying in the region and would still have to be supported by the Island's backbone.

There is no way, for an Island to reduce the route update rate r_e of outside flying aircraft. This rate is mainly dependent on the traffic, the size, and the routing architecture of the other Islands.

The only way to limit the traffic due to aircraft flying outside the Island is therefore to limit the number of homes hosted in the Islands. But homes must be located somewhere; the problem paused by the location of Homes needs therefore to be further investigated.

An Home may be located:

1. Within the Island, in the backbone
2. Within the Island, outside the backbone
3. Outside the Island.

The Home concept exists for allowing inter-Island communication with aircraft. It must then be noted that for ATC purposes, provided that the ATN Islands are set-up such that their geographical spread matches ATC communication requirements, there may not be a requirement for inter-Island communications in respect of aircraft. That are mainly the airlines that are perceived to require this facility. On the other hand airlines have no requirements for communication with aircraft of other companies. Hosting a Home Routing Domain within the backbone of an Island may then appear to be a bad choice: it results in having the Home aware of all the routes to the aircraft of other airlines flying in the Island whereas it is not interested by these routes, and forces the backbone to know, without specific requirements, all the routes to the aircraft of the related particular airline.

When the Home is located within the Island, outside the backbone, the Home routing Domain is alleviated from the traffic pertaining to communication with aircraft of other airlines. On the other hand, the backbone still has to support routing traffic due to aircraft of the related airline flying in other Islands.

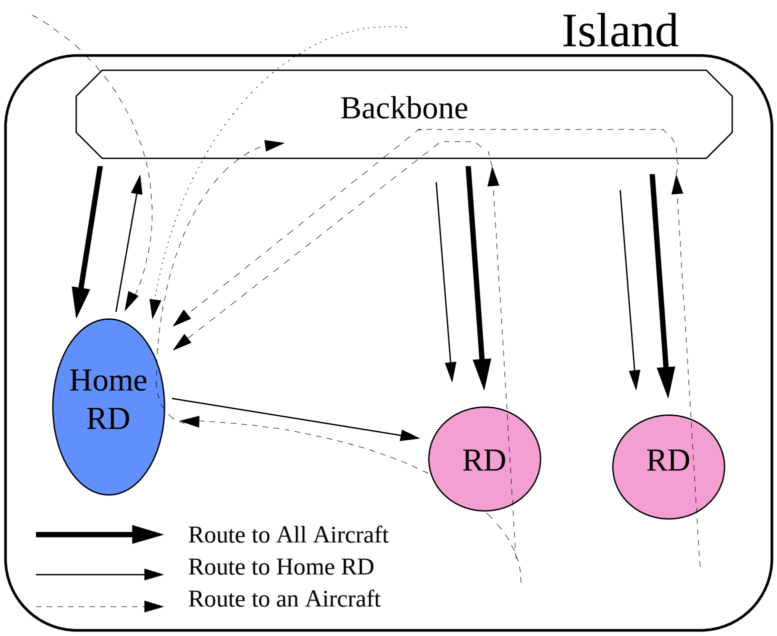


Figure 8: Routing Traffic Flows

The preferred solution would then be to have the Home Routing Domains outside the ATN Island.

We will propose that the European airlines form (with the service of IACSPs) an independent separate European « Homes » RDC located outside the European Island(s). This European Homes RDC will consist of the set of the Home Routing Domains of the different European Airlines and will hence be the sink of the routing information pertaining to the European airlines aircraft flying everywhere in the world. This RDC will be connected to the European ATN Islands but also to the Islands in other regions of the world.

A question may arise for the Home Routing Domains of general aviation aircraft. It is assumed that national ATSOs will be responsible for the Home RD of all general aviation aircraft registered in the country. In this specific case, the Home RD is therefore not proposed to be located outside the ATN Island but to be part, within the Island, of the national ATSO ATN domain.

3.2.2.4 Minimising the Inter-Island transit Routing traffic

Inter-Island transit air/ground routing traffic is to be supported by a backbone, when the Island is located on the path of other Islands toward Home Routing Domains. As already stated, for ATC purposes, provided that the ATN Islands are set-up such that their geographical spread matches ATC communication requirements, there may not be a requirement for inter-Island communications in respect of aircraft. That are mainly the airlines that are perceived to require this facility. It is therefore assumed that the ATS Organisations will not be candidate for supporting the cost of the inter-Island air/ground traffic in the absence of ATC requirements for such a traffic and that the management of this traffic will be delegated to airlines and IACSPs. The ATS Organisations will likely prefer an approach where the backbone of their Islands are not used to transit Inter-Island air/ground traffic.

Assuming that the European ATN consists of one or several Islands and of several Home Routing Domains outside this (these) Island(s), the solution for minimising the inter-Island transit air/ground routing traffic in Islands is to avoid having this (these) Island(s) on the best path from other Islands toward the Home Routing Domains. This can be done by adopting a star topology of Islands around an « external » backbone provided by airlines and IACSPs and dedicated to the traffic to/from Home Routing Domains.

This dedicated backbone could be the backbone of the « European Homes RDC » mentioned at the end of the previous section and which was proposed to group all the Home Routing Domains of European airlines .

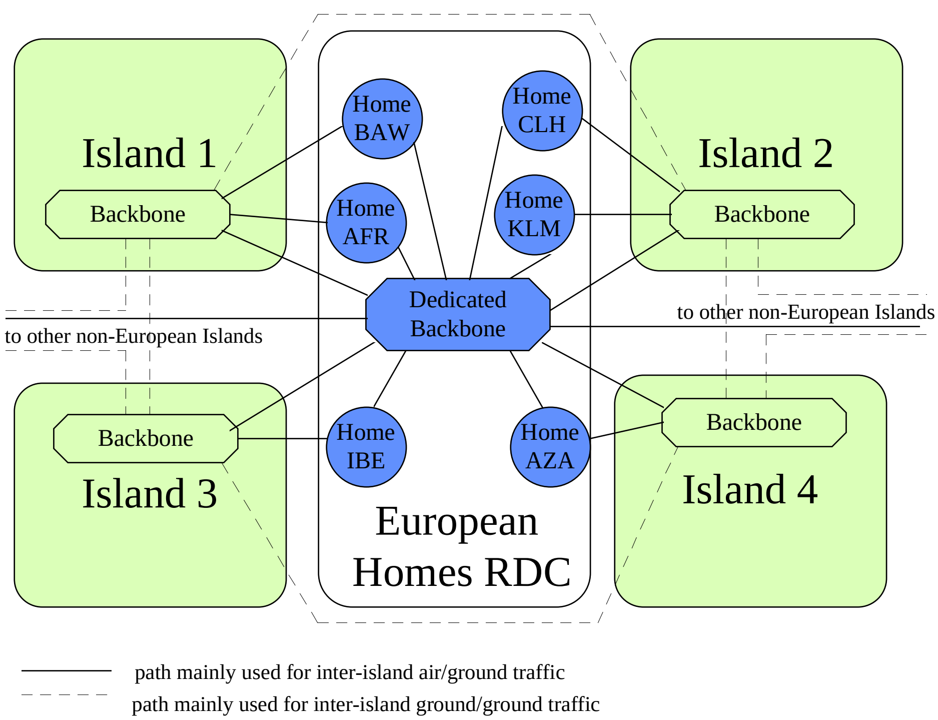


Figure 9 : Minimising the inter-island transit routing traffic

With regard to the Inter-Island ground-ground communications, the main requirements exist for ATS purpose (e.g. AMHS). It is therefore assumed that inter-Island ATS dedicated links will be established and maintained by ATSOs between backbone routers of the directly connected Islands.

3.2.3 Multiple Islands versus a hierarchical organisation of Islands

With the underlying criteria to minimise the routing traffic load in the ATN routers, the previous section derives 2 main solutions for organising the European ATN into Islands:

- a multiple Islands scheme where the European ATN would be organised into a number of adjacent interconnected Islands with an external backbone, managed by airlines and IACSPs and dedicated to the Inter-Island transit traffic.

- a hierarchical scheme where the European ATN would consist of one Regional Island with a top level backbone interconnecting Sub-Islands, and alleviated from the inter-region transit traffic by the use of an external backbone dedicated to the traffic to/from Home Routing Domains.

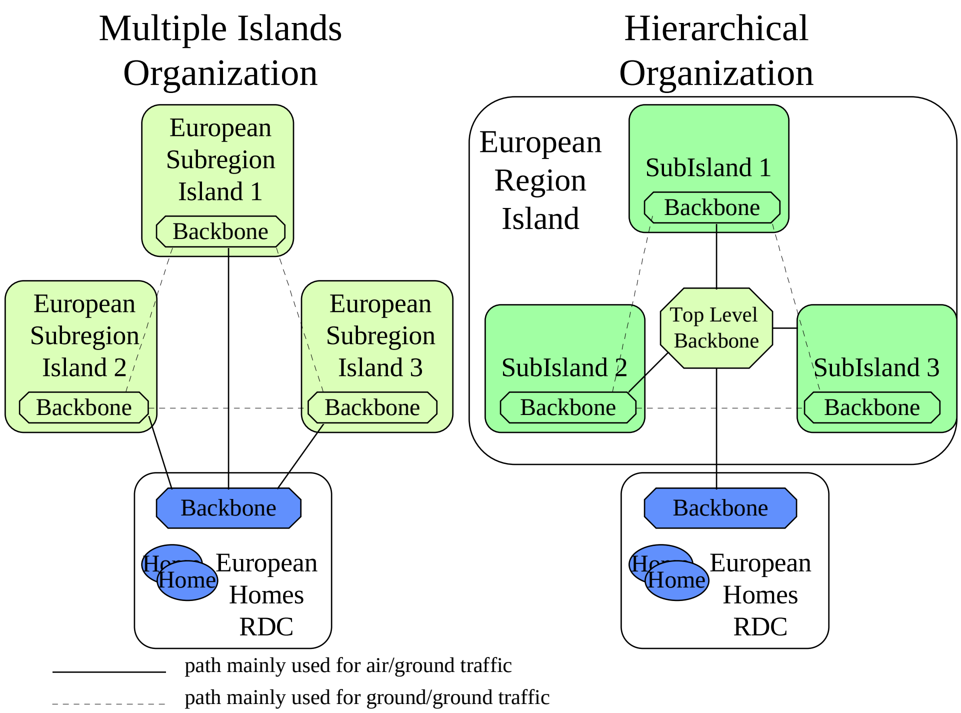


Figure 10: Multiple Islands and hierarchical routing organisations

The 2 models can be seen as being very similar (considering that the Sub-Islands of the hierarchical scheme would have the same geographical spread as the corresponding Islands in the multiple Islands scheme). This is a good point; it shows that the way to organise the European ATN converges to a single idea to subdivide the European ATN region into a number of ATN subregions (which are Islands in one case and SubIslands in the other cases) directly interconnected for the exchange of ground/ground traffic, and indirectly interconnected via another backbone for the exchange of air/ground traffic.

The main difference between the 2 emerging possible organisations is that the hierarchical model introduces an additional backbone dedicated for the specific Inter-European subregion air/ground traffic whereas the multiple Islands scheme relies on a more general backbone service provided by airlines and IACSPs.

The selection between these 2 organisations depends on the interest for the European ATS Organisations to control the air/ground traffic exchanged between European subregions. In other words, if there is an ATC requirement for ground End Systems in one European Subregion to communicate with an Aircraft flying in another European subregion, then it might be desirable to ATS Organisations to keep control of the inter-subregion air/ground traffic by adopting the hierarchical organisation.

Conversely, if there are no ATC requirements for ground End Systems in one European Subregion to communicate with an Aircraft flying in another European subregion, then the management (and the cost) of the inter-subregion air/ground traffic can be placed in the hands of the Airlines and of the IACSPs.

Considering that at the boundary of European subregions, the use of limited coverage A/G subnetwork for the continental ATN traffic exchange may result in situations where the FIR controlled by a given ACC is partially covered by the VDL or Mode S ground station (and by the A/G router) of an adjacent country in an adjacent subregion, it is assumed that there will be ATC requirements for inter European subregion air/ground traffic. **It is consequently proposed to retain the hierarchical organisation**

3.2.4 Proposed overall Routing Organisation of the European ATN

With regards to the various aeronautical traffic densities within the ECAC coverage, the ATN Islands and Homes IDRP Convergence Modelling Study [EUR3] has identified, based on an analysis of characteristics of ECAC air-traffic nowadays and forecasts for the period 2005-2015 found in [EAT18], three main European subregions:

1. The Western subregion, which covers the oceanic area and most of the core area, and consists of the following countries: United Kingdom, the Benelux Countries, France, Germany, Switzerland, Ireland, Spain and Portugal

2. The Eastern subregion, which covers a part of the core area, and mostly peripheral area, and consists of the following countries: Austria, Italy, Greece, former Czechoslovakia, Hungary, Romania, Croatia, Slovenia, Bulgaria, Turkey, Cyprus, Malta

3. The Northern subregion, which covers Scandinavia and countries around the Baltic Sea: Norway, Sweden, Denmark, Finland, Latvia, Lithuania, Poland

On the basis of the conclusion of the previous section which retains a hierarchical organisation, the overall Routing Organisation of the European ATN is proposed to consist of:

- a European « Region » ATN Island subdivided into three SubIsland RDCs (the Western, Eastern and Northern SubIsland RDCs) interconnected via a backbone.

- an independent separate European « Home » RDC formed by the Airlines and their service providers. This RDC does not contain any Routing Domain with A/G connectivity. It is a transit RDC connected with the European « Region » ATN Island and with non-European Islands and hosting the home Routing Domain of the European Airlines.

3.3 Internal Organisation of the European Region ATN Island

3.3.1 General

This section discusses the possible internal organisation of the European « Region » ATN Island.

The overall routing organisation proposed in the previous section resulted from the primary necessity to minimise the update rate to be supported by the European ATN Island's backbone. The route update rate to be supported by the ATN routers is indeed perceived as the main constraining factor for the organisation of the ATN in each region.

It is now assumed that the selected number of SubIsland RDCs composing the European Region ATN Island (e.g. 3) and the geographical spreads of these subIslands RDCs (e.g. Western, Eastern and Northern European subregions) constitute the good compromise that will result in having an acceptable and minimal traffic load for the routers on the European Island's backbone.

It is time to focus on the design of the internal organisation of each of the identified European subregions. Each subregion will consist of a SubIsland RDC encompassing a SubIsland backbone required to hide the detail of the route changes to the top level European Backbone routers and the Routing Domains of the different organisations in the subregion.

It is assumed that each state forms one RDC, even if it only contains one RD so that to limit impact on other organisation in the event where the national organisation is further changed from a single RD topology to a multiple RDs topology.

The smaller administrations such as the Benelux Administrations are assumed to organise their systems into a single Routing Domain, while larger administrations will be assumed to organise their systems into several Routing Domains.

For the definition of the overall Routing Organisation of the European Region ATN Island, details on the internal organisation of the national RDCs are not really needed. A good generic scenario is to assume that a Routing Domain is created in each country around each national ATC Centre.

The table below lists the ATC Centres operating in the different countries:

Subregion (SubIsland RDC)	Country (Nation RDC)	ATC Centre (Routing Domains)
WESTERN	United Kingdom	London Manchester Scottish
	Belgium	Brussels
	France	Brest Paris Reims Aix Bordeaux
	Germany	Berlin Bremen Dusseldorf Frankfurt Karlsruhe Munich
	Switzerland	Geneva Zurich
	Ireland	Dublin Shannon
	Netherlands	Amsterdam
	Spain	Barcelona Canarias Madrid Seville
	Portugal	Lisbon
	Eurocontrol	Maastricht
NORTHERN	Norway	Oslo Stavanger Trondheim Bodo
	Sweden	Stockholm Sundsvall Malmo
	Denmark	Copenhagen
	Finland	Rovaniemi Tampere
	Latvia	Riga
	Lithuania	Vilnius
	Poland	Warsaw Poznan
EASTERN	Austria	Vienna
	Italy	Brindisi Milan Rome Padua
	Greece	Athens Makedonia
	Czech republic	Prague
	Slovakia	Bratislava
	Hungary	Budapest
	Romania	Arad Bacau Bucharest Cluj Constanta
	Croatia	Zagreb
	Slovenia	Ljubljana
	Bulgaria	Varna Sofia
	Turkey	Ankara Istambul
	Cyprus	Nicosia
	Malta	Malta

Within each national RDC, it is assumed that the national RDs will be directly interconnected. It is indeed likely that the national ATS Organisations will be reluctant to rely on the subregional backbone for intra-national ground/ground communication.

For transnational ground/ground communication, it is both institutionally and technically unlikely that national ATS Organisations could offer their ATS-dedicated ATN networks to serve as transit network for AOC or long distance ATSC traffic (i.e. ATSC traffic between non-adjacent ATSOs). It is therefore assumed that the national Administration will choose to have their Routing Domain Confederations acting as non-transit RDCs, and that highly multi-national communications between not directly adjacent ATS Organisations will be provided through the backbones. Each national ATS Routing Domain or Routing Domain Confederation will consequently have to be directly connected to the backbone.

However, considering the requirements that will exist in Europe for ground-ground ATN traffic between adjacent ATC centres of the same or different countries, between ATC centres and adjacent airports in the same or different countries, and between adjacent airports of the same or different countries, and considering the current practices by which a CAA already feeds its radar or flight plan data to another one, it may also be assumed that there will be a tendency to establish, for trans-national ATSC communications between adjacent countries, direct bilateral agreement for interconnecting ATN routers.

For the ground topology within the European ATN Island, we can identify 2 extreme scenarios:

1. The most simple routing scenario, where there are no direct interconnection between routers of adjacent countries and where the transnational ground/ground communication goes through the backbone.

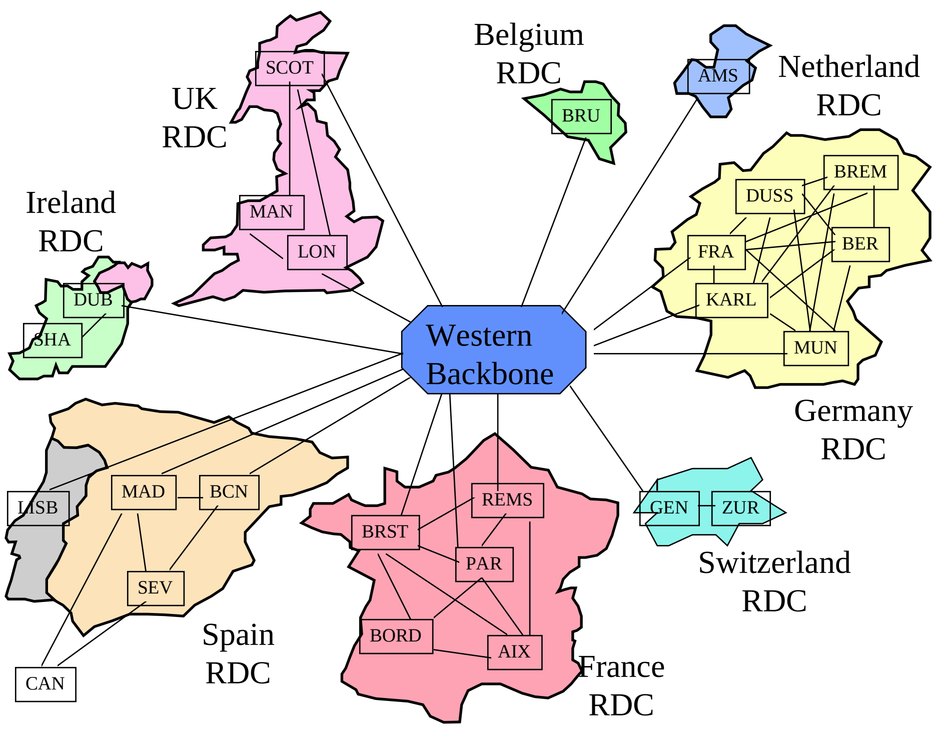


Figure 11: Simple regional routing organisation scenario

2. The most complex routing scenario, consisting in an extensively meshed topology where the ATS Routing Domains are for the most directly interconnected with the ATS Routing Domains of all adjacent countries.

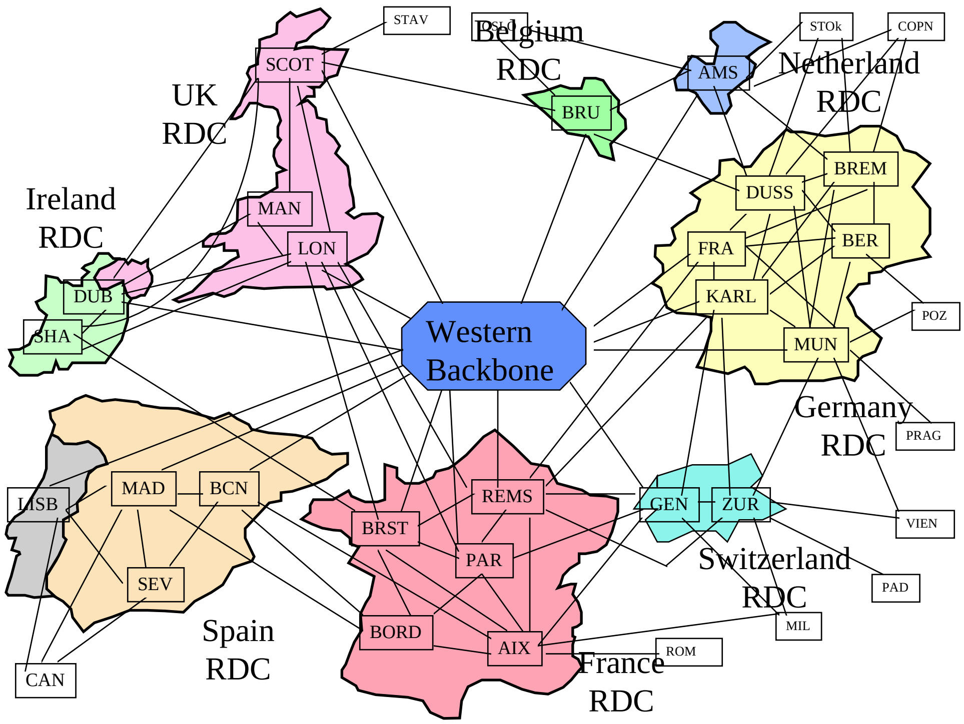


Figure 12: Complex regional routing organisation

The impact of the different possible topologies on the routing performance is to be analysed. This is the subject of the next section.

3.3.2 Optimising the routing within a European Subregion

3.3.2.1 Routing performance

3.3.2.1.1 Definition

The routing performance will be defined here as a function of the swiftness of routing information propagation and of routing convergence.

The delay of the routing information propagation is mainly dependent on the length of paths that routing information packets need to follow for having the information actually known by all relevant routers, and is so function of the number of the routers involved in the transit of the information, and of the information processing and readvertisement time of these transit routers.

Convergence is the process of agreement, by all routers, on optimal routes. When a network event causes routes to either go down or become available, routers distribute routing update messages. Routing update messages permeate networks, stimulating recalculation of optimal routes and eventually causing all routers to agree on these routes. Slow convergence can cause routing loops or network outages.

The routing propagation delay is minimal when the length of paths between any pair of routers is minimal. Minimising the propagation delay tends therefore to promote fully meshed topology where each router is directly interconnected with each other router, and where the path between any pair is consequently reduced to one single subnetwork hops.

On the other hand, the IDRP Convergence Modelling studies have demonstrated that fully meshed topologies introduce routing loops and consequently make the routing unstable because of the multiple readvertisements of every route. A fully interconnected architecture increases the routing overhead and the routing convergence delays exponentially in the number of nodes. Minimising the convergence delay tends to promote topologies without routing loops such as star or tree type topologies. However, the star or tree type topologies are generally not optimal in term of routing optimisation: these topologies present the drawback to centralise the routing around main nodes which become inevitable go between source and destination systems for the data traffic.

3.3.2.1.2 Effect of the off-backbone topology on the routing performance

3.3.2.1.2.1 Ground/Ground routing performance

The routes to ground Routing Domains are very stable (as compared to routes to aircraft). There could hence be no particular requirement for optimising the delay of propagation and the delay of convergence of Routes to ground Routing Domains. However it is assumed that in the case of the failure of a link or of the reboot of a router at the boundary of a national RDC, there will be a requirement for a quick rerouting of the traffic on an alternate path allowing to maintain the transnational communications.

In the case of the most simple topology, consisting of national RDCs only interconnected by the backbone, all the routes to ground Routing Domains will be exchanged from the national RDCs to the backbone and from the backbone to the national RDCs. This is a star type topology, without loop, and which hence minimises the convergence delay. The path between any national RDC, is relatively short (national RDC to backbone to national RDC), implying short propagation delays. It can therefore be assumed that the ground/ground routing will be naturally performant on such a simple topology.

In the case of the most complex topology, consisting of an extensively meshed ATN network where the ATS Routing Domains are for the most directly interconnected with the ATS Routing Domains of all adjacent countries, it could be feared that the convergence delays be prohibitive. However, if we assume that the national Administrations will not accept to act as transit domains for other Organisations, they will not readvertise the route to adjacent RDs to other adjacent RDs. As a consequence, and even with an extensively meshed topology, the policy rules of the national ATS Organisations will make that the ground/ground routing information will not be flooded in the Island but will be parsimoniously disseminated on a point to point basis between adjacent Organisations and between Organisations and the backbone. By restricting the readvertisement of routes, the possible routing loops are totally suppressed and the convergence delays of routes to ground Routing Domains will be minimal. The path between any national RDC will be either direct or indirect via the backbone, and will consequently be short, implying short propagation delays. It can be therefore assumed that the ground/ground routing will be naturally performant on such a complex topology.

In conclusion, both extreme topologies are assumed to provide good ground/ground routing performance

3.3.2.1.2.2 Air/Ground routing performance

As far as the air/ground routing traffic is concerned (i.e. routes to the aircraft) it must be noted that outside the backbone, the ATN routing policies constrain the propagation of the routes to the aircraft in a way which avoids routing unstability due to the presence of routing loops: ATN Routers in Routing Domains outside the Backbone are compelled to advertise the routes to aircraft only to the adjacent RD advertising the best route to the backbone. As a consequence, and independently of the complexity of the meshing of Routing Domains outside the backbone, routes to aircraft are therefore only propagated on the direct unique optimal path toward the backbone as if adjacencies with other routers not being on the optimal path to the backbone did not exist. This is illustrated by Figure 13 below.

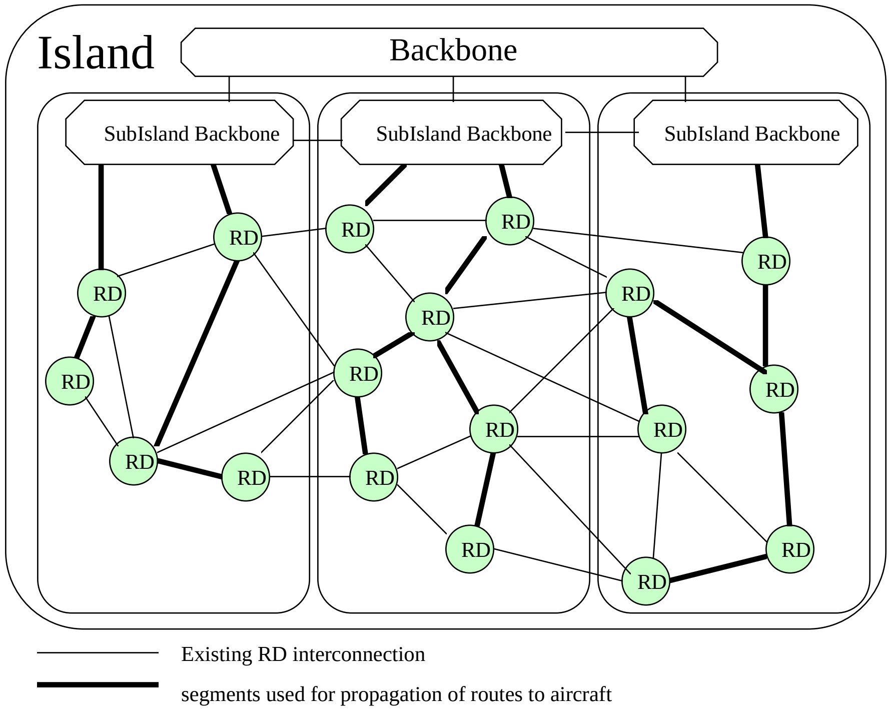


Figure 13: Propagation of routes to the aircraft

Outside the backbone, the way to optimise the air/ground routing performance is therefore to minimise the routing propagation delay by minimising the length of path from Routing Domains having air-ground connectivity to the backbone; the ideal case being to have every Routing Domain with air-ground connectivity being directly connected to the backbone.

3.3.2.1.3 Conclusion

Having assumed that the national RDCs will not act as transit domains for adjacent countries, outside the backbone, the complexity of the meshing has little effect on the global routing performance in the concerned subregion. Both identified topology scenarios rely, for the most amount of routing information to be exchanged, on the performance of the backbone. The backbone appears therefore as the key element for the global routing performance within a subregion.

3.3.2.2 Routing efficiency

3.3.2.2.1 General

A routing organisation can be performant in the way routing information is propagated, converges and stabilises, without being necessarily performant in providing optimum paths (shortest, fastest, or other criteria depending on metric); neither does it guarantee that the data traffic will be well distributed amongst routers. The routing evaluation criteria covering these other aspects is called here routing efficiency.

The simple and complex topology scenarios identified in the section 3.3.1 have both been considered performant as concerns the convergence and the propagation of the routing traffic, provided that the backbone is performant. The preferred scenario has however not been identified (the routing performance having not been a sufficient criteria). It is now proposed to consider both scenarios with regard to the resulting routing efficiency.

As far as the simplest scenario is concerned, all transnational air/ground and ground/ground data exchanges go through the backbone. This topology presents therefore the drawback to centralise all the traffic on the backbone; the backbone routers are the inevitable go between source and destination systems and must be dimensioned in number and in switching capacity to support the traffic load corresponding to all transnational data exchanges. The data packets follow systematically an indirect path from the source RD to the backbone, then through the backbone, and from the backbone to another RD. This scenario is therefore not the most efficient, but it presents the advantage to concentrate the complexity and the cost of the routing on the backbone.

With regard to the complex scenario, while transnational air/ground data exchanges go through the backbone, the most of ground/ground transnational exchanges follow the direct path existing between the adjacent RDs of adjacent countries. The backbone routers are consequently alleviated from most of the ground/ground traffic of the subregion, and the path followed by the ground/ground traffic is shortened to one single hop between the source and destination RDs. This scenario is therefore very efficient, with the penalty of the cost of administrative and technical activities that will be necessary to set up and operate the numerous bilateral interconnections.

3.3.2.2.2 Conclusion

As a conclusion both scenarios have advantages and drawbacks and there is certainly a trade-off to be found between the 2 extreme approaches.

It can be assumed that in each subregion the ATN organisation will begin following the approach of the simple scenario by creating a backbone and interconnecting each national ATN to this backbone; this is indeed a routing organisation required in any case for allowing the transnational air/ground communication. In the time, when more and more ground/ground applications will migrate to the ATN (e.g. radar data exchange), it will certainly become necessary to support direct communications between Routing Domains of adjacent countries.

As a way to avoid implementing the topology of the complex scenario where all RDs would be directly interconnected with each adjacent RD of adjacent countries, an acceptable compromise could then certainly be to interconnect one RD of each national RDC with one RD of each adjacent national RDC as illustrated by Figure 14.

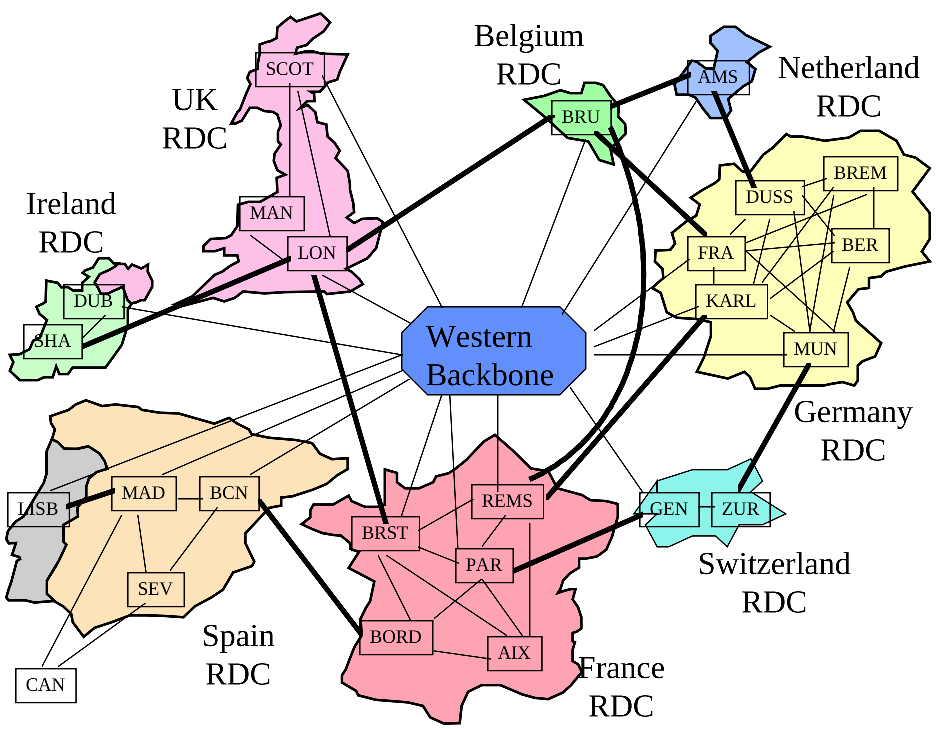


Figure 14: Basic compromise regional routing organisation

This compromise scenario is satisfactory and suitable for any of the European Subregions; it should hence be retained as the basic scheme for the interconnection of national RDCs within each subregion.

The backbone remains however the key element for the global routing performance; no interconnection scenario can therefore be validated without considering the performance in the backbone.

The next section addresses the optimisation and efficiency of the routing within the backbone. From the discussion will follow a better way to organise the routing within a subregion.

3.3.3 Intra-backbone routing performance

3.3.3.1 General

From a routing efficiency point of view, the inter-domain routing within the backbone should be arranged in such a way that any IDRP routes crossing the backbone would have to go at most through 2 backbone BISs. In other words, any CLNP packets should be able to go from any RD to any other RD connected to the backbone in one single hop through the backbone.

In the most simple scenario, the solution to minimise the number of hops between backbone BISs is that each backbone BIS maintains direct routing peering with each other. This way each BIS acquires routing information about destinations reachable through every other backbone BIS. Such direct peering allows to acquire « first hand » information about destinations which are directly reachable through adjacent backbone routers and select the optimum direct paths to these destinations. A single CLNP hop objective through the backbone would be accomplished.

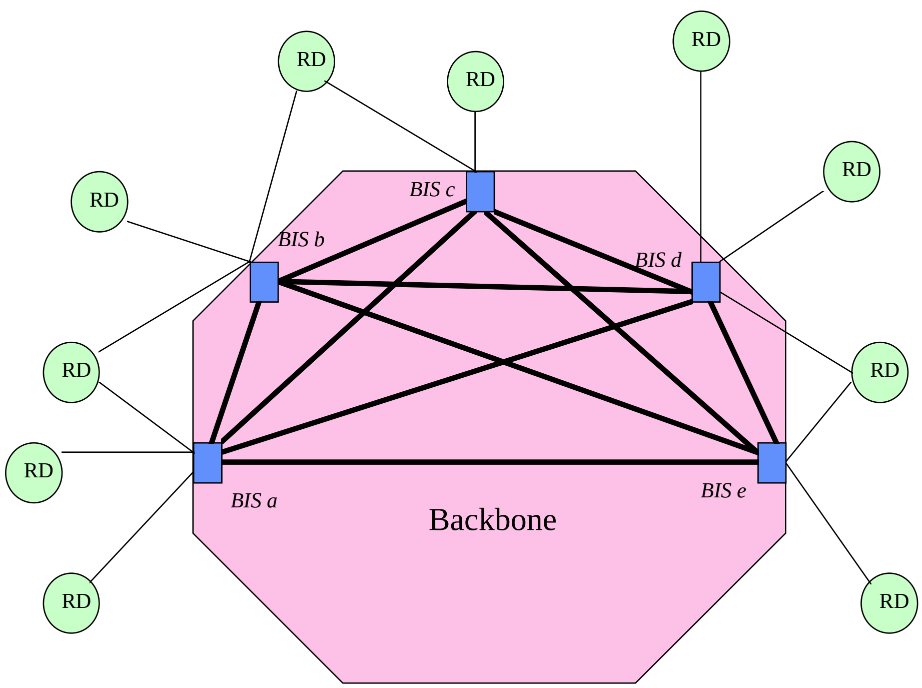


Figure 15: Fully meshed backbone architecture

Within a backbone, the ATN SARPs routing policy rule is to flood all routers with all routing information: each backbone router must inform all other adjacent backbone routers about all known routes to fixed and mobile RDs. This is the case where loops in the topology strongly impact the convergence delays. The IDRP convergence modelling studies have concluded that the backbone should not consist of more than three fully interconnected routers of different Routing Domains.

This limit of three fully interconnected routers in a backbone seems very constraining and cumbersome particularly when considering that the European ATN will expand and include more and more BISs. It is indeed likely that there will be a requirement for fully meshed backbones consisting of more than 3 BISs. Redundancy of Backbone BISs, and the possible limitations on adjacency number of Backbone

BISs, together with the increasing number of off-backbone routers requiring a direct connection with the backbone will indeed certainly necessitate the multiplication of BISs in the Backbone.

There are 3 possible ways to go beyond this limit of three routers in a fully meshed backbone without impacting the convergence delay. The first solution is to have all backbone routers belonging to the same Routing Domain. Indeed, within a Routing Domain, the BISs do not readvertise the routes learned from adjacent BISs in the local Routing Domain to other adjacent BISs in the local Routing Domain. This is because, the IDRP protocol requires that all BISs belonging to the same routing domains establish a full mesh connectivity with each other for the purpose of exchanging routing information acquired from other domains; the external routing information being advertised by each BIS directly to all other BIS of the domain, the re-advertisement of route within the routing domain is not necessary. Routing loops are therefore suppressed and the convergence delays would not be strongly impacted by the number of routers in the backbone.

The second solution is derived from the first one but assumes a fully meshed topology of routers belonging to different routing domains. The solution would consist in avoiding the re-advertisement of route using a policy rule which forbids each backbone router to readvertise the routing information learned from an adjacent backbone router, to any other adjacent backbone router. This policy rule would then have the same effect as the intrinsic non-readvertiment IDRP rule for BISs in the same Routing Domain: by forbidding the route re-advertisement, routing loops are suppressed and the convergence delays are not anymore strongly impacted by the number of routers in the backbone.

These 2 first solutions present some drawbacks: first, they are not tolerant to link failures: the failure of the link connecting 2 BISs causes the loss by each of the 2 BISs of the routes advertised by the other BIS. The other problem is the number of peers each BIS has to maintain. For a fully meshed backbone with N BIS, these approaches require each such router to maintain (N-1) peering relations. And considering that each ATN BIS has to support 4 Routing Information databases per connected adjacent BIS, the maximum number of connections that an ATN BIS can support may become a limiting factor.

The third solution is based on the use of special routers called route servers. It is presented in the next subsection.

3.3.3.2 The IDRP route server alternative to a full mesh routing

3.3.3.2.1 Principle

The principle is to reduce the number of direct IDRP peering relations and to make the exchange of routing information among the backbone BISs through indirect peering: a backbone BIS would acquire the routing information provided by all other backbone BISs by peering with a particular BIS called "Route Server". The use of a route server **is possible when all routers and the route server are connected to a same common subnetwork** (e.g. an X.25 WAN, an ATM subnetwork) allowing direct communication between any pairs of routers and between the routers and the route server.

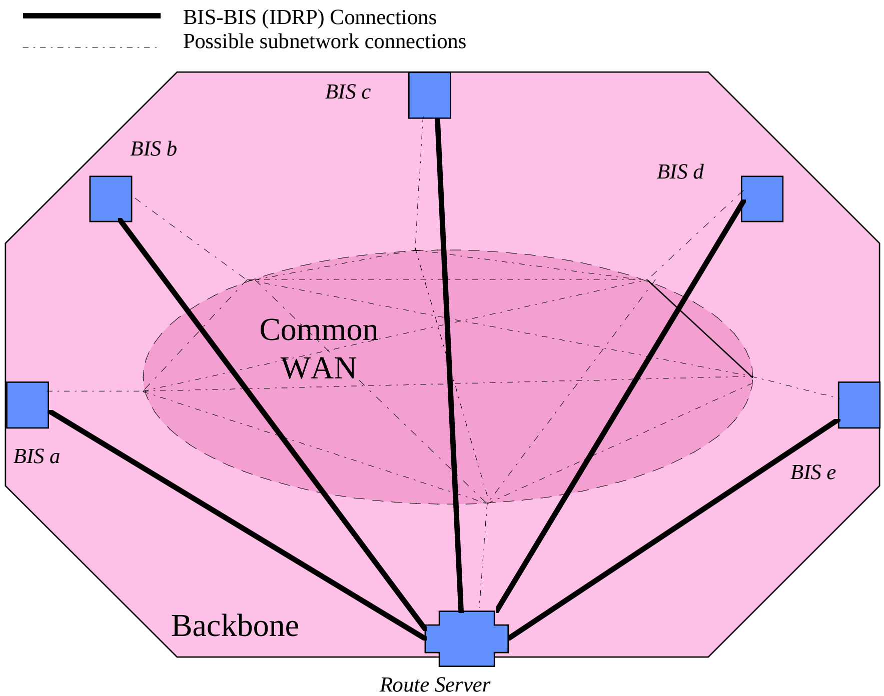


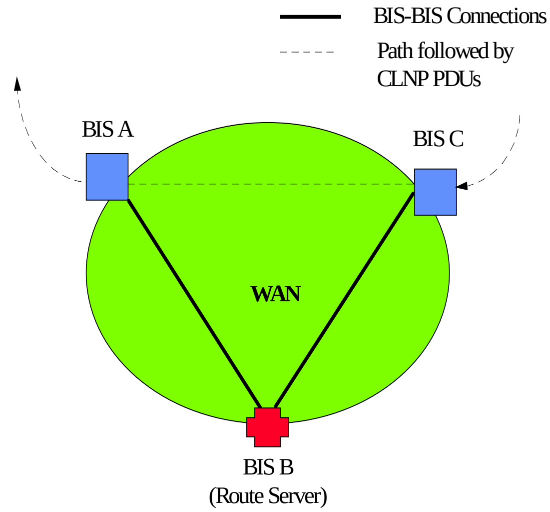
Figure 16: Backbone architecture relying on the use of a Route Server

A Route Server is a system that participates in IDRP, but doesn't participate in the actual CLNP packet forwarding. A Route Server is a BIS dedicated to the processing of routes: it acquires routing information from all the BISs connected to a common WAN, performs decision process over this information, and then redistributes the results to the routers.

When a Route Server acquires a route from a BIS, and passes the route to other BISs, the Route Server **specifies the direct subnetwork address of the router from which the route was acquired. This way CLNP traffic bypasses the Route Server, and flows directly between the routers without going through the Route Server**.

To better understand the route server function, consider the following example:

- Three BISs A, B and C are all attached to the same WAN
- Through the WAN, A can reach directly B and C, B can reach directly A and C and C can reach directly A and B
- A and B share a BIS-BIS connection; B and C share a BIS-BIS connection
- B is a route server



if A propagates a route to B, the route server function of B will make B readvertise this route to C with an additional NEXT_HOP attribute, indicating that the true Next Hop BIS for this route is A. As a result, all CLNP packets following this route will directly be forwarded by C to A and this even if A and C do not share a BIS-BIS connection.

It is easy to see that by using Route Server when N BISs are connected to a common WAN, instead of (N-1) peering relations, each BIS has to maintain only 1 peering relations -- the relation with the Route Server. Thus, this approach presents a clear improvement (in terms of the required number of peering relations) over the 2 first solutions.

In addition to improved scaling with respect to the number of peering IDRP connections, the route server approach also improves scaling with respect to the volume of routing information. In presence of multiple routes to a destination only the Route Server has to maintain all these routes, while other routers (on a common WAN) that peer with the Route Server have to maintain at most one route -- the one selected by the Route Server.

Note that the Route Server is still expected to be capable of peering with all the routers connected to a common WAN; the Route Server is also expected to be capable of storing all the routes received from all the routers. So, the approach improves scaling on most, but not all the routers. Specifically, the approach reduces the load on all the routers, except for the Route Server, -- the load on the Route Server is the same as on any router in the case of a complete mesh peering. However, the Route Server is only assumed to handle IDRP Traffic; it does not participate in the CLNP forwarding. It can therefore be considered that a Router alleviated from the task of forwarding packets will be in a position to manage more routing traffic than a classical BIS both forwarding CLNP packet and processing IDRP routes.

To eliminate a single point of failure associated with a single Route Server, a small number of Route Servers (e.g. 2-3) can be deployed. This way each BIS will maintain a peering relation with every Route Server connected to the WAN. If one of the Route Servers goes down, the information provided by the other Route Servers should be sufficient to preserve routing.

3.3.3.2.2 Drawback of the approach

The use of a route server has one drawback, as compared to the other 2 solutions. With complete mesh peering each BIS acquires routing information from all of the other adjacent BISs, and performs the selection process (selecting best routes) based on its local route selection criteria using the acquired information as an input. As a result, with the complete mesh approach there is no interdependencies on the selection criteria among different BISs. With the approach outlined in this section the selection is done by the Route Server. Thus, if two different BIS connected to the same WAN have different selection criteria, then the Route Server can accommodate either of them, but not both.

For example, if a destination X is reachable via two BISs, E1 and E2, connected to the common WAN, and some other BIS A (connected to the network) prefers the route through E1, while some other BIS B (also connected to the network) prefers the route through E2, then the Route Server can make its selection process consistent with either A (thus advertising the route through E1 to all of its peers, including A and B), or with B (thus advertising the route through E2 to all of its peers, including A and B), but not both.

To accommodate certain diversity among the route selection criteria of the BISs connected to a common WAN the scheme presented in this section could be augmented with selective direct peering between BISs. This way most of the routing information will still be acquired via the Route Server, while "exceptions" (due to the diversity of route selection criteria) could be handled via direct peering. Therefore, the scheme outlined in this section is appropriate as long as route selection criteria among all the BISs connected to the WAN are fairly consistent among themselves.

Another solution could be that the Route Server does not apply any selection criteria to the routes received from the BISs for the purpose of distributing all these routes to its clients. In such a case, all routes acquired from the BISs would be relayed to all BISs. With such an approach however, the BISs connected to the WAN, although alleviated from the task of managing a large number of BIS-BIS connections, will not be alleviated from the route pre-selection task that could have been made by the route server.

3.3.3.3 Conclusion

In those portions of the European ATN where a fully meshed topology is required, it is believed that the use of Route Servers will be of a major interest. The use of Route Servers will allow the implementation of virtually meshed topologies, taking advantage of the large scale subnetwork technology (e.g. international X.25 or ATM WAN) which might be available and optimising the routing (1 CLNP hop over these networks) while avoiding the routing stability problems inherent to true fully meshed topologies.

The use of route servers is particularly of interest within the backbone. For a backbone consisting of less than 3 backbone routers, a fully meshed interconnection of these routers may suffice to insure a good routing performance level within the backbone and consequently within the region. On the other hand, if more than 3 backbone routers are necessary for achieving the interconnection of the different Routing Domains in the subregion, an architecture based on the use of route servers should be adopted for the backbone. The backbone should then consist of the number of backbone routers necessary for achieving the interconnection of the different Routing Domains in the subregion, each being simply interconnected with a route server, and possibly with a second backup route server, for the purpose of eliminating a single point of failure.

With this recommended backbone architecture, the basic routing organisation scheme identified in section 3.3.2.2.2 for the European Subregions, would become the one represented for the Western subregion on Figure 17.

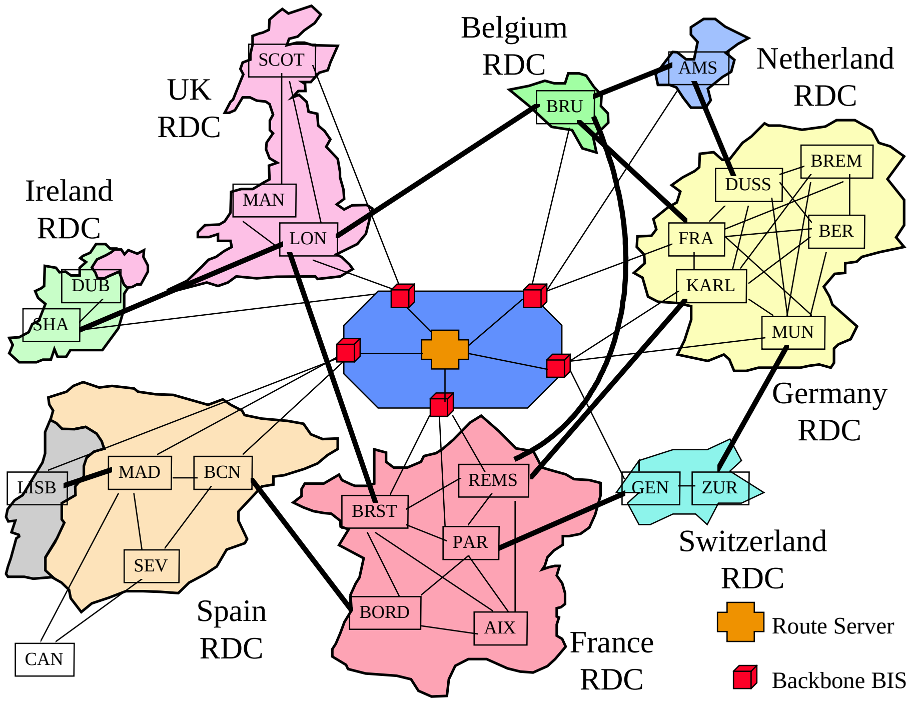


Figure 17: Basic routing organisation with an enhanced backbone architecture

3.3.4 Generalising the benefit of Route Servers in the whole subregion

The Route Servers offers so much advantage that their use should also be considered outside the backbone. Indeed, provided that there is a common Wide Area Network available for interconnecting the routers within the subregion, interconnection of off-backbone RD with Route Servers may allow any direct RD to RD and RD to backbone communication for all RDs in a subregion with a minimum number of IDRP connections to be maintained. The generalisation of the use of route servers is discussed in this section. Since the subject may appear somewhat abstract, the discussion is proposed to be driven with reference to a concrete example.

Consider a subset of Figure 17, as the one represented on Figure 18:

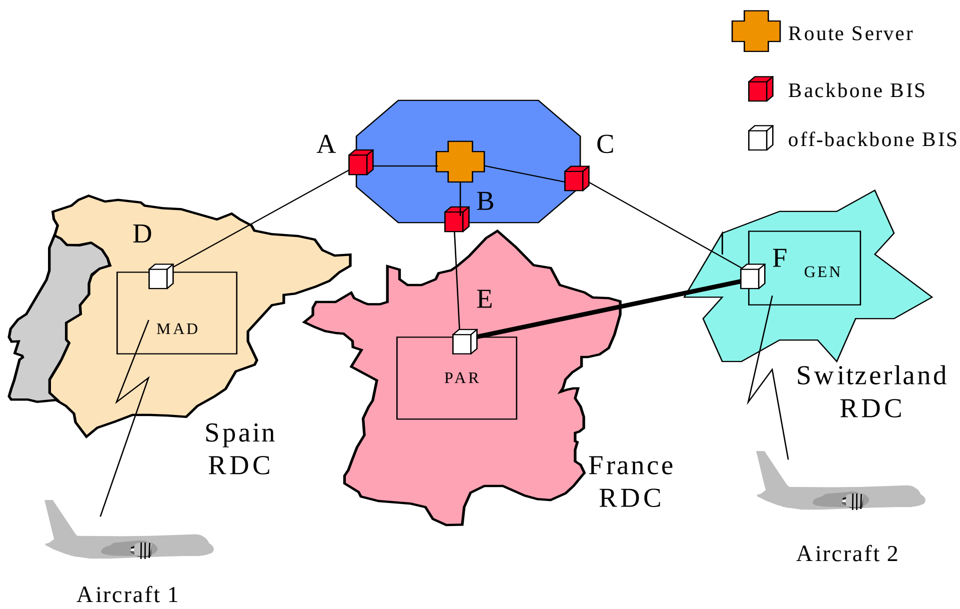


Figure 18: Example derived from the basic routing organisation

If the Western subregion was resumed to this subset, the routing table within each router would be quite simple. Consider for instance the case of router F in the Geneva ACC RD; its routing table would consist of the following entries:

Destination	Next Hop	Next Hop Subnetwork Address
Madrid RD	C	SN address of C
Paris RD	E	SN address of E
Aircraft 2	Aircraft 2	Mobile SN address of Aircraft 2
All Aircraft	C	SN address of C

As far as the Backbone BISs are concerned, the Route Server acquires from all Backbone BISs the set of routes to each ground or mobile destination within the subregion and provides then back each of them with the direct addresses of the suitable egress backbone BISs to each destination in the subregion. The routing table of backbone BIS C would for instance be filled with the following information:

Destination	Next Hop	Next Hop Subnetwork Address
Madrid RD	A	SN address of A
Paris RD	B	SN address of B
Geneva RD	F	SN address of F
Aircraft 1	A	SN address of A
Aircraft 2	F	SN address of F

The table below lists the resulting path that CLNP packets issued from the Geneva RD would follow to reach each of the possible destination:

Source/destination	path followed by the CLNP packets
from Geneva RD to Madrid RD	F-C-A-D
from Geneva RD to Paris RD	F-E
from Geneva RD to aircraft 1	F-C-A-D-Aircraft 1
from Geneva RD to aircraft 2	F-Aircraft 2

It may be observed that the path from Geneva to Paris is shorter than the path from Geneva to Madrid. This is due to the facts that between Geneva and Paris, a subnetwork is assumed to be available for interconnecting routers of either RDs, and that a direct IDRP connection has been established between these routers.

If a subnetwork was available for direct communication between Geneva and Madrid, a direct path could exist for CLNP packets exchanged between these 2 Routing Domains. This would however likewise be possible at the cost of maintaining an IDRP connection between routers of either RDs.

Let us consider now a routing architecture where the use of Route Servers is generalised to the whole subregion and therefore extended beyond the limit of the backbone. With such a routing organisation, both backbone and off-backbone BISs establish an IDRP connection with the Route Server as illustrated by Figure 19.

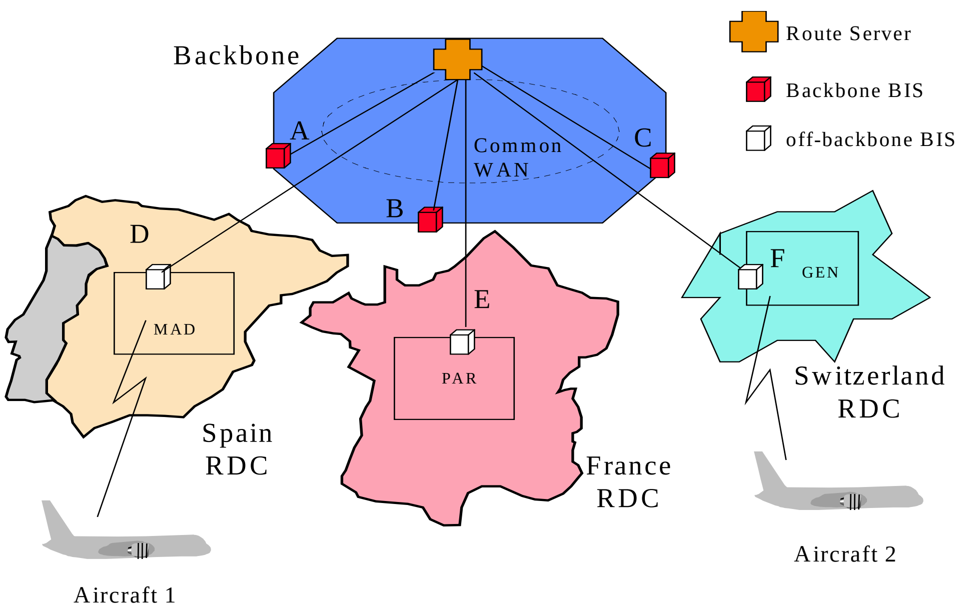


Figure 19: Generalising the benefit of Route Servers

The Route Server acquires then from all connected off-backbone BISs the set of routes to each ground or mobile destination within the subregion.

The Route Server can then provide back the off-backbone BISs with the direct routes to every ground destination within the subregion.; in the same time, the Route Server can provide the backbone-BIS with the direct routes to every ground and to every mobile destination within the subregion.

These exchanges of information are represented on Figure 20:

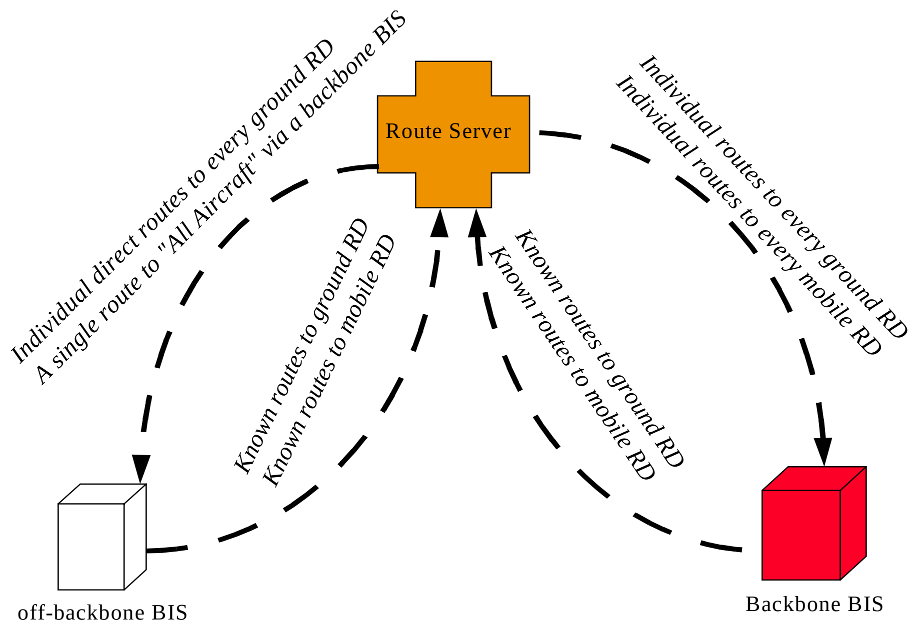


Figure 20: Routing information flows within a subregion

Let us resume the example with such a new routing organisation, and consider the case of router F in the Geneva ACC RD; its routing table would consist of the following entries:

Destination	Next Hop	Next Hop Subnetwork Address
Madrid RD	D	SN address of D
Paris RD	E	SN address of E
Aircraft 2	Aircraft 2	Mobile SN address of Aircraft 2
All Aircraft	C	SN address of C

As far as backbone routers are concerned, the routing table of backbone BIS C would for instance be filled with the following information:

Destination	Next Hop	Next Hop Subnetwork Address
Madrid RD	D	SN address of D
Paris RD	E	SN address of E
Geneva RD	F	SN address of F
Aircraft 1	D	SN address of D
Aircraft 2	F	SN address of F

The resulting paths that CLNP packets issued from the Geneva RD would follow to reach each of the possible destination would then be the ones listed in the following table:

Source/destination	path followed by the CLNP packets

from Geneva RD to Madrid RD	F-D
from Geneva RD to Paris RD	F-E
from Geneva RD to aircraft 1	F-C-D-Aircraft 1
from Geneva RD to aircraft 2	F-Aircraft 2

It may be observed that all paths to ground destinations boil down to one single hop through the common WAN from the source to the destination RD and that paths to mobile RDs boil down to 2 hops, one from the source to a backbone BIS and a second from the backbone BIS to the ground RD currently in contact with the aircraft.

This organisation is therefore optimal from a point of view of the routing. Furthermore, by reducing the number of IDRP connections to be established, the approach simplifies administrative issues such as the setting up of bilateral agreements.

Such an organisation is additionally in line with the EUROCONTROL EATCHIP Communications Team (COM-T) activities on the integration of ATSO aeronautical private data networks: an EATCHIP COM-T working group is indeed considering the feasibility and benefits of establishing a managed pan-European ATS data Wide Area Network through utilisation of National and Regional data networks. Although these current subnetwork interconnection activities are intended to satisfy urgent operational requirements with short term solution, such a Pan-European Wide Area Network would certainly be available for the support of the ATN traffic.

In the Western region, a pan-European ATC X.25 subnetwork, consisting of the interconnection of RENAR, REDAN CAPSIN and RAPNET, is likely to be available in the timeframe where the ATN will be deployed in this region. The optimal routing organisation resulting from the generalised use of Route Servers could therefore be put in place. The complete scenario would consist in interconnecting each national RD with one single (or two for backup reason) route server of the backbone. With such an organisation, each RD within the region would be informed on the direct path, via the pan-European X.25, to any other RD in the region and to the backbone. This would allow to have the same efficiency as if all RDs were interconnected with all other RDs (adjacent or not) in the region, with the single price of one (or two) BIS-BIS connection with the backbone route server.

As a transition path toward this complete optimal routing organisation, it will be sufficient that each national administration interconnects only one of their Routing domains to one (or two) route server(s) of the backbone. This is illustrated by Figure 21.

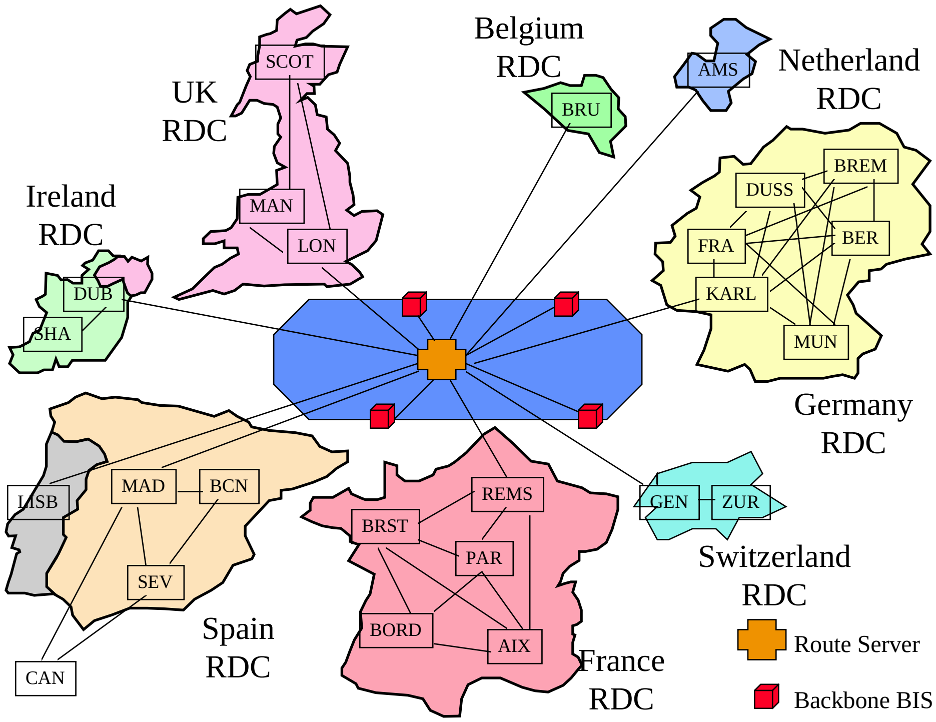


Figure 21: Optimal Routing Organisation relying on the generalised use of Route Servers

To finish with this section, it might be necessary to answer a question that is potentially raising from this discussion: the optimal routing organisation based on the generalised use of route servers is only possible when a common Wide Area Network is available for providing full subnetwork interconnectivity to the routers; however, in a European subregion where such an international ATC subnetwork is available, there may still be some countries that are not (yet) connected to (i.e. in the geographical coverage of) this common WAN; does this prevent to retain the optimal approach for the routing organisation in this subregion ?

The answer to this question is no. It is indeed possible to mix the optimal and basic routing organisation scenario. In such a case, countries which have access to the international WAN will interconnect their BISs directly with the Route Server, while countries which are not in the coverage of the common international WAN will interconnect their BISs with backbone routers.

As an example, if Ireland in Figure 21 had no access to the international WAN, its BIS would have to be interconnected with a backbone router (via a subnetwork to be determined (e.g. a leased line)) instead of being interconnected with the route server.

3.3.5 Proposed Organisation of the European Region ATN Island

3.3.5.1 Routing Organisation (summary and conclusion)

The three subregions of the European Region ATN Island should be ATN SubIsland RDCs organised according to the following principles:

- For those European subregions, where an international ATC Wide Area Network is available, the optimal routing organisation relying on the generalised used of route server should be adopted. This routing organisation is described in section 3.3.4 and illustrated by Figure 21 on page 44.

- For those European subregions, where no international ATC WAN is available, the basic routing organisation introduced in section 3.3.2.2.2 should be adopted. If more than 3 backbone routers are necessary in the backbone for achieving the interconnection of the different Routing Domains in this subregion, the backbone architecture should be based on the use of route servers as described in section 3.3.3.3 and illustrated by Figure 17 on page 39.

- For those European subregions, where an international ATC WAN is partially available an approach mixing the principles of the basic and optimal routing organisations should be followed. More specifically:

  - Countries having access to the international WAN should establish an IDRP connection between one (or several) of their BISs and the backbone route server

  - Countries having no access to the international WAN should establish an IDRP connection between one (or several) of their BISs and a backbone router.

A top level backbone is used for the interconnection of the three European subregions and for the interconnection of the whole European Region ATN Island with other ATN Islands and with the European Homes RDC. This backbone should be architectured following the same principles as for the subregional backbones: if more than 3 backbone routers are necessary for achieving the internal and external interconnection requirements of the Island, the use of top level route servers is recommended.

3.3.5.2 Proposed partnership in the deployment of the ATN infrastructure

Although this may go beyond the scope of this work package, it is of interest to say a word on the possible co-operation between ATSOs for the provision of the European ATN infrastructure.

It is first assumed that national ATN infrastructures will be provided and managed by national ATSOs, or possibly by another party operating by delegation from the national Civil Aviation Authority.

With regard to the implementation of the subregional backbones, the provision and administration of the route servers is proposed to be considered separately from the case of the backbone routers.

The route servers are common equipment shared between all ATN actors within the subregion. Although the provision and administration of such equipment could be delegated by all states in a subregion to one of the national ATSO or to a third party service provider, it is more likely that such a task falls on a supranational organisation such as Eurocontrol.

The provision and administration of subregional backbone routers is a separate issue. Although backbone routers may be considered as common subregional equipment in the same way as the route servers, there might be some technical advantages for certain administrations to operate their own backbone BIS (large countries may be for instance interested in getting locally first hand information on routes to the aircraft, for the purpose of shortening the subnetwork path to aircraft flying in their airspace (this may avoid round trip through X.75 gateways when communicating with aircraft)). It is therefore assumed that the control, ownership and sharing of backbone BISs will depend on national ATN implementation strategies. All the following three scenarios may coexist:

- A national ATSO (or other organisations such as an IACSPs) operates a backbone BIS on its own

- in a part of the subregion, a number of ATSOs share a backbone BIS. The administration of this router is delegated to one of these ATSOs

- ATSOs share a backbone BISs which are provided and administrated by Eurocontrol.

As an example in the Western subregion, we could imagine that:

- Germany would operate its own backbone BIS
- France and Switzerland would share a backbone BIS administrated by France
- Spain and Portugal would share a backbone BIS administrated by Spain

- UK and Ireland would share a backbone BIS administrated by UK
- The Benelux countries would share a backbone BIS administrated by Eurocontrol.

3.4 Routing AOC traffic within the Island

The ATS Organisations are expected to co-ordinate and maintain control, directly or indirectly, over the ATN communication without unduly restricting the airlines requirements for communication. Within any arrangement of communication service provision, it must be ensured that all aeronautical communication (ATSC, AOC, AAC, APC and SM) can be provided to the maximum extent possible through common airborne and ground equipment. The possible ways of organising the routing were investigated up to now by focusing on the communication requirements of ATS Organisations . However, the routing organisation must additionally meet the communication requirements of non-ATS users and the suitability of the emerging solutions for the AOC traffic exchanges is to be considered.

On one hand, IACSPs are assumed to complement the ATN A/G service provision; they may implement their own A/G BISs and hence provide the airlines and the ATS Organisations with alternate routes to the Aircraft. In order to have these routes available to all interested parties within a subregion, the active IACSPs will then likely be connected to the backbone and will be requested to feed the backbone with any alternate routes they may know to aircraft flying in the related airspace.

However, IACSPs cannot be considered as the only providers of AOC (and possibly APC/AAC) traffic permitted routes to aircraft. It is assumed that a number of the A/G BISs belonging to ATS Organisations will be attached to mobile subnetworks upon which AOC traffic exchanges are authorised (e.g. VDL, satellite subnetworks). These ATS A/G BIS will hence be potentially able to advertise AOC traffic permitted routes to Aircraft. These routes must as well be made known to the backbone routers in the concerned subregion. In the same way National Airport Operators are assumed to implement A/G BIS with Gatelink connection to parked aircraft, and will hence also provide routes to aircraft permitted for all traffic types that will have to be advertised to the backbone.

The AOC permitted routes to aircraft known by the A/G BISs of the national ATS Organisations and Airport operators could be advertised toward the backbone via the ATN infrastructure and the subnetwork of the ATS Organisations; but this would result in authorising the AOC data traffic to use the same path (and then go through the set of ATN routers and subnetworks of the ATS Organisations). This is unlikely; in general, it is assumed that national ATS Organisations will not accept to offer their ATS-dedicated ATN networks to serve as transit network for AOC traffic. The AOC-permitted routes and AOC data traffic transiting between the ATS Organisations or Airport Operators A/G BISs and the backbone must therefore go through an alternate complementary ATN infrastructure.

ATS Organisations will unlikely be candidate for paying the cost of such an alternate ATN infrastructure. It is therefore assumed that this task will be delegated to IACSPs: the A/G BISs of ATS Organisations and Airport Operators offering AOC permitted routes to aircraft will then be assumed to be connected to an IACSP subnetwork and interconnected with an IACSP BIS. The IACSP(s) will then be responsible of implementing the ATN routers and subnetworks infrastructure necessary for the advertisement of routes to the backbone (and possibly also to the Home RD of the concerned Airlines) and for the transit of the AOC data traffic. The organisation of such an ATN infrastructure is under the responsibility of the IACSP(s) and outside the scope of this study.

Figure 22 below illustrates the proposed scenario for the support of AOC traffic in the European subregions.

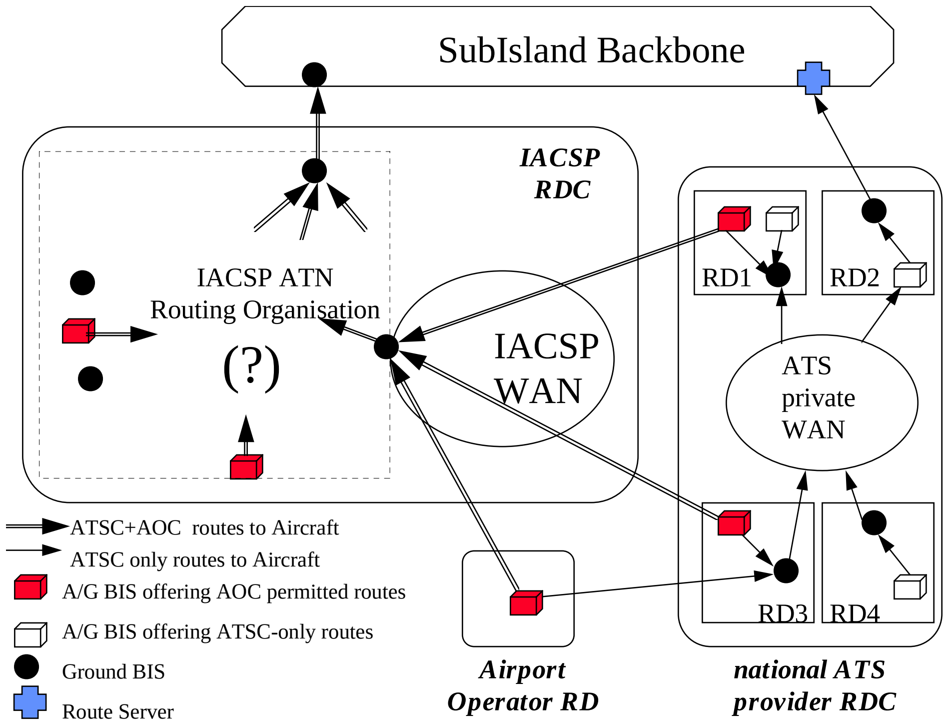


Figure 22: Routing AOC traffic within the Island

3.5 Routing Organisation for Airlines and IACSPs

IACSPs (with aircraft operators) are assumed to participate in the implementation of the ATN, at the following 3 levels:

1. At national level, depending on the national strategy of the ATSO, IACSPs may be contracted for the provision of ATN services meeting local ATS communication requirements.

2. At subregional/regional level, IACSPs may deploy an ATN infrastructure meeting airlines communication requirements, and completing potentially the regional ATS communication service by offering alternate/backup ATN routes to the aircraft.

3. At inter-regional level, IACSPs and airlines are assumed to look after the implementation and interconnection of Home Routing Domains and to consequently participate in the routing and forwarding of inter -island data traffic to/from aircraft.

It is assumed that IACSPs and airlines will implement the ATN infrastructure suitable at each level for meeting the particular requirements. The Routing Organisation for this ATN infrastructure is out of the scope of this study.

4. Routing Organisation of the Target European ATN

4.1 Introduction

The aim of this chapter is to define the target routing organisation of an ATN in the geographical area considered in the ACCESS project, and to describe a technically feasible deployment scenario meeting the identified user requirements and technical and organisational constraints.

The proposed deployment scenario and routing organisation is based on the outcomes of ACCESS WP 202 (Define geographic area & services), WP 204 (Ground/Ground Subnetworks) and WP 205 (Air/ground Subnetworks).

Outcomes of ACCESS WP 202 provide guidelines for the selection of the preferred areas for the deployments of ATN End Systems. These principles are taken into account for proposing an ATN systems deployment scenario, and deriving the physical location of ATN End Systems in the target European ATN topology.

The ground network infrastructure used to interconnect the identified deployed systems is derived from the outcomes of WP 204, and is used as a basis for the identification and localisation of the required ATN ground routers.

The air-ground network infrastructure that will be available is derived from the outcomes of WP205, and is used as a basis for the identification and localisation of the ATN Air-Ground routers.

Once proposed a geographical target ATN systems deployment scenario, this chapter defines a suitable routing organisation, identifying the Routing Domains and Routing Domain Confederations boundaries following the main principles of the overall Routing Organisation scheme presented in chapter 3.

4.2 Overview of the outcomes from WP202, 204 and 205

4.2.1 Location of ground End Systems

WP202 provides recommendations on the locations for ATN End Systems in the 2010 timeframe in the area considered in the ACCESS project. They are:

- CFMU Brussels and Brétigny,
- The main approach ACCs (namely London, Manchester, Paris-Orly, Paris-CDG, Berlin, Dusseldorf, Frankfurt, Munich, Brussels, Amsterdam, Milan, Rome, Barcelona, Madrid and Palma) for CM, CPDLC, ADS, FIS, RVR, and SIGMET services, radar data and flight plan processing, :
- The en-route ACC (namely. London, Manchester, Scottish, Dublin, Shannon, Paris, Reims, Aix-Marseille, Bordeaux, Brest, Berlin, Bremen, Dusseldorf, Frankfurt, Karlsruhe, Munich, Brussels, Amsterdam, Maastricht, Brindisi, Milan, Rome, Padua, Barcelona, Canarias, Madrid, Seville, and Lisbon ACC) for CM, CPDLC, ADS and SIGMET services, radar data and flight plan processing, and flow management.
- The main airports (namely London-Heathrow, London Gatwick, Manchester, Paris-Orly, Paris-CDG, Frankfurt am Main, Munich, Dusseldorf, Brussels, Amsterdam-Schipol, Milan, Rome, Barcelona, and Madrid airports) for CPDLC services, for AIS and MET information access, and for flight plans submission
- The Centre of operations of the main Airlines (namely London Heathrow (British Airways and Virgin), Frankfurt (Lufthansa), Paris-CDG and Paris-Orly (Air France), Amsterdam (KLM), Rome and Milan (Alitalia), Madrid and Barcelona (Iberia), Brussels (Sabena), Dublin (Aer

Lingus), Lisbon and Porto (TAP), Luxemburg (Cargolux), Hannover (Hapag Llyod), Dusseldorf (LTU) for flight plan processing and AOC traffic exchange.

- The RMCDEs for radar data exchange
- The AMHS/AFTN Switching Centres

4.2.2 Ground connectivity

WP204 discusses the choice of the ground subnetworks to be used in the implementation of the European ATN. The recommended approach, during the early stages of the ATN implementation, is to use the existing subnetwork infrastructure rather that to develop a new ATN-dedicated one. The discussion shows that, where possible, the ATN ISs should be interconnected by means of existing national ATS X.25 WANs. For international subnetwork connections among ATN routers, the interconnection (via X.75 gateways) or the merging of national ATS PSNs is recommended.

The majority of the current national and regional data networks maintained by ATSOs is based on packet switched technology and appears to be ideally suited to support the ATN traffic. Plans for interconnecting the existing X.25 networks already exists and it is likely that a number of the national network will have already been interconnected at the time of the ATN deployment, making available an international ATS X.25 network covering a large part of the area under study.

For the definition of the target ATN Routing Organisation in the area covered by the ACCESS study, we will therefore assume that:

- for intra-national interconnection of ATN routers of the national ATS Organisation, , the existing WANs and LANs will be used.

- for trans-national interconnection of ATN routers of different ATS Organisations, the international WANs formed by the interconnection or the merging of the national X.25 network will be used, where possible. In other cases, direct interconnection will have to be investigated on a case-by-case basis; the transnational ATN communication can take place via the backbone or via a direct given media (e.g. leased line) used to interconnect the ATN routers.

With regard to AOC communications, it will be assumed that IACSPs networks will be required. The ATS ground subnetworks are indeed likely to be closed to non-ATS users for non-ATSC traffic.

4.2.3 Air/Ground connectivity

The target Air/Ground ATN infrastructure is under investigation (WP205). In the ACCESS time-frame (i.e. up to 2010) it is likely that the VDL Mode 2 subnetwork be integrated within the European ATN infrastructure as the primary means for the provision of air/ground services. With respect to a secondary back-up facility (Mode S or AMSS) no conclusion has been reached at this time**.** For the definition of the target ATN Routing Organisation in the area covered by the ACCESS study, we will assume that:

- One A/G BIS (possibly backuped with one or several other A/G BISs) is implemented in each ACC. Each of these A/G BIS will be connected to the VDL Ground stations and/or Mode S GDLPs covering the related FIR. In ACCs controlling an oceanic area (namely Scottish, Brest, Madrid and Lisbon), the A/G BIS will additionally be connected to a satellite GES.

- One A/G BIS with Gatelink connectivity with parked aircraft is implemented in the airports serving as a centre of operation for important aircraft operators (i.e. London Heathrow, Frankfurt, Paris-CDG, Paris-Orly, Amsterdam, Rome, Milan, Madrid, Barcelona , Brussels, Dublin, , Lisbon, Porto, Luxemburg , Hannover, Dusseldorf) and in the other main airports processing at least 500 daily movements (i.e. Munich, Palma, London-Gatwick, Manchester, Bonn)

4.3 ATN Systems Deployment Scenario

4.3.1 General

ATN routers will be deployed on the sites where ATN applications are run. In each of these sites, the ATN routers may be intra-domain IS, ground BISs or Air/Ground BISs depending on the adopted routing organisation and on the A/G connectivity requirements.

The sites where ATN applications are run have been identified in the previous section. They are:

- en-route and approach ACC for ATS application
- airports for ATS and AOC applications
- global ATS Sites (e.g. the CFMU, meteo centres or AFTN/AMHS switching centres)

This section discusses the deployment of ATN systems in each of these sites.

4.3.2 ATN deployment in Airports

4.3.2.1 External and Internal connectivity requirements

An airport site hosts 3 different categories of ATN actors:

- Commercial Aircraft Operators (CAOs), operating various types of flights (scheduled airlines, chartered flights, air taxi services, freight, ..) from/to the airport,
- An Airport Authority, in charge of running the airport,
- a Terminal ATC Authority in charge of providing local ATC services

Every actor is assumed to implement its own ESs on its side and to have its own private connectivity requirement provided for (this level of detail is outside the scope of this study). For the purpose of this study, this private connectivity will be symbolised by a Local Area Network (although it might amount physically to no more than a point-to-point link from a single computer to an ATN IS). Several actors may share some local networking resources for the sake of limiting costs (technical and commercial details of these arrangements are outside the scope of this study). At least one ATN ES must exist in the ATS part.

The internal connectivity requirements are between:

- the Terminal ATC and the Airport Authority
- CAOs and both the Airport Authority and the Terminal ATC

With regard to the external connectivity requirements, the following is assumed:

- an Air/Ground BIS for ATN interconnection via Gatelink with the aircraft at the gate, is implemented and must be interconnected with the 3 ATN actors in the airport. This Air/Ground BIS must be connected to the SITA X.25 network and/or to other private or public WANs, for allowing AOC ATN communication between remote Airline Centre of Operations and the Aircraft at the airport. For ATSC traffic the Air/Ground BIS must be interconnected with the national ATS Organisation ATN.
- The Terminal ATC is one of the ATN site of the national ATS Organisation and is connected to the national private ATS Wide Area Network.

4.3.2.2 Proposed generic ATN deployment in Airports

Airports are the physical locations where many pre-tactical and tactical ATS and AOC applications are run. This physical concentration makes airports a first choice target for an ATN-based data communication integration effort. Each Airport site should consequently be equipped with at least two ATN routers:

- an ATS-dedicated ground BIS, managed by the Terminal Air Traffic Authority, (or by another party operating by delegation from the Civil Aviation Authority of the concerned Member State)

- a general purpose Air/Ground BIS, managed by the Airport Authority or by another party operating by delegation from the Airport Authority

This provision allows to establish an ATS-only internetworking subset, so as to alleviate responsibility and liability concerns with respect to ATS applications.

Based on the connectivity requirements previously expressed, the baseline architecture for interconnecting ATN components in an airport, is the generic model depicted on Figure 23:

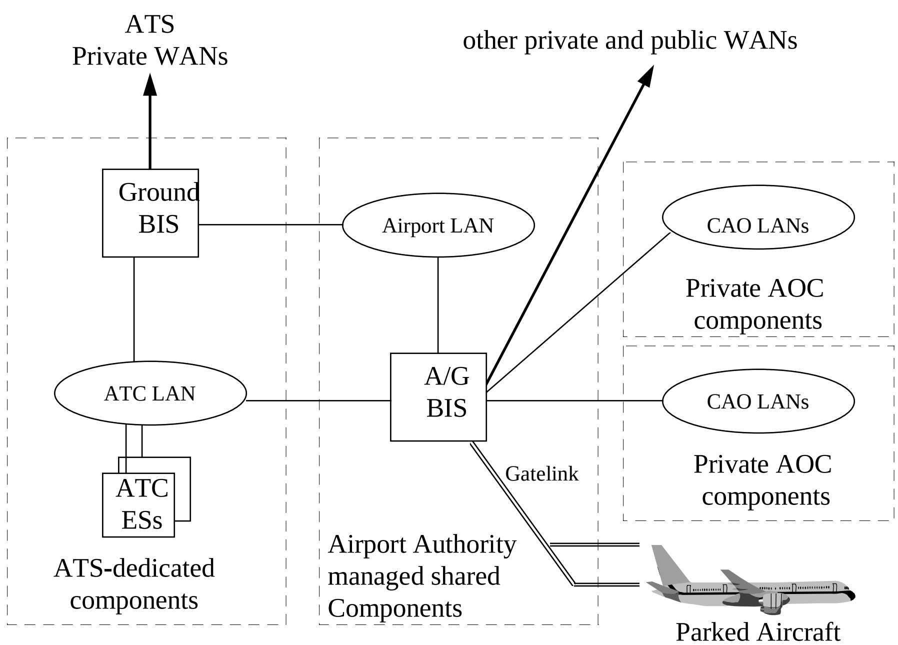


Figure 23: Baseline ATN infrastructure in airports

4.3.3 ATN deployment in ACCs

Each ACC should be equipped with at least one IS for interconnecting the ACC LAN(s) (to which the ATN ES(s) are assumed to be attached) to the national ATS WAN.

In ACCs with A/G connectivity, this IS will be an A/G BIS, thus being additionally connected to Air/Ground subnetworks. Furthermore, if one of the attached mobile subnetwork is authorised for AOC traffic, this Air/Ground BIS must be connected to an IACSP network and/or to other private or public WANs, for allowing AOC ATN communication between remote Airline Centre of Operations and the Aircraft.

In ACCs without A/G connectivity, this IS may be either an Intra-Domain IS or a ground BIS depending on whether the IS is at the boundary of a routing Domain or not.

Having assumed that all ACCs will have A/G connectivity (see section 4.2.3), the baseline architecture for an ACC is the one depicted on Figure 24. It is simpler than for an airport as there is only one main actor and one category of applications involved.

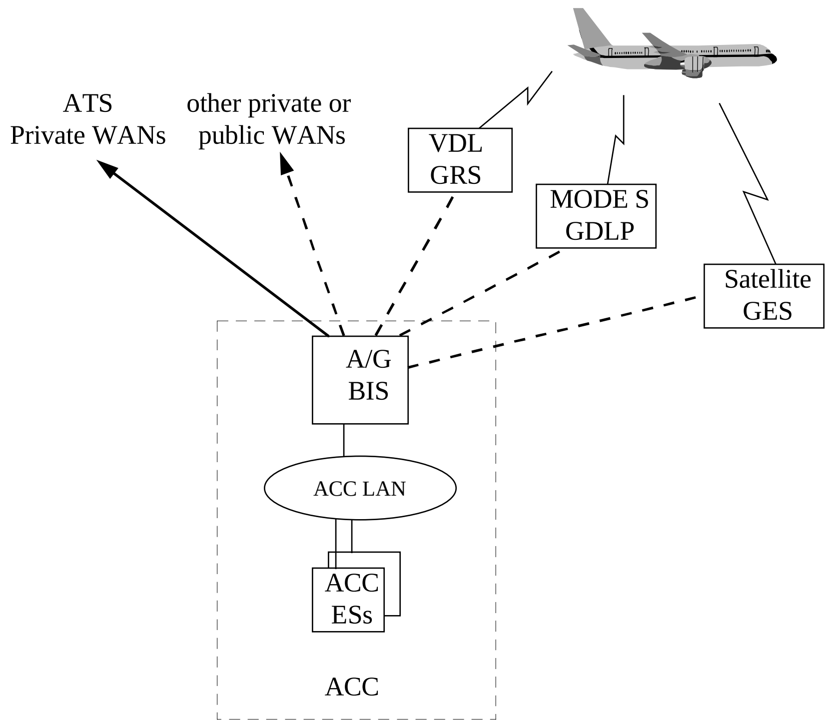


Figure 24: Baseline ATN infrastructure in ACCs

4.3.4 ATN deployment in global ATS Sites

Other ATS Sites should be equipped with at least one IS for interconnecting the LAN(s) to the national ATS WAN and possibly to other private and/or public WANs if connectivity is required with non-ATS actors.

Assuming that these ATS Sites have no A/G connectivity, the IS may be either an Intra-Domain IS or a ground BIS depending on whether the IS is at the boundary of a routing Domain or not.

4.3.5 Overall Interconnection Scenario

Within a given European country, the resulting overall interconnection scenario is the one depicted on Figure 25:

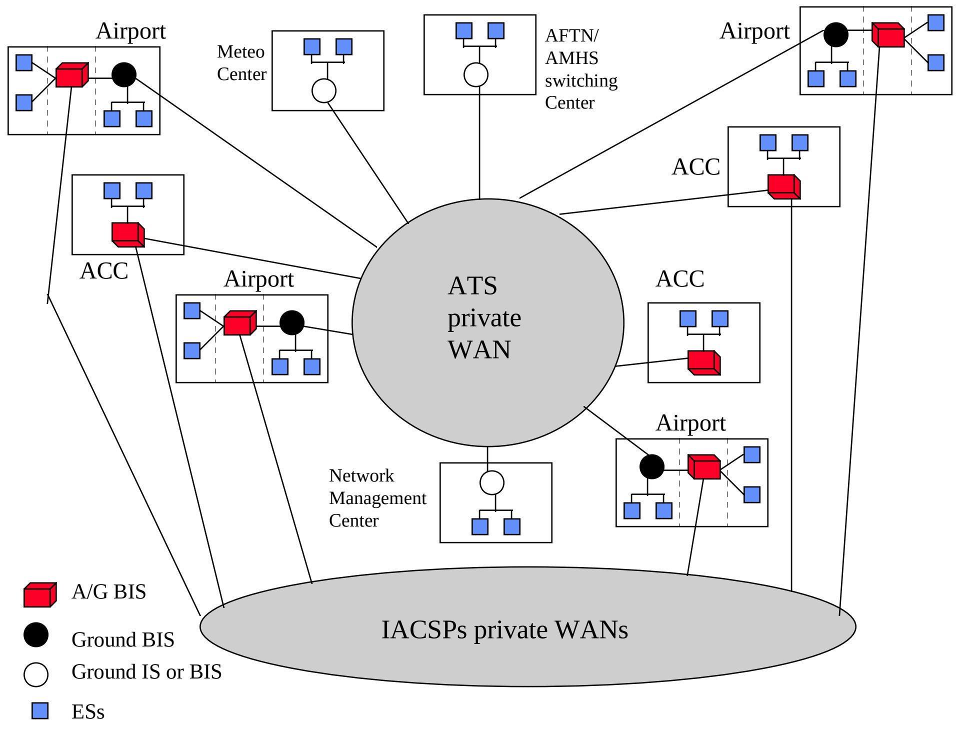


Figure 25: Generic National ATN infrastructure deployment scenario

4.4 Proposed Routing Organisation for the target ATN in the area covered by the Access Project

For the routing organisation of the target ATN in the area covered by the ACCESS study, the general principles emerging from the discussions in chapter 3 are proposed to be retained.

With regard to the overall architecture, the European ATN will be assumed to consists of:

- one global European "Region" ATN Island.
- An independent separate European "Homes" RDC formed by the Airlines and their service providers and responsible for the inter-Island transit of traffic to/from aircraft, originated from or destined to or crossing Europe. This European Homes RDC will consist of the set of the Home Routing Domains of the different European Airlines and will be the sink of the routing information pertaining to the European airlines aircraft flying everywhere in the world. This RDC will not encompass any Routing Domain with A/G connectivity

As concerns the interconnection of the European ATN with non European Islands, the following assumptions are made:

- The European "Region" ATN Island will be directly interconnected with non-European Islands. These interconnections will primarily be used for the exchange of ground-ground ATSC traffic. The European "Region" ATN Island will be interconnected with the European "Homes" RDC. Interconnection between Islands will be established between backbones.
- The European "Homes" RDC will be interconnected with the European "Region" ATN Island and with other Islands on other continents. These interconnections will primarily be used for the exchange of ground/ground and air/ground AOC traffic.

This overall architecture is represented on Figure 26.

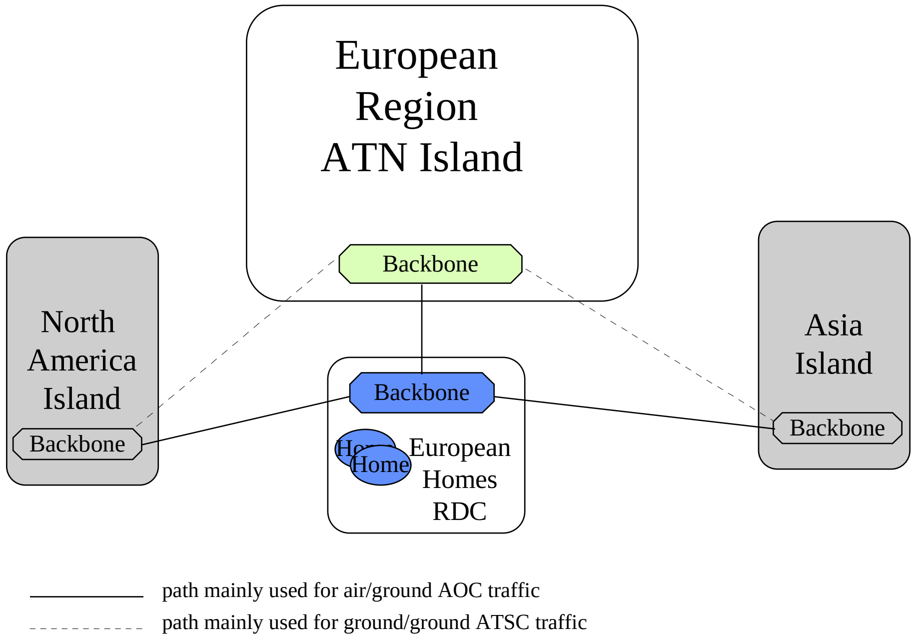


Figure 26: Proposed Overall architecture of the target European ATN

For the target ATN, the European Region ATN Island will be assumed to consist of one subregion only (the western subregion) and Italy will be assumed to be part of this subregion. As there is one single subregion, there is no need of a top level backbone. The western subregion backbone, will be assumed to be the top level backbone.

Within the European Region ATN Island, each national ATS Organisation is assumed to form its own RDC. Each national ATS RDC may consists of one or several Routing Domains.

The backbone will consist of a route server (possibly backuped with other route servers, the number of backup systems being to be determined) and of a number of backbone routers. The Route Server will be provided and managed by Eurocontrol. On the other hand, the control, ownership and sharing of backbone BISs will depend on national ATN implementation strategies. It is assumed that:

- Germany, France and Italy will operate their own backbone BIS
- Spain and Portugal will share a backbone BIS administrated by Spain
- UK and Ireland will share a backbone BIS administrated by UK
- The Benelux countries will share a backbone BIS administrated by Eurocontrol.

Each national ATS RDC having access to the pan-European ATS X.25 network will interconnect one of its Routing Domains to one or two Route Servers of the backbone.

The states having no access to the pan-European ATS X.25 network will interconnect one of their routing domains directly to a backbone router using a media to be determined (e.g. leased line).

Eurocontrol will be assumed to be an RDC connected to the backbone in the same way as the states having access to the pan-European ATS X.25 WAN

IACSPs providing AOC traffic transit service between the backbone and their own A/G BISs and/or the A/G BISs of other organisations (Airport operators, ATS Organisations) are each assumed to form an RDC. On one side, the IACSP RDCs will be directly attached to the backbone; one of their BIS will be interconnected with a backbone BIS. On the other side, IACSPs BISs will be interconnected with the Airport Operators and ATS Organisations A/G BISs that accept AOC traffic. The internal organisation of IACSP RDCs is out of the scope of this study.

With all these assumptions the proposed topology is the one illustrated by Figure 27.

Note: As a working hypothesis used to enhance this picture, Ireland has been assumed to have no access to the pan-European X.25 WAN and is consequently not connected to the backbone Route Server but to a backbone BIS

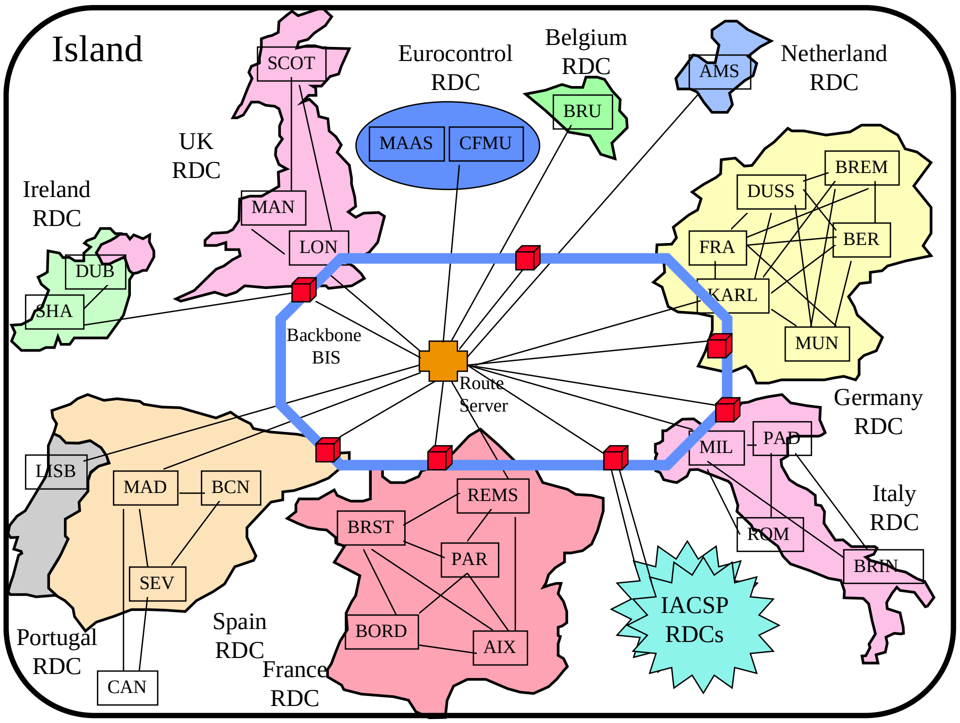


Figure 27: Proposed Routing Organisation for the target European ATN

With respect to intra-national routing organisation, in the absence of national routing organisation plans, the following generic scenario will be assumed:

1. national ATS Organisation

   - an ATS Routing Domain will be created in each national ATS RDC around each national ATC Centre. It will encompass the ATC Centre, and all airports and other possible ATS sites in the related FIR. Within a Routing Domain, all BISs must be directly interconnected with each other. The A/G BIS of the ACC, the ATS ground BIS of each airport in the Routing Domain, and the possible BISs in other ATS centres of the Routing Domain, will therefore be directly interconnected.

   - It is assumed that the national RDs will be directly interconnected with each other national RDs. This will be achieved by interconnecting the A/G BIS of each ACC with each A/G BIS of other ACCs.

   - The A/G BISs that accept AOC traffic will be interconnected with a BIS of an IACSP

2. national Airport Operator

- In the main airport, the airport operator will form a Routing Domain consisting of the A/G BIS offering Gatelink access to the aircraft, of its possible ESs, and of possible ESs of other local non-ATM organisations having a requirement for ATN communication (e.g. Access Control Authorities (Police, Custom, Immigration, Tax & Duties,..) Commercial Service Providers (car rental services, Gift Shops...)).

- The Airport Operators A/G BIS will be interconnected with the local ground BIS of the national ATS Organisation and with a BIS of an IACSP. The national ATS Organisation will accept the transit of ATSC traffic to/from the RD. The IACSP will accept the transit of all types of traffic to/from the Airport Operator.

3. national Military organisations

   - It is assumed that the military organisation will access the European ATN by direct interconnection with their national ATS Organisation. Secure gateways should be used to provide interoperability between ATN End-Systems and military operated End Systems. It is assumed that the military End Systems are located on a secure network operated and managed by the military for operational purposes. The ATN side of the Gateway should act as an ATN End System of the national ATSO, located within the routing organisation of the national ATSO and as such should appear in the national ATSO ATN addressing plan. The ATSO should be responsible for management of the ATN side. The military organisation should be responsible for the management of the non-ATN side and of the security implications.

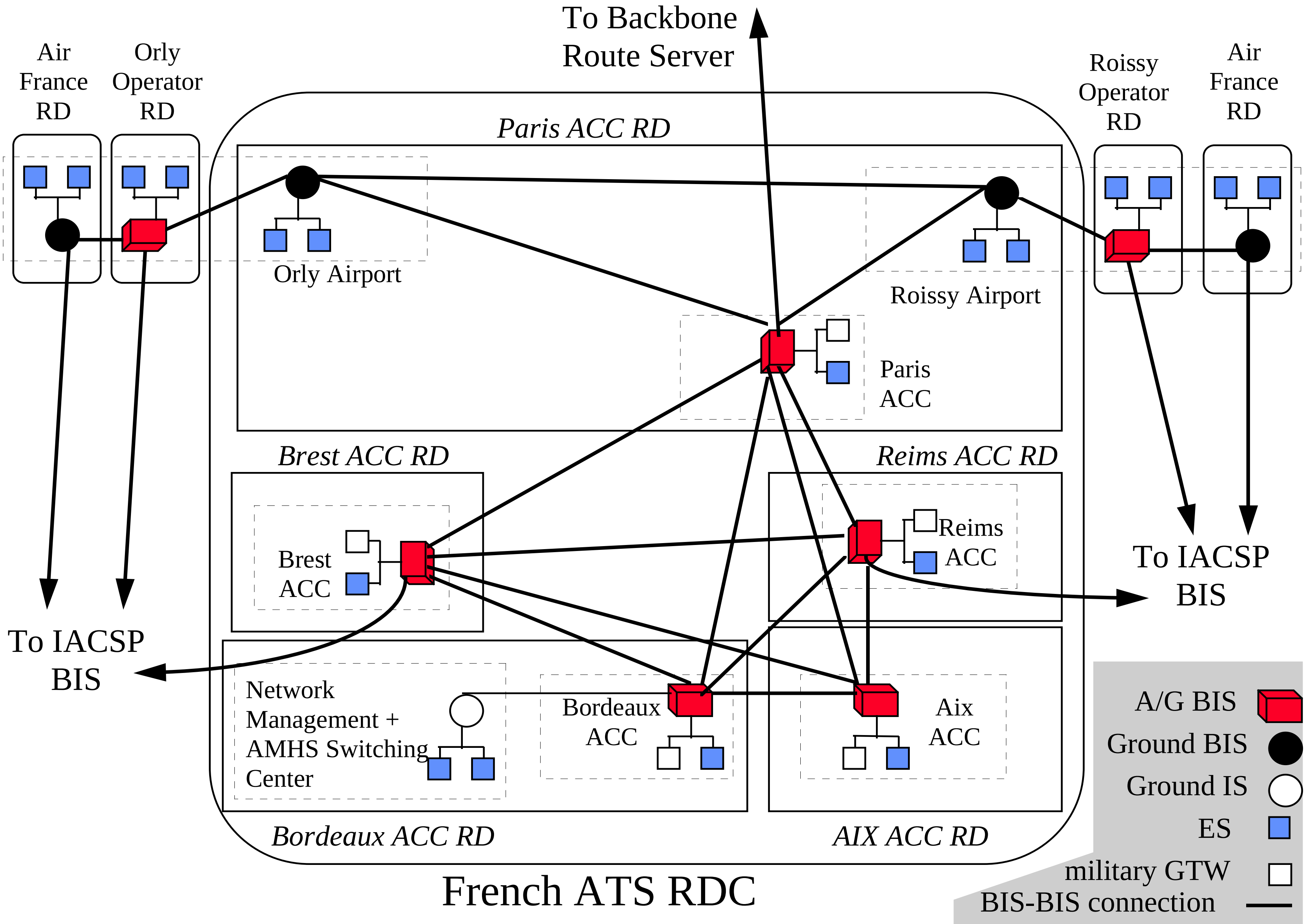
4. national Meteorological Service Providers

   - It is assumed that the Meteorological organisations will access the European ATN by direct interconnection with their national ATSO. The meteorological End Systems should act as ATN End Systems of the national ATSO, located within the routing organisation of the national ATSO and as such should appear in the national ATSO ATN addressing plan.

5. Local Aircraft Operators

   - In Airports serving as their centre of operation, the airlines are assumed to implement ESs and form a Routing Domain. They may implement a Ground BIS or prefer to rely on the ATN service provided by an IACSP. Airlines ground Routing Domains will be interconnected with the local Airport Operator and with the IACSP.

As an example, the next figure is an application of this generic intra-national routing organisation scenario on the French case.


To Backbone Route Server
Air France RD
Orly Operator RD
Paris ACC RD
Roissy Operator RD
Air France RD
Orly Airport
Roissy Airport
Paris ACC
Brest ACC RD
Reims ACC RD
Brest ACC
Reims ACC
To IACSP BIS
To IACSP BIS
Network Management + AMHS Switching Center
Bordeaux ACC
Aix ACC
Bordeaux ACC RD
AIX ACC RD
French ATS RDC
A/G BIS
Ground BIS
Ground IS
ES
military GTW
BIS-BIS connection

5. Conclusion

The Routing Organisation of the target European architecture is proposed in section 4.4 of this document, and the conclusion of this document will not be used to summarise the result of this work package but to highlight some further essential points that may have been neglected in the discussion.

First, ACCESS is not in a position to answer all the questions related to the optimal organisation of the future European ATN. The ACCESS proposal is based on a number of architectural assumptions which would then need to be refined and validated. The endorsement of a specific routing organisation necessitates additional complex studies because a network architecture is made of a number of various parameters such as protocols tuning, subnetworks performance, topology choices, routing strategy, etc. In order to answer these questions, and because so many options are possible, it is highly recommended to complement the analysis results by network modelling and simulation studies. Simulations will allow to validate the assumptions, support the actual design decisions by quantitative figures and provide the basis for a comparative assessment of the proposed solution with alternative architectural options.

Among the many unknowns considered in this document, the question of the intra-national routing organisation has certainly be the one answered with the biggest uncertainty. A generic model for the intra-national routing organisation was proposed. However, depending on national constraints (e.g. number of ACCs and Airports, current networking environment, etc...) this model may not be very suitable and may require refinements.

Lastly, the design decisions on the ATN routing architecture are primarily driven in this report by the criteria to minimise the route management load in the ATN routers. The rational for this criteria is that the ATN can only work if the ATN routers are in a position to absorb and process the routing traffic in real time and converge quickly to valid routing decisions. The route update rate to be supported by the ATN routers is hence perceived as one of the main constraining factors. There are however other reasonable design criteria (e.g. the cost) which, when considered as the preferred design criteria, may lead to different « optimum » routing architectures. It is therefore recommended that alternative proposals for the European ATN routing organisation be developed following a different approach and be used for a comparative assessment of architectural options.

Appendix A - Acronyms

AAC	Aeronautical Administrative Communications
ACARS	Aircraft Communications Addressing and Reporting System
ACC	Area Control Centre
AFTN	Aeronautical Fixed Telecommunication Network
AIS	Aeronautical Information Service
AMHS	ATS Message Handling System
AOC	Aeronautical Operational Communications
APC	Aeronautical Passenger Communications
ATC	Air Traffic Control Centre
ATM	Air Traffic Management
ATN	Aeronautical Telecommunication Network
ATS	Air Traffic Services
ATSC	Air Traffic Services Communications
ATSO	Air Traffic Services Organisation
BIS	Boundary Intermediate System
CAA	Civil Aviation Authority
CAO	Commercial Aircraft Operator
CFMU	Central Flow Management Unit
CLNP	Connection-Less Network Protocol
EATCHIP	European Air Traffic Control Harmonisation and Integration Programme
EATMS	European Air Traffic Management System
ECAC	European Civil Aviation Conference
ENOC	European Network Operating Concept
ES	End System
GDLP	Ground Data Link Processor
GES	Ground Earth Station
IACSP	International Aeronautical Communications Service Provider
ICAO	International Civil Aviation Organisation
IDRP	Inter Domain Routing Protocol
IS	Intermediate System
METAR	Meteorological Actual Report
NSAP	Network Service Access Point
OSI	Open System Interconnection
PSN	Packet Switched Network
QoS	Quality of Service
RD	Routing Domain
RDC	Routing Domain Confederation

SARPs	Standard And Recommended Practices
SIGMET	Significant Meteorological Information
SM	System Management
TAF	Terminal Area Forecast
VDL	VHF Digital Link
WAN	Wide Area Network