CEC TEN-T ATM Task UK/96/94

ACCESS

ATN Compliant Communications

European Strategy Study

Interim Deliverable 1 (Network Architecture)

Proposed Network Architecture of the European ATN

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Issue 2.0	20/05/98	Correction of editorial errors and modifications to take into account NATS & DFS comments
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EXECUTIVE SUMMARY

This document is the ACCESS Interim Deliverable 1 and constitutes the synthesis report of all documents produced in the Network Architecture sub-phase of ACCESS phase 2 - Part 1.

The objective of the ACCESS phase 2 - part 1 - Network Architecture sub-phase was to define the architecture of the Target European ATN of year 2010 in a geographical area consisting of the following countries: UK, Ireland, Benelux, Germany, France, Italy, Spain and Portugal. This geographical area is further named the « ACCESS area ».

The subphase started in April 1997 and was closed in April 1998. The work performed started with a review of the current communications infrastructure and progressed by focusing on the following aspects of the European ATN implementation:

- Identification of the ATS air/ground and ground data link services which will be operated in the European ATN of 2010 and definition of the location of the ATN End Systems that will support these services.
- Definition of the routing organisation of the European ATN with a proposal for the division of the European ATN into ATN Islands, Routing Domains and Routing Domain Confederations, and for the deployment and interconnection of ATN routers.
- Identification of the ground subnetworks to be used for interconnection of the ATN systems (routers and End Systems).
- Selection of air/ground subnetwork(s) that are to be deployed in the Region to provide primary and/or back-up air/ground ATN datalink services.
- Definition of the naming and addressing plan of the European ATN.
- Consideration for the performance analysis and dimensioning of the European ATN and definition of a framework for analysing, predicting, and planning the quantitative parameters of the network.

The review of the current communication infrastructure showed that there is no overall communications framework within which states are evolving their national networks and that no entity/user group is likely or will agree on a policy to implement ATN on its own. States will probably continue to evolve their infrastructure on an “as needed” ad-hoc basis unless a European wide strategic policy to implement the ATN is decided.

Nevertheless, the emerging tendency observed in some ACCESS countries in terms of implementation of ATN applications is as follows:

- the ATN CPDLC application will be implemented everywhere in the ACCESS area.
- the ATN ADS application will be implemented in the NAT ATC centres of the ACCESS area.
- The ATN FIS application will certainly be made available in the whole ACCESS area as centralised ground FIS servers installed by type of data and per country.
- The ATN AMHS application will be implemented in the ACCESS area to support the exchanges of data currently supported by AFTN/CIDIN (CFMU data, meteorological data and aeronautical information data).

ATN End Systems will therefore be deployed where users and providers of the selected ground and air/ground services are located, i.e. CFMU facilities, national AFTN Centres, AIS offices, MET offices, ATSO Flight Plan Submission Offices, ACCs, Flight Pan Processing Systems and Controller Positions.

The endorsement of a specific ATN routing organisation appeared to be a difficult decision surrounded by controversy. During this initial phase of the ACCESS project, it was not possible to answer all the questions related to the subject; the assessment of the appropriateness of a network

architecture is indeed dependent on a number of various parameters such as protocols tuning, subnetwork performance, topological choices, routing strategy, etc.; and the choice of a solution will also be governed by political considerations surrounding the implementation strategy of the European ATN.

ACCESS developed two different proposals (Options 1 and 2) for the European ATN routing organisation. The two proposed network topologies converge on a number of points, but also diverge on other aspects, the main of which being the architecture of the European ATN Backbone: option 1 proposes a distributed Backbone architecture relying on the use of a *route server* distributing air/ground and ground/ground routing information to the Backbone routers; and possibly distributing ground/ground routing information to off-backbone routers; option 2 proposes a centralised architecture where the European ATN Backbone would consist of a single Backbone router[1]. A comparative assessment of the different architectural options, is programmed, in the next ACCESS phase (from May to August 1998), in order to reach a consensus, resulting in a concrete proposal for the routing framework of the ATN network in Europe.

However, it must be recognised that the final endorsement of a specific routing organisation will require additional complex studies. This is because the actual ACCESS proposal will remain based on architectural assumptions that will need to be refined and validated. ACCESS recommends therefore to complement the analysis result by network modelling and simulation studies. As a starting basis, ACCESS set up a framework for analysing, predicting and planning the quantitative parameters of the network. The framework consists of a series of analytic and simulation activities to be carried out.

The use of existing national Packet Switched Networks (PSNs (e.g. RENAR, CAPSIN, RAPNET, ...)) is recommended for the interconnection of ATN routers within countries. The current (or planned) X.75-based PSNs interconnection is recommended to be used where possible for international subnetwork connections among ATN routers. The interconnection of PSNs by means of ATN routers only, is rejected as the primary approach for building up a generalised international networking service in the ACCESS region and timeframe, because this would require either the migration of all existing ATS applications towards ATN End Systems or the use of undesirable gateways..

With regard to the air/ground subnetwork(s) that are to be deployed in the European Region and in the ACCESS time-frame (i.e. up to 2010), it is concluded 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 air/ground subnetwork service ACCESS was not in a position to conclude the preferred technology and recommends that a further study is initiated to identify the optimal solution for a secondary air/ground subnetwork taking into account current European plans for the deployment of Mode S, the stability and maturity of the VDL Mode 4 SARPs, the availability and costs of the AMSS subnetwork and the plans regarding the emerging LEO/MEO satellite based systems. This conclusion is consistent with the recommendations of the EATCHIP COM-Team.

The next ACCESS Part 1 subphase (May - August 1998) will progress various topics related to the Target European ATN of year 2010. A third subphase (August - November 1998) will work on a transition plan from the current telecommunication infrastructure towards this Target ATN and will result in a proposal for an initial ATN Network in the ACCESS Region in year 2005.

The ACCESS Project is still planned to be completed by the end of 1998.

[1]Option 2 of the Routing Organisation is still under development at the time the present report is published.

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1. Introduction

1.1 Genesis of ACCESS

As part of the new CNS/ATM concept, the Aeronautical Telecommunication Network (ATN) has a strategic role to play in providing the internetworking connectivity required for supporting the ATS and AOC data exchanges between the various end systems involved. This connectivity is to be provided across the evolving variety of data networking technologies of the deployed subnetworks. This is required for supporting aeronautical data exchanges between ground based end systems, and between ground based end systems and aircraft based end systems.

With the level of internetworking connectivity that the ATN will provide, it will become much easier to introduce new end systems. This will facilitate the evolution of operations from voice based data exchanges to data link based data exchanges with the resulting improvements in operational efficiency.

In 1997, the ICAO Air Navigation Commission approved the publication of the ATN SARPs in Annex 10. In parallel large projects have been initiated for the development of ground and airborne pre-operational ATN systems (ProATN, EOLIA), and operational ATN software (ATNSI/RRI) as well as for ATN Conformance Tests Suites (RAF and ATNSI/CTS now grouped into the CAERAF Project). These projects are expected to result in the provision of operational and pre-operational CNS/ATM-1 software and/or systems from 98-99 onwards.

A specific Task Force has been created under the aegis of the Eurocontrol EATCHIP programme to prepare the implementation of ATN in Europe, and work has started on the definition of implementation plans for the deployment of the initial European ATN network within all administrations, organisations, airlines and industries involved in the ATN and aiming at using it in the coming years.

This is to complement and coordinate all this work that NATS, DFS and STNA decided to launch the 'ATN Compliant Communications European Strategy Study' (ACCESS). The ACCESS Project is a European Commission co-funded project formally titled “ATN Implementation Feasibility Studies”. It is ATM Task UK/96/94 under the Trans-European Networks - Transport (TEN-T) programme, managed by DG VII within the Commission.

1.2 Description of the ACCESS project

1.2.1 General Objectives

ACCESS aims at defining the initial architecture of the ATN in the European Core Area (i.e. selection of the initial applications, definitions of the initial network topology, definition of the routing organisation and of the addressing plan, etc ..), and will propose initial solutions as regards the security, safety/certification, network management, institutional, and other issues as well as a transition plan from the current European aeronautical telecommunications infrastructure towards an European ATN network.

A second part of the ACCESS project addresses the ATSMHS Interoperability/Validation testing.

1.2.2 Project organisation

ACCESS has been broken down into three successive phases:

- Phase 1 - Project Scoping (January-March 1997)
- Phase 2 - Study Tasks and Trials (April 1997 - October 1998)
- Phase 3 - Final Report Preparation (November-December 1998)

Phase 1, i.e. the Project Scoping phase, ended as planned in March 1997. This phase served to define the scope and aims of the project, defining in detail the work packages to be undertaken and allocating responsibility for their completion. The phase resulted in the production of the project plan, the

Quality plan, the Consortium agreement, and a synthesis report which describes the outcomes of former ATN related European studies and projects.

Phase 2 (the report development phase) is split into two independent parts :

- Part 1 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. It addresses topics related to both network and application infrastructure.
- Part 2 covers the AMHS Interoperability/Validation testing.

Phase 3 is the final phase and will produce the final report and present the project results to the CEC.

The present document is only related to Phase 2, Part 1 of the project, i.e. ATN implementation.

1.3 Description of ACCESS Part 1: ATN Implementation

1.3.1 Time frame and geographical area considered by ACCESS

The time frame considered in the ACCESS project is 2000-2010. The initial ACCESS ATN is assumed to be deployed during the initial period 2000-2005. This initial ACCESS ATN must however be considered in the time as the first brick to a global and mature target ACCESS ATN that would meet most of ground-ground and air-ground ATN communication requirements currently identified. The target ACCESS 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. These two steps are identified in this document as the **Initial ACCESS ATN** and the **Target ACCESS ATN.**

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

As a practical work approach, it has been decided within the project to focus first on the Target ACCESS ATN and to derive then the Initial ACCESS ATN in the scope of the Transition Planning Work Package (WP240).

The geographical area considered in ACCESS consists of the following countries as illustrated in Figure 1: 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.

Because of the limited amount of resources and time available to perform the project, the choice of a larger geographical area, such as the entire ECAC area, would have compromised the overall quality of the results. However, it must be noted that the recommendations resulting from the ACCESS study will be scaleable, i.e. can be extended to the rest of Europe outside the defined ACCESS geographical area.

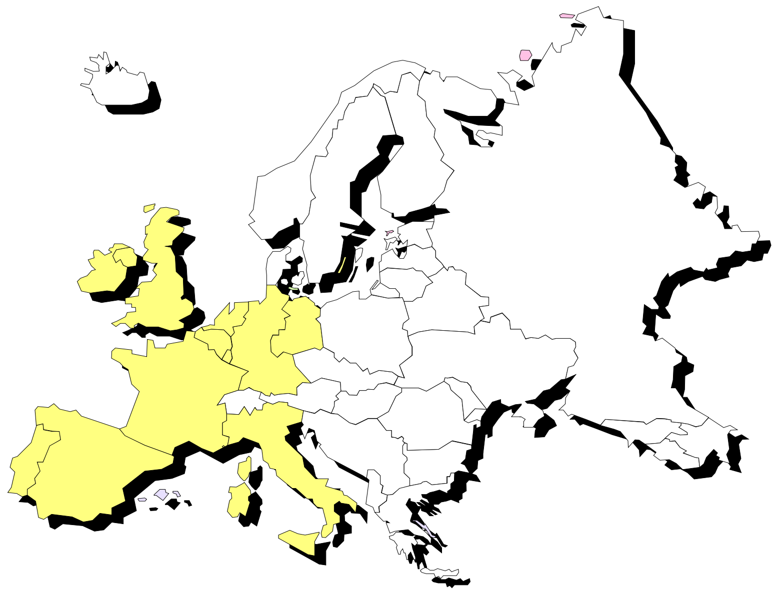

Figure 1: The geographical area considered by the ACCESS project

1.3.2 Work Breakdown Structure

The ACCESS phase 2 - Part 1 is divided into three sequential sub-parts:

- The first sub-phase (April 1997 - April 1998) defines the proposed **Network Architecture**, i.e. the main elements of the Target ACCESS ATN. It results in Interim Deliverable 1.
- The second sub-phase (March - July 1998) will propose solutions for **Network Implementation Issues** related to the Target ACCESS ATN but not studied or not completed during the first sub-phase (e.g. security, certification, etc.). It will result in Interim Deliverable 2.
- The final sub-phase (August - October 1998) will propose a **Transition Plan** from the existing network infrastructure to the Target ACCESS ATN infrastructure, and will define the Initial ACCESS ATN. It will result in Interim Deliverable 3.

This document is the ACCESS Interim Deliverable 1 and constitutes therefore the synthesis report of all documents produced in the Network Architecture sub-phase of ACCESS phase 2 - Part 1.

1.3.3 Relationship with the EATCHIP ATN Implementation Task Force

At the beginning of 1997, the EATCHIP/COMTeam endorsed the proposal to create an ATN Implementation Task Force (ATNI-TF) which will report to the RASA Subgroup (RASA : Requirements Analysis, Strategy and Architecture).

The main objective of the Task Force is to produce an Implementation Plan to be endorsed by users and implementors of the ATN in Europe. This Task Force met for the first time in May 97.

During the creation of this Task Force within the EATCHIP/COMT/RASA subgroup, the existence of the ACCESS project was noted and the need for a consistent approach between the work of the two structures was recognised.

Both parties have realised that they would benefit from a close co-operation :

- the ACCESS project will make assumptions and proposals dealing with specific national issues, however the Consortium does not have any authority to decide upon issues such as national systems implementation; consequently, the ACCESS project needs a formal ATC forum in which its outcomes could be presented and approved,

- the ATNI-TF will be a European ATC forum dealing with ATN implementation issues in Europe. In order to be productive, such a Task Force will need to form working structures which will tackle specific issues related to ATN Implementation in Europe. The ACCESS project can be one of these working structures if it is recognised as such within the Task Force (which is the case).

This close co-operation is now effective :

- the progress of the ACCESS project is regularly presented to the EATCHIP ATNI-TF,
- ACCESS reports (in particular the Interim Deliverables) are distributed to the Task Force members,
- the ATNI-TF work plan explicitly considers ACCESS results as an input to its *Design & Implementation Work Package*,
- the NATS, DFS and STNA people in charge of the ACCESS project are also the NATS, DFS and STNA representatives to the EATCHIP ATNI-TF.

Similarly, the ICAO Regional Group responsible for the Aeronautical Fixed Service telecommunications in Europe, i.e. EUR-AFS, decided to create a specific subgroup in charge of ATN Implementation. The activities of this group are also co-ordinated with both the EATCHIP ATN Implementation Task Force and the ACCESS Project.

2. Proposed Target ATN Architecture in the ACCESS Geographical Area

2.1 General

This document is the ACCESS Interim Deliverable 1. It constitutes the synthesis report of the Network Architecture sub-phase of ACCESS phase 2 - Part 1.

The objective of the ACCESS phase 2 - part 1 - Network Architecture sub-phase was to define the architecture of the Target European ATN of year 2010 in the geographical area covered by the ACCESS project

The Network Architecture subphase consisted of the following Work Packages:

Work Package Number	Work Package Title	Work Package resulting report	Summary of the resulting report is provided in section:
WP201	Review of Current Communications Infrastructure	[A201]	2.2
WP202	Definition of Area of Study and Services to be supported	[A202]	2.3
WP203	Definition of Routing Architecture - Option 1	[A203]	2.4.2.2
WP203A	Definition of Routing Architecture - Option 2	[A203A]	2.4.2.3
WP204	Choice of Ground Sub-networks	[A204]	2.4.3
WP205	Choice of Air/Ground Sub-networks	[A205]	2.4.4
WP206	Definition of Addressing Plan	[A206]	2.5
WP207	Performance Analysis and Dimensioning	[A207]	2.6

The following sections summarise the main results of each of these work packages.

2.2 Current Communication Infrastructure (WP201)

2.2.1 Introduction

The objective of ACCESS Work Package 201 was to provide a description of the current National data communications networks implemented in the States, the existing regional and international data communications networks and the current main applications that are implemented in the European region (CFMU, AIS, OPMET, OLDI/SYSCO and radar data transmission). The following sections provide a short summary of the outcomes of this Work Package.

2.2.2 National Packet Switched Networks

From an environment of dedicated point to point links for specific applications between ATM sites, most European States have recognised the cost/efficiency and performance gains to be realised through the deployment of a common aeronautical packet switched network (typically X.25 based) capable of supporting the data communications needs of existing ATM related applications including radar data, flight plan related data, AIS data, met data etc. This resulted in the deployment of CAPSIN in UK, RENAR in France, RAPNET in Germany and Benelux, REDAN in Spain, etc...

These national packet switched networks are now extensively used for operational ATC purposes and there is even an important activity towards their interconnection typically using X.75 technology.

The network management of the national packet switched networks is typically a centralised function in each State and is based upon proprietary systems.

It has been recognised that although national networks are under the management of the ATS provider there is no possibility to control the underlying trunk network that is typically provided by a public telecommunications provider (e.g. France Telecom in France as regards the RENAR network). This is why States have recognised the need to provide back up networks in the case of failure of underlying trunks.

With the ever increasing demands placed on ground/ground national packet switched networks States are evaluating the introduction of new technologies, e.g. Frame Relay, Asynchronous Transfer Mode.

At least one State is considering the provision of the packet switched service through a third party service provider.

Some States are planning to or have deployed TCP/IP solutions to support their internal communications requirements.

2.2.3 Regional and international data communications networks

2.2.3.1 RAPNET

RAPNET is a packet switched data network with nodes at sites in Germany, the Netherlands, Belgium and Luxembourg. The network is “closed” in the sense that protocols used between pairs of nodes are proprietary and specific to the commercial products used. The connections to other networks are implemented with X75.

2.2.3.2 AFTN/CIDIN

The international AFTN is still used extensively. In general, connections between AFTN centres are based on low speed asynchronous links. In the European region however, the transmission of AFTN messages is mostly done via CIDIN and there is a general trend to migrate remaining asynchronous links over CIDIN links.

The AFTN network has been “fine tuned” to the needs of aeronautical applications during the long period of its operation. The introduction of new applications and significant new traffic flows lead to major reconfigurations. The European part of the international AFTN is also highly subject to influences from outside the European Region.

The network has a high level of availability in spite of the fact that each international switching centre is operated by a different administration and no overall network management function is in place (There are currently some activities being undertaken to introduce centralised network management functions). Robustness is achieved, for example, by automatic rerouting algorithms in CIDIN. However unacceptable levels of failures still do exist and CFMU statistics show, for example, that some destinations on the periphery of the network are not reachable for significant periods.

2.2.3.3 Central Flow Management Unit (CFMU) Network

The only international aeronautical network available when CFMU networking was planned was the AFTN/CIDIN. But, at that time, the existing AFTN/CIDIN was not able to satisfy all CFMU requirements and needed to be supplemented. The SITA network could not be considered for policy reasons except for connections to Aircraft Operators. It was finally decided to base the CFMU network on British Telecom (BT) services/infrastructures: Network services provided and managed by BT are used as a virtual backbone for CFMU communications. In addition, CFMU is subscribing Packet switching (CPS) and frame relay (CFRS) services from BT.

This situation illustrates the problems of using the offerings of a service provider when high availability is a requirement: long, multiple leased lines to access nodes may be necessary. But these lines are dedicated to only one type of traffic.

High availability is also a requirement at the (approximately) 60 Flow Management Positions. But this application makes only small use of the dedicated 9,600 bps lines accessing the BT network.

Due to the large volume of message traffic generated and processed by the CFMU (comparable with that handled by a major AFTN/CIDIN switch), channelling the traffic through one or even a small number of switches would cause major bottlenecks. For this reason, the virtual network provided by BT is used to distribute message traffic across 6 AFTN/CIDIN nodes and 2 SITA nodes using X.25 services. Note that also here leased lines are necessary to connect BT nodes with AFTN/CIDIN and SITA nodes.

With this method of accessing the AFTN/CIDIN, a significant overlay of the EUR AFTN/CIDIN has been implemented. This is justified by the large fraction of AFTN/CIDIN traffic which is destined for / originates in the CFMU.

2.2.4 Applications

2.2.4.1 OLDI

ACCs are typically connected with most adjacent ACCs through OLDI links, most of them following the OLDI standard (X.25;ST-ICD). OLDI connections between States are either based upon dedicated leased lines or achieved through RAPNET. Some States use their OLDI links to support the transmission of AFTN and OPMET data.

2.2.4.2 Aeronautical Information Service

The international exchange of AIS data (e.g. NOTAMS) is typically achieved through the use of AFTN/CIDIN. States typically implement their own AIS database for the reception, storage and retrieval of NOTAMS. National retrieval of NOTAM information is typically achieved through the national packet switching network.

2.2.4.3 OPMET

The international exchange of OPMET data is typically achieved through the use of AFTN/CIDIN.

2.2.4.4 Radar Data

The exchange of radar data is typically supported through the use of dedicated leased lines though there is a trend towards the use of the national aeronautical packet switched networks. Some National aeronautical packet switched networks have functionality incorporated to support the broadcast of data (e.g. to support the provision of radar data).

A number of States have deployed RMCDEs to facilitate the exchange of radar data between ACCs. RMCDEs are typically connected to radar sensors via dedicated leased lines.

Some States have adopted the ASTERIX standard for the exchange of radar data. Whilst some States employ proprietary formats with the intent of migrating to the ASTERIX standard.

2.2.5 Conclusions

On a national basis States have recognised the advantages to be gained through the migration of their application specific networks to a common aeronautical packet switched network and have, or are taking steps, to do so.

However, on a European wide basis there is no overall communications framework within which states are evolving their national networks.

National networks are being interconnected on an ad-hoc basis utilising X.75 technology without any consideration of migration towards the ATN.

No entity/user group is likely or will agree on a policy to implement ATN on its own. States will probably continue to evolve their infrastructure on an “as needed” ad-hoc basis unless a European wide strategic policy to implement the ATN is decided.

2.3 Proposed D/L Services (WP202)

2.3.1 Introduction

The objectives of the ACCESS Work Package 202 were to review the European CNS/ATM operational requirements for ATC data link services and to propose a selection of such services for the target ACCESS ATN of year 2010. The following sections summarise the outcomes of this Work Package. They provide a status of the currently foreseen D/L services in the ACCESS Region as well as some guidances upon the possible locations of End Systems.

2.3.2 Inventory of the Air-Ground and Ground Data Link Services

Air/ground data link services are defined from the specification of ATC operational requirements independently of the technology used to support the communications. In Europe, the EATCHIP ODIAC SG has defined a baseline reference set of data link services proposed to be implemented in the ECAC area. The ODIAC SG and several European studies (EATCHIP COM.ET2.ST15, COPICAT) categorise the air/ground data link services into three main types of services:

- services based on exchange of messages between the aircrew and the controller. These services provide them the capability to exchange via data link controlling and informative ATC messages and to handle the transfer of voice and data link communications. They allow to automate some systematic exchanges such as the retrieval of the departure clearance or the request for pushback clearance or taxi information.
- services providing ground systems and controllers with aircraft parameters. Aircraft generated data automatically reported are requested by various ground systems for different purposes: automatic display of aircraft heading and speed to the controller, automatic consistency checking of airborne and ground flight plans, processing of meteorological data measured by the aircraft, detection of conflict or route deviation, etc...
- services providing aircrew with ground parameters. Meteorological and aerodrome related information are sent on request or automatically to the aircrew.

Ground/ground data link services - already in operation in Europe based on the AFTN/CIDIN and X.25 communication infrastructures - support exchanges of various types of aeronautical data (radar data, meteorological data, flow management and air space management data, ATC centres co-ordination data). Ground communication requirements are increasing in Europe as a consequence of the centralisation of certain essential ATC functions (e.g. CFMU) and the need to increase the level of co-ordination between European ATC centres. The internationalisation of these exchanges makes necessary a world-wide agreed definition of the ground data link services.

2.3.3 Communication Environments

Data-link applications are designed to provide operational users with the communication functions needed to operate the air-ground and ground data link services.

The ATN applications defined so far support most of the data link services listed in the previous section. ATN applications standardised by ICAO are CPDLC (Controller Pilot Data Link Communications), ADS (Automatic Dependant Surveillance), CM (Context Management), FIS-ATIS (Automatic Terminal Information Service), ATC Interfacility Data Communications (AIDC) and the ATS Message Handling System (AMHS). The specification of ATN applications has been made easy by the definition by ICAO of an « upper layer architecture », i.e. a framework in which the ATN applications are plugged in. Functions for structuring the application dialogues (Session layer) and negotiating the application data encoding rules (Presentation layer) are provided to the applications.

Other types of applications defined outside the ATN environment (e.g. Mode-S specific services based applications or ACARS applications) are also candidate to support the communication requirement of these data link services.

2.3.4 ATS Data Link Services for the Target European ATN (2005-2010)

2.3.4.1 Air/Ground Data Link Services

It is not possible to define the exhaustive list of the data link services likely to be in operation in 2010 in the ACCESS area. Very few states in the ACCESS area have started data link implementation analysis and the choice of services is obviously dependant on the current ATC infrastructures. The operational benefits of each state expected from the introduction of the data link need to be clearly stated to be able to identify the data link services required to be implemented.

Nevertheless, the emerging tendency observed in some ACCESS countries in terms of implementation of ATN applications is as follows:

- the ATN CPDLC application will be implemented everywhere in the ACCESS area. This application supports most of the services reducing the use of the VHF channel (transfer of communication, exchange of clearance and information messages and departure clearance) and provide facilities to check automatically the consistency between the air and ground ATC data. The exchange of downstream messages supported by this application is obviously of interest for oceanic ATC centres.
- surveillance purpose services can be provided by more efficient and optimal means than through the ATN ADS application, at least in the continental area. With the exception of the oceanic ATC centres where the ADS application will enhance the radar based surveillance capability, the ATN ADS application is seen as a backup solution when no other solution is possible. This observation leads to the recommendation to implement the ATN ADS application in the NAT ATC centres of the ACCESS area only.
- availability of Flight Information Services through data link is going to increase significantly the quality of the pilot environment by providing him with more information and with a better updating level. The ATN FIS application will certainly be made available in the whole ACCESS area as centralised ground FIS servers installed by type of data and per country.

Depending on the strategy selected by each state for the ground topology of their air/ground End Systems, two study scenarios can be envisaged:

1. the first scenario assumes a centralised distribution of the ATN ESs: one CPDLC ES per en-route ACC, one FIS ES per country and per type of information (ATIS, RVR, SIGMET) and one ADS ES per oceanic ACC.
2. the second scenario assumes a distributed topology. En-route ACCs, approach ACCs and main airports would have each a CPDLC ES. The ATIS and RVR services would be available at each approach ACC in a dedicated FIS ES. An ADS ES would be installed in each en-route ACC and approach ACC to support ATC functions based on downlinked aircraft parameters like surveillance, flight plan processing, conflict detection, etc….

It is likely that the reality in 2010 will be half way between the two scenarios depending on the national implementation plans of the ACCESS area states.

2.3.4.2 Ground Data Link Services

The ATN AMHS application will be implemented in the ACCESS area to support the exchanges of data currently supported by AFTN/CIDIN (CFMU data, meteorological data and aeronautical information data). It is assumed that AFTN and CIDIN have been completely replaced by the AMHS in the ACCESS area by 2010. However, at that time, only few applications will have been redeveloped as native AMHS applications. The meteorological application OPMET has a reasonable chance of migrating completely to AMHS. For the other applications and to support the traffic with non-ATN areas, AMHS/AFTN-CIDIN gateways will be in operation. It is assumed that the ATN AIDC application will be deployed in the ACCESS area to replace the current OLDI connections. Finally, the ATN Internet is envisaged to be used for some international radar data transfer.

Based on the above selection of the ground data link services, the location of ground/ground End Systems by 2010 is assumed to be as follows:

- AMHS/AFTN-CIDIN gateways shall be located in the national AFTN centre of the ACCESS area as necessary to communicate with non-ACCESS regions (North Atlantic, South America, Africa, Eastern Europe and Middle East).
- ATN ES will be located where users of the selected ground services are located, i.e. CFMU facilities, AIS offices, MET offices, ATSO Flight Plan Submission Offices, ACCs, Flight Plan Processing Systems and Controller Positions.

2.3.5 ATS Data Link Services for the Initial European ATN

It was not the objective of this work package to determine which ATS data link services could be initially deployed in the ACCESS area, however some input material is provided to allow further development of this question in ACCESS Work Package 240 ("Transition Issues") which will be performed in summer 1998. Criteria likely to be used for selecting the initial data link services to be deployed in the ACCESS area by 2005 are identified and discussed. Operational benefit, standardisation status, degree of experimental maturity, criticality of the service, etc… are some examples of the aspects required to be addressed when selecting the initial services.

2.4 Proposed Topology of the ATN network

2.4.1 Introduction

The study of a suitable topology for the Target European ATN was performed in the scope of the following ACCESS Work Packages:

- The Work Packages 203 and 203A on the routing architecture. The purpose of these Work Packages was to define options for a routing framework of the target European ATN, i.e. the definition of Routing Domains, Routing Domain Confederations, the location and types of routers, etc.
- The Work Package 204 on the definition of ATN ground-ground subnetworks. This Work Package has established principles for the use of ground subnetworks and has made proposals for the initial choice of subnetworks.
- The Work Package 205 on the definition of ATN Air-Ground Subnetworks. This Work Package took into account existing European work on this subject (such as the EATCHIP deliverable ST-15), and has made proposal for the most appropriate air/ground subnetworks.

The following sections summarise the outcomes of these Work Packages.

2.4.2 Routing Architecture (WP203 & WP203A)

2.4.2.1 General

One of the main objective of this phase was to define a suitable routing organisation for the European ATN in the geographical area and the timeframe considered in the ACCESS project, and to describe a technically feasible deployment scenario of the required ATN Routers. The intent was to define the architecture of the European ATN in terms of Routing Domains (RDs), Routing Domain Confederations (RDCs), and ATN Islands[2] and to propose a general interconnection scheme at the national, European inter-national, and world-wide inter-regional levels.

This task was perceived as being of a key importance for a successful achievement of the objectives of the project, and the subject was hence considered as deserving a particular attention. This is because the routing architecture will derive the number and locations of routers in the network and the distribution of routing messages between them. A poor routing architecture would result in a non-optimal network (i.e. costly and possibly open to problems such as congestion, black holes, etc...).

The endorsement of a specific routing organisation appeared to be a difficult decision surrounded by controversy. It appeared that ACCESS was not in a position to answer all the questions related to the

[2]ATN RDs, ATN RDCs, ATN Islands are notions defined in ICAO ATN SARPs.

subject; the assessment of the appropriateness of a network architecture is indeed dependent of a number of various parameters such as protocols tuning, subnetwork performance, topological choices, routing strategy, etc.; and the choice of a solution will also be governed by political considerations surrounding the implementation strategy of the European ATN.

At this stage of the project, it was therefore felt that there was several alternative solutions and that each possible routing organisation deserved to be analysed before the project concluded its work on the European ATN architecture.

It was consequently agreed to develop two different proposals, following different approaches and to perform, later on in the project, evaluation and validation of the two resulting options. It is expected that further analysis and simulations will 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.

The first proposal is referred to as the “European ATN routing organisation - Option 1” and is summarised in section 2.4.2.2 below. The second proposal referred to as the “European ATN routing organisation - Option 2” was still under development at the time the present report was edited. However, initial conclusions developed in Option 2 and dealing with the network architecture for ATN air/ground traffic exchanges is presented in section 2.4.2.3.

A so-called Routing Workshop will be organised within ACCESS in June 98 to discuss both options and decide upon the optimal ATN routing architecture for Europe.

2.4.2.2 European ATN Routing Architecture - Option 1

2.4.2.2.1 Proposed overall Routing Architecture for the European ATN

A first conclusion of the option 1 report is that the European ATN should consist at the upper level of one single and global European ATN Island, completed by an independent separate European “Home” Routing Domain Confederation (RDC) formed by the Airlines and their telecommunications service providers and hosting the home Routing Domains of the European Airlines.

The « Home » concept is an ATN concept which allows one Routing Domain (or one Routing Domain Confederation) to attract and receive all the information on routes to all aircraft of the associated airline (or of the associated group of airlines). This concept exists for allowing inter-Islands communication with aircraft. This facility will mainly be required by airlines to reach their aircraft. Separating the « Home » domains from the European ATN Island will allow to alleviate the European ATN Island backbone from the airline specific inter-island routing and data traffic.

The proposed overall organisation is illustrated by Figure 1 below.

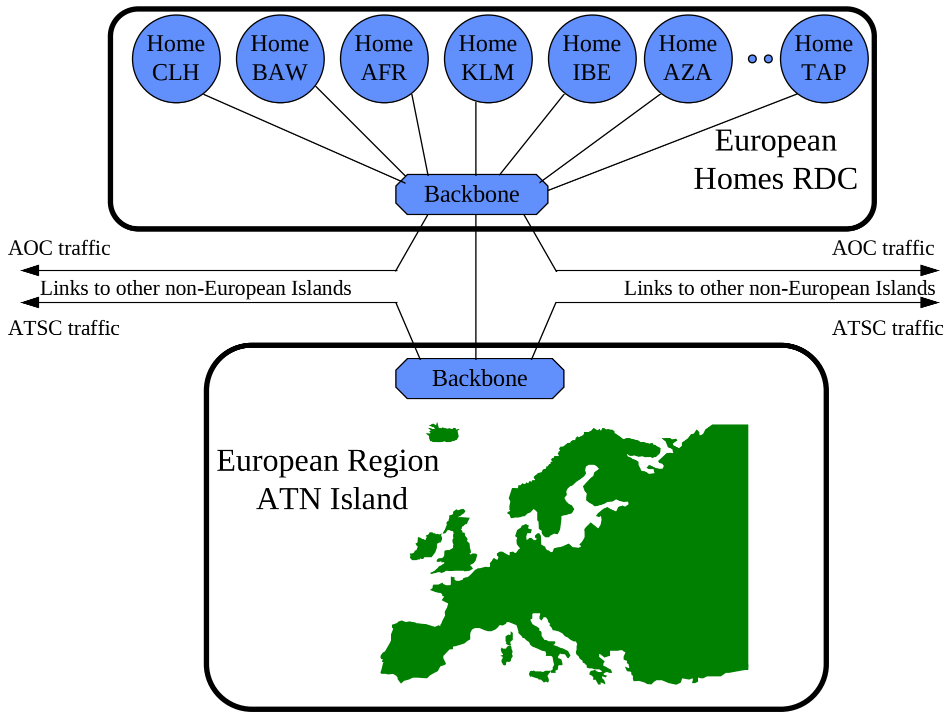

Figure 1: Proposed overall Routing Architecture for the European ATN

2.4.2.2.2 Internal organisation of the European ATN Island

Assuming that in 2010, a consequent number of aircraft will be ATN-equipped, and on the basis of the results of the « ATN Islands and Home IDRP Convergence » study [EUR13], Option 1 report proposes to divide the target European ATN Island into three subregions:

1. The Western ATN subregion, which covers the oceanic area and most of the core area
2. The Eastern ATN subregion, which covers a part of the core area, and south-east European countries.
3. The Northern ATN subregion, which covers Scandinavia and countries around the Baltic Sea

Each subregion is proposed to be organised into a separate Routing Domains Confederation. The 3 so-called *SubIsland RDCs* would be interconnected via an upper level backbone as depicted in Figure 2.

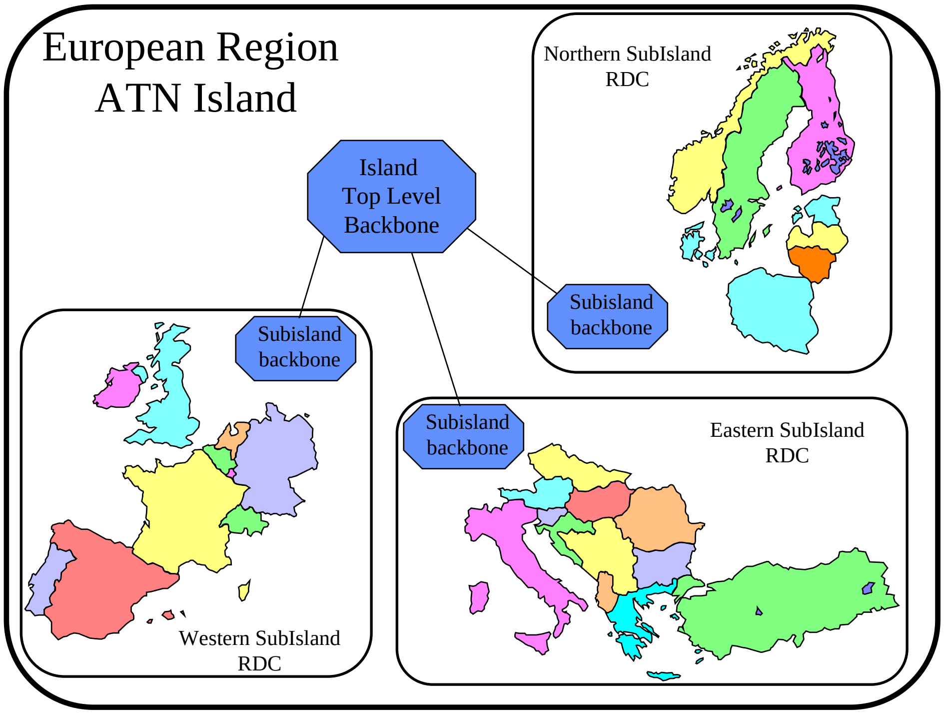

Figure 2: Option 1 proposal for the internal Routing Architecture of the European ATN Island

This architecture allows to keep in an acceptable range, one of the critical performance parameter of any ATN routing organisation: the so-called routing update rate. This rate corresponds to the frequency of the changes in the routing tables of the ATN backbone routers.

The ATN can only work if the backbone routers are able to absorb and process the routing updates in real time and converge quickly to valid routing decisions. Dividing the European ATN Island into several subIslands allows to limit the routing update rate.

2.4.2.2.3 Internal Organisation of the European SubIslands RDCs

Each subregion is considered as a SubIsland RDC containing its own backbone and the Routing Domains of the different organisations in the subregion. As a generic scenario it has been assumed that the States will form one Routing Domain around each national ATC Centre and will group all their Routing Domains into national RDCs.

Another assumption is that ATS Organisations will generally not offer their ATS-dedicated ATN networks to serve as **transit** network for AOC or long distance ground-ground ATSC traffic (i.e. ATSC traffic between non-adjacent ATSOs): national ATSOs will choose to have their Routing Domain Confederations acting as non-transit RDCs, and will rely on the backbone for multi-national communications. Each national ATS Routing Domain or Routing Domain Confederation will consequently have to be directly connected to the backbone of the SubIsland RDC.

Within each subregion, the backbone is therefore perceived as a key element for the global routing performance.

Option 1 recommends to optimise the performance in the backbone thanks to the use of a special router, called a **route server**. A route server is a system dedicated to the processing of the routing information and which does not participate in the actual user data packet forwarding. A route server is dedicated to the acquisition of the routing information, to the processing and selection of the optimal routes and to the redistribution of these optimal routes to standard ATN routers. On their side, the standard ATN routers focus on switching user data packets.

The use of a route server allows to optimise the routing, to minimise the number of routers interconnections and avoids the routing stability problems inherent to meshed topologies.

As a basic proposal, option 1 recommends the use of a route server in the backbone for the distribution of routes to backbone routers. The resulting basic proposal for the routing architecture within a subregion is illustrated by Figure 3.

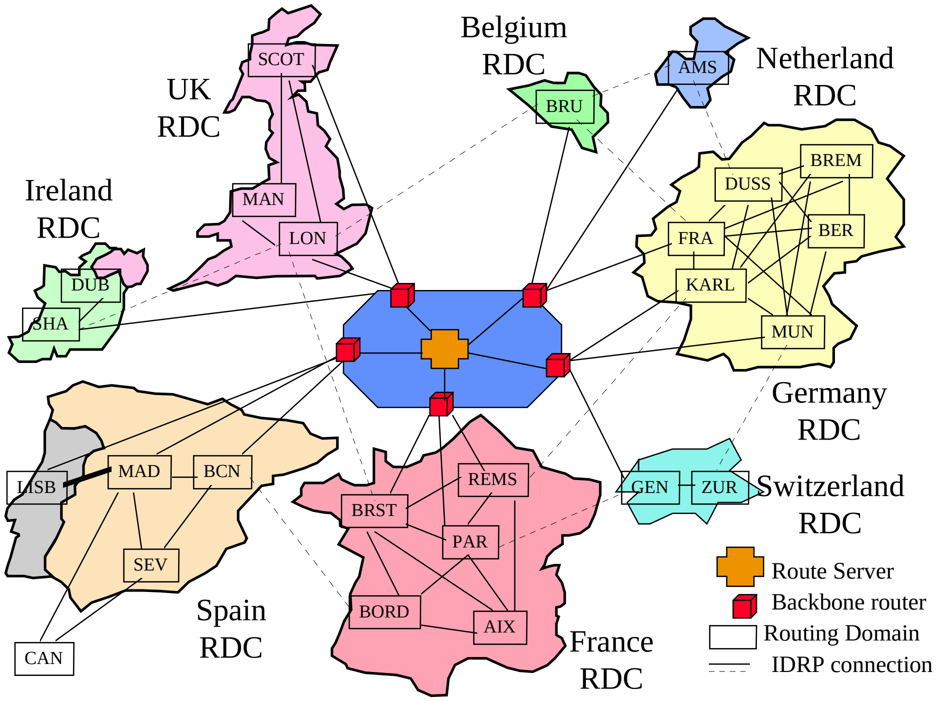

Figure 3: Option 1 proposal for the basic ATN architecture in a European subregion

The use of a route server will also allow the deployment of backbone routers close to (within) the national Routing Domain Confederation, and consequently to shorten the paths between communicating End Systems. In the Western Subregion, it has been assumed that:

- Germany would operate its own backbone router
- France and Switzerland could share a backbone router administered by France
- Spain and Portugal could share a backbone router administered by Spain
- UK and Ireland could share a backbone router administered by UK
- The Benelux countries could share a backbone router administered by Eurocontrol.

The option 1 report further proposes to extent the benefits of the route server, beyond the backbone, to the distribution of routes to off-backbone routers.

2.4.2.2.4 Routing Organisation for Airlines and International Aeronautical Communication Service Providers

Given the assumed unwillingness of ATSOs to open their ATS-dedicated ATN ground networks to the transit of AOC traffic (although this will have to be confirmed), International Aeronautical Communication Service Providers (IACSPs) could 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 the ACCESS study.

2.4.2.2.5 Routing AOC traffic within the Island

The A/G routers owned by ATSOs and accepting the relaying of AOC traffic toward/from the aircraft will have to be directly interconnected with the ground IACSPs ATN infrastructure if the ATSOs are not willing to open their ATS-dedicated subnetworks (e.g. such as the ATC X.25 PSNs) to serve as transit subnetwork for AOC traffic.

2.4.2.2.6 ATN Systems Deployment Scenario

2.4.2.2.6.1 Deployment of ATN Routers

2.4.2.2.6.1.1 General

ATN routers will be deployed on the sites where ATN applications are run (i.e. the sites which have been identified in sections 2.3.4.1 and 2.3.4.2). In each of these sites, the ATN routers may be intra-domain routers, ground inter-domain routers (ground BISs) or Air/Ground inter-domain routers (A/G BISs) depending on the adopted routing organisation and on the A/G connectivity requirements.

2.4.2.2.6.1.2 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 is consequently proposed to 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 identified in the report, the baseline architecture for interconnecting ATN components in an airport is the generic model depicted on Figure 4:

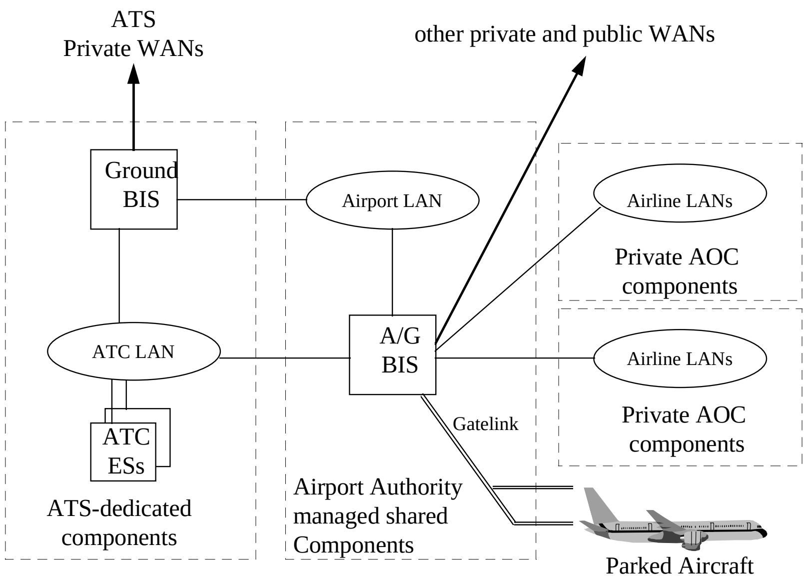

Figure 4: Baseline ATN infrastructure in airports

2.4.2.2.6.1.3 ATN deployment in ACCs

Each ACC should be equipped with at least one router for interconnecting the ACC LAN(s) to the national ATS WAN.

In ACCs with A/G connectivity, this router will be an A/G BIS, thus being additionally connected to Air/Ground subnetworks. If one of the attached mobile subnetwork is furthermore 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 direct A/G connectivity, this router may be either an Intra-Domain router or a ground BIS depending on whether the router is at the boundary of a Routing Domain or not.

For an ACC with direct A/G connectivity, the baseline architecture is the one depicted on Figure 5. It is simpler than for an airport as there is only one main actor and one category of applications involved.

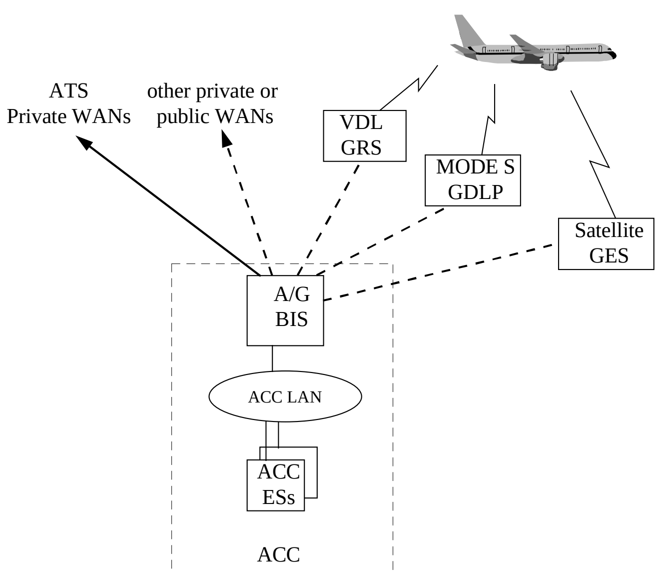

Figure 5: Baseline ATN infrastructure in ACCs

2.4.2.2.6.1.4 ATN deployment in global ATS Sites

Other ATS Sites should be equipped with at least one ATN router 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 direct A/G connectivity, the router may be either an Intra-Domain router or a ground BIS depending on whether the router is at the boundary of a Routing Domain or not.

2.4.2.2.6.2 Generic national ATN deployment scenario

Within a given European country, the resulting Option 1 generic and overall interconnection scenario is as follows:

1. national ATS Organisation
    - an ATS Routing Domain is created in each national ATS RDC around each national ATC Centre. This Routing Domain encompasses the ATC Centre, and all airports and other possible ATS sites in the related FIR. Within each such Routing Domain, all BISs are directly interconnected with each other, as required by the IDRP standard.
    - It is assumed that the national RDs will be directly interconnected with each other national RDs 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 airports, 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
    - 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.

2.4.2.3 European ATN Routing Architecture - Option 2

Editor's note: Option 2 was still under development when this report was edited. The following sections contain therefore only initial conclusions of the related work, not approved yet within the ACCESS consortium.

2.4.2.3.1 Proposed overall Routing Architecture for the European ATN

Option 2 report proposes the same overall routing architecture for the European ATN as the one proposed in option 1 report (see section 2.4.2.2.1), i.e. the European ATN is proposed to consist **of one ATN Island, complemented by an external "European Home RDC"** comprising the home Routing Domains associated with the European commercial aircraft.

If mandated by operational or institutional constraints, the option 2 report considers that a separation of the European Islands into a few (2 or 3) ATN Islands would be acceptable.

2.4.2.3.2 Internal organisation of the European ATN Island

In Option 2 report, the backbone is considered as a (non-perfect) safety net, which should be designed so that to provide the required backup functionality but which does not need a highly sophisticated bullet-proof architecture. **A simple backbone architecture which contains only a single backbone router** (or 2 for redundancy and back-up purposes) **is considered appropriate** and acceptable given that a single-point-of-failure can be avoided and the availability of the backbone ensured according to the required performance margins.

Option 2 report further recommends that **the RDs within the European ATN Island are grouped around the European Island's backbone according to a star-type topology** (see Figure 6, Alternative A)**.** In order to limit the number of direct attachments to the backbone (i.e. direct attachment of each states and organisations), **this routing star is proposed to be organised in a hierarchical fashion whenever operationally and institutionally acceptable** (see Figure 6, Alternative B).

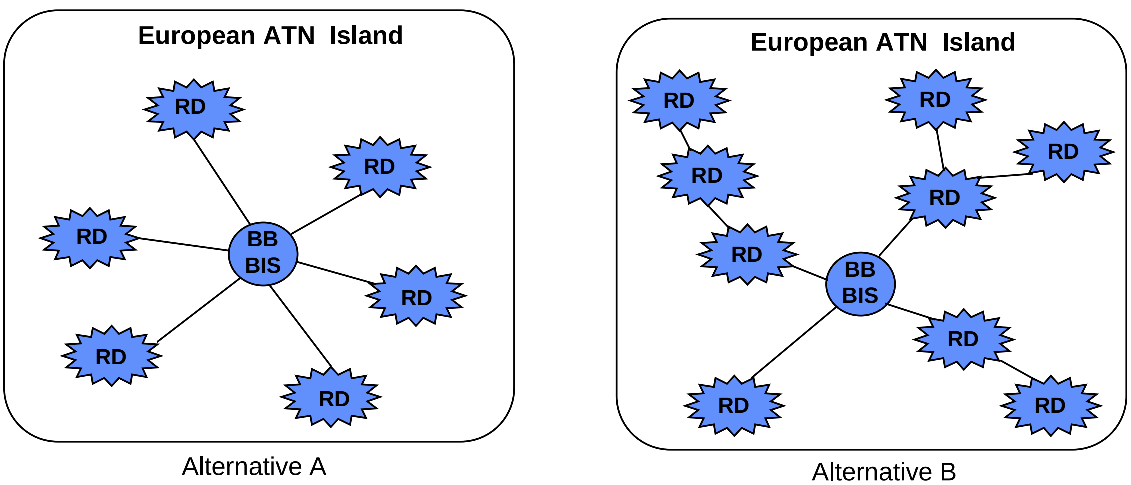

Figure 6: Basic Alternatives for Connecting RDs to the Island's Backbone

The report further recommends to use **one single inter domain router (BIS) within each Routing Domain**.

The set of recommendations expressed in the option 2 report allows to derive the following baseline architecture for the internal organisation of the European ATN Island.

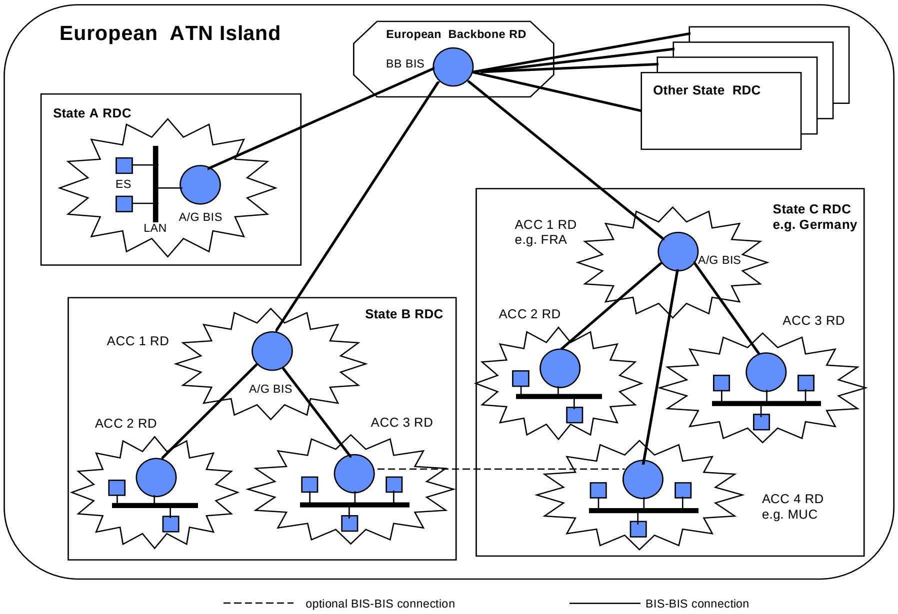

Figure 7: Option 2 of the proposed Routing Architecture for the European ATN Island

2.4.3 Ground-ground subnetworks (WP204)

The implementation of the ATN will necessitate considerable capital expenditure on the part of ATSOs and aircraft operators. The expenditure will be associated, for example, with the deployment of routers, end systems and A/G subnetworks and the implementation of ATN applications. These ATN components represent new technology and associated investments will not be avoided.

The situation with respect to ground subnetworks, on the other hand, is different. Here there is the possibility, according to ATN principles, of sharing the use of data communications infrastructure between the ATN and other users. This could be the infrastructure which is already in existence or which will be implemented for other purposes in the same time-frame as the introduction of the ATN. This situation is made possible by the flexibility of the ATN concept and could lead to considerable cost-savings when compared with the implementation of dedicated ground subnetworks.

The majority of national and regional data networks currently maintained by ATSOs is based on packet switched technology which appears to be ideally suited for use by aeronautical applications.

The discussion in the ACCESS report shows that the existing packet switching networks will meet the ATN requirements in terms of Quality of Service and will still be technically relevant in 2010. **The use of existing national PSNs is recommended for the interconnection of ATN routers within countries. The current (or planned) X.75-based PSNs interconnection is recommended to be used where possible for international subnetwork connections among ATN routers.** The interconnection of PSNs by means of ATN routers only is rejected as the possible primary approach for building up a generalised international networking service in the ACCESS region and timeframe, since it would immediately imply the migration of the existing applications which exchange data through these networks to ATN applications. The cost of such a migration makes it unacceptable for ATSOs at the moment.

The use of dedicated leased lines as ATN subnetwork should be considered when:

- no other suitable subnetworks are available;
- between a pair of routers there are large traffic volumes which cannot be handled by other subnetworks;
- existing subnetworks would have to be extended such that the ATN traffic would become the major traffic flows in a given area;

- dedicated leased lines are the most economic solution in a given case.

With regard to the subnetwork technology used by the ATN backbone, ACCESS makes the following recommendations:

- in the European areas where an international ATC WAN is (or will be) available, it is of interest that the backbone routers and the backbone route server be connected to and use this international ATC WAN for the exchange of data and routing traffic.
- In the European areas where an international ATC WAN is not available, the deployment of a high capacity backbone subnetwork may be advisable. The recommended subnetwork technology for such a high capacity core subnetwork is a combination of ATM and dedicated leased lines.

2.4.4 Air-ground subnetworks (WP205)

One of the key decisions that any region must make as a part of the deployment of the ATN is the selection of air/ground subnetwork(s) that are to be deployed in that region to provide primary and/or back-up air/ground Datalink services.

One objective of ACCESS was to identify the preferred choice of air/ground technology to be integrated into the European ATN infrastructure. Such a selection was to be made based upon an analysis of existing trials and studies that have addressed the subject of air/ground subnetworks and to take into account the policies and plans of European and non-European ATS providers, aircraft operators, communications service providers and finally ICAO. The final selection must be based on a number of criteria including ability of the selected technology to fulfil performance, reliability and coverage requirements whilst taking into consideration issues related to costs, ownership, service availability, service provision, etc.

Currently there are four candidate technologies that have been or are in the process of international standardisation through ICAO, these being:

- Mode S Data Link
- AMSS
- VHF Data Link (VDL)
- HF Data Link

Whilst there are other possible satellite technologies (e.g. Low Earth Orbit, Medium Earth Orbit) that are potential providers of ATN compatible air/ground Datalink services it has been assumed that such technologies are unlikely to be standardised, validated and commercially available to support air traffic services within the time-frame of the initial European ATN implementation. However, noting that the ICAO AMCP has been reviewing the potential of these new satellite technologies with respect to their applicability to ATS it is recommended that this assumption be reviewed and this report be updated accordingly once the final AMCP recommendations on this subject are concluded.

The EATCHIP ST.15 study (Analysis Options for Initial Air/Ground Data Networks) has been found to be of particular relevance to this study since it has conducted an extensive and detailed analysis of the various air/ground technologies and assessed their abilities to comply with the types of Datalink air/ground communication services that have been envisaged for use in the European Region by the EATCHIP ODIAC SG, such services also being those upon which the ACCESS services have been defined (see section 2.3). Phase 1 of the ST.15 study was to inventorise the potential air/ground technologies and air/ground services that were foreseen to be available in the coming decade. That Phase resulted in a number of possible options for deployment within the time-frame of the study, i.e. 1995 to 2005. Phase 2 subsequently applied a set of user defined criteria to the inventory produced in Phase 1 and concluded that:

- in the 1995 to 2000 time-frame an ACARS based service should be provided as a interim step and
- 2000 - 2005: For this time period it was proposed to study the VDL Mode 2 system as a candidate for a main subnetwork. It was also proposed to study the VDL Mode 4, the Mode S and the SATCOM systems as possible complementary options. The COM Team amended the proposal of the Phase 2 study by requesting that the VDL Mode 4 subnetwork be examined as a candidate for a main subnetwork in addition to VDL Mode 2 subnetwork”. [EAT 19]

Phase 3 subsequently studied the air/ground data subnetwork options selected in Phase 2 considering their technical feasibility, cost and the implementation programme. The results of the ST15 Phase 3 study were presented at the COMT-11 meeting held in Brussels (10-11/2/98). COMT endorsed the ST15 report and recommended " *to implement in the ECAC States the VDL Mode 2 system, as the first ATN air-ground subnetwork, to support initial ATS and Airline data link services*". The COMT also made recommendations regarding the use of other air-ground subnetworks e.g. Mode-S, SATCOM and VDL Mode 4. In particular "*to include, inside the EATCHIP Communication Work Program, complementary activities relating to:*

- *The definition or selection of the QoS requirements that will be representative of future Air/Ground datalink services;*
- *The availability of necessary standards;*
- *To assess the ability of VDL Mode 4 to fulfil these requirements; and if the assessment is positive to:*
    - *develop the operating concept of VDL Mode 4*
    - *conduct a safety analysis for VDL Mode 4.*
- *To continue to monitor VDL Mode 3 developments and assess its capabilities as appropriate." [EAT 20]*

Another key activity of relevance to the conclusions of this part of the ACCESS study is the work of WG-D of the ICAO AMCP which is currently in the process of developing two reports:

- an assessment of the various air/ground digital links providing for voice and/or data communications against their operational requirements and an overview of the performance characteristics of these systems (study called "AMCP study report for the evaluation of CNS systems") and,
- a comparative analysis of the candidate data links for navigation and surveillance applications (study called "AMCP study report for the development of datalinks for Navigation and Surveillance").

The current drafts of these reports are insufficiently mature for any sound conclusions to be drawn. It is however recommended that the final ACCESS recommendations are re-visited once the AMCP reports are finalised and endorsed by ICAO.

IATA recently established a Task Force to "establish the airlines' requirements for the future data link infrastructure". Due to time-scale limitations and given the fact that the AMCP was conducting a detailed performance assessment of the candidate air/ground technologies the Task Force report, which was endorsed by the IATA Flight Operations Committee, did not conduct a performance assessment of the various air/ground technologies. However, the report did present a strong preference for VDL based air/ground services. The report additionally highlighted a number of technical and economic reasons for implementing VDL rather than the Mode S subnetwork. Though not formally documented it is understood that IATA will encourage VDL Mode 2 implementation with a view to migrate to the integrated voice/data VDL Mode 3 system. There is currently no known formal IATA position on VDL Mode 4.

From a performance perspective and in the context of the validation of the ATN SARPs the FAA presented a validation report to the ICAO ATNP WG1 in Brazil in March 1998 and concluded that the range and value of ATSC classes/transit delay requirements defined in the SARPs were valid and that a VDL Mode 2 service would provide a Class B service (4.5 seconds one way transit delay) and Mode S a Class C service (7.2 seconds). These conclusions are based on the subnetworks supporting the optimum airborne configuration and being operated within the intended capacity.

A number of initiatives that are either utilising or developing air/ground technologies are currently underway. The POEMS project is scheduled to deliver 3 SARPs compliant Mode S surveillance systems (with Mode S subnetwork interfaces, i.e. GDLP) by the end of 1999. Both the Pro-ATN and Euro VDL Mode 2 projects will result in the deployment of VDL Mode 2 services that will provide a combined coverage for a significant portion of European airspace in addition to developing the appropriate VDL Mode 2 avionics systems. The ADS Europe trial has acquired significant experience in the use of the AMSS ATN Data 3 compliant satellite service.

Given the current status, planned availability and performance characteristics of the various technologies UK NATS considers that VDL Mode 2, subject to confirmation through appropriate R&D initiatives (e.g. simulation), will be capable of meeting its expected ATS communications demand for data link services. It is therefore the preferred choice for implementation for the time-frame in question, i.e. up to 2010 with a preference to migrate to the integrated voice/data VDL Mode 3 system as and when it becomes operationally deployed. UK NATS currently has no requirements for Mode S data link operation in domestic airspace. However, NATS is currently assessing requirements for the deployment of Mode S for basic surveillance. UK NATS plans to offer an ATN compliant AMSS based ATS service circa 2000 in the UK North Atlantic FIR. The use of HF data link as a back-up service in the NAT is currently under review.

Like NATS, STNA considers that VDL Mode 2 will be the appropriate and main ATN air/ground subnetwork in Europe for the next decade, i.e. up to 2010. Mode S and AMSS will be considered to be used as ATN back-up subnetworks.

As regards, the future of VHF technologies, STNA considers that, up to 2010 at least, the “8,33 kHz” solution will satisfy the requirements for voice telecommunications and that no clear requirements for data/voice integration exist today in Europe. In fact, STNA is not convinced that such a requirement will ever arise. If so, VDL Mode 3, as it is specified today, is not believed to be the appropriate technical solution. In fact, given the foreseen increase in ATC data telecommunications, a dedicated data subnetwork with better performance than VDL Mode 2 might be the answer to future ATC air/ground telecommunications requirements. Clearly, this means that STNA believes that the current proposed VHF technologies (“8.33 kHz” for voice and VDL Mode 2 for data) will satisfy the ATC air/ground telecommunications requirements up to 2010, and that none of the currently proposed technologies are believed to be satisfactory for longer terms solutions.

STNA considers the VDL Mode 4 as a possible complementary solution to Mode S for the support of ADS-B service, but the latter needs to be better defined in terms of operational objectives before the appropriate telecommunication supporting technology be precisely selected. VDL Mode 4 is not considered to be suitable for the support of point-to-point telecommunications in the context of ATN.

The DFS regard VDL Mode 2 becoming the primary link for non time critical ATS data link services in the medium time frame (from 2005 onwards). Therefore the VDL Mode 2 digital link will initially be used in parallel with ACARS (carrying initial data link applications) and will finally succeed ACARS. The necessity of the usage of a complementary data link (e.g. Mode S, SATCOM) will be the subject of further investigations to be concluded by 2001. The necessity of a data link for the provision of time critical ATS data link services (e.g. VDL Mode 3, VDL Mode 4) is a further subject of investigation to be concluded by 2002.

The US FAA is currently investigating, through OpNet based simulations with ARINC, the use of VDL Mode 2 to support the early introduction of ATS data link services. The FAA considers VDL Mode 3 remains a candidate for the next generation of data link systems. In response to the views of the US airlines the FAA no longer has plans to deploy Mode S data link as an ATN subnetwork. Mode S for basic surveillance is currently operational in the majority of US airspace. The FAA plans to introduce Mode S based enhanced surveillance from the end of 1997 onwards.

It is expected that both the current major aeronautical telecommunications service providers, ARINC and SITA, will be in a position to offer initial VDL Mode 2 services circa 2000 that will provide coverage for the core area of Europe. The question of third party service provision of communications services will be addressed later in the project.

Given the analysis conducted in the development of this task, **it is concluded that in the ACCESS time-frame (i.e. up to 2010) the VDL Mode 2 subnetwork be integrated within the European ATN infrastructure as the primary means for the provision of air/ground services**. There is currently no clear agreed European policy as to which VDL Mode should be deployed beyond the foreseen ACCESS time-frame.

With respect to a secondary back-up air/ground subnetwork service ACCESS was not in a position to conclude the preferred technology and recommends that a further study is initiated to identify the optimal solution for a secondary air/ground subnetwork taking into account the needs, requirements plans and constraints of the European region. This further study should, inter alia, take into account current European plans for the deployment of Mode S, the stability and maturity of the VDL Mode 4

SARPs, the availability and costs of the AMSS subnetwork and the plans regarding the emerging LEO/MEO satellite based systems.

2.5 Proposed Addressing plan (WP206)

2.5.1 Introduction

There are two aspects of interest when discussing addressing in the ATN. The first is the set of administrative requirements for obtaining and allocating names or addresses; the second is the technical aspect of such assignments. Only technical issues were addressed in Phase 1, in the scope of the Work Package 206. Institutional issues will be studied during Phase 2.

The following sections provide a summary of the proposed guidelines and for the Internetwork, Transport, Upper Layer and Application addressing in European ATN ATSC systems, and for the ATS Application Naming.

2.5.2 European ATN Internetwork Addressing

The ATN internetwork address that is used to uniquely identify and locate a given network service user within the context of the ATN, is called the ATN Network Service Access Point (NSAP) address. An ATN NSAP address is a 20-octet string.

According to the SARPs, the first 4 octets of the NSAP addresses shall be set to:

- 47002781hex in all ground systems administered by an ATSC authority
- 470027C1hex in all mobile systems administered by an ATSC authority

ACCESS recommends that the fifth octet of the NSAP address of all European ATSC ground and mobile systems be set to 83hex (the ICAO Region Identifier for Europe)

The following approach is proposed for the allocation of values to octets 6 and 7 of European ATSC systems:

1. In systems administered by a national ATSC authority, octets 6 and 7 of the NSAP address should be derived from the State's two character alphanumeric ISO 3166 Country Code, represented as upper case characters. (e.g. 'FR' for all systems administered by a French ATSC authority)
2. In systems administered by a supra-national organisation, octets 6 and 7 of the NSAP address should be set to a two character alphanumeric code, registered with the European addressing authority and represented as lower case characters. (e.g. 'eu' for all systems administered by Eurocontrol)

According to the SARPs, octet 8 of the NSAP address shall be set to 00.

For mobile ATSC systems, octets 9, 10 and 11 shall be set to the 24-bit ICAO Aircraft identifier

For ground ATSC systems, octet 9 is proposed to be set as follows:

- 01 for systems in operational Routing Domains of a national ATSO
- 11 for systems in non-operational Routing Domains of a national ATSO
- 21 for systems in operational Routing Domains of a national military organisation
- 31 for systems in non-operational Routing Domains of a national military organisation
- 61 for systems in operational Routing Domains of a national meteorological organisation
- 71 for systems in non-operational Routing Domains of a national meteorological organisation

For ground ATSC systems administered by a national ATSO, octets 10 and 11 are proposed to be derived from the 2 last characters of the 4-letter ICAO location indicator associated with the FIR where the systems are located.

For the Airport operators, it is proposed that the value of octets 9, 10 and 11 be derived from the three-character alphanumeric international code of the airports (e.g. 'CDG' for Paris-CDG Airport operator).

Values of the other octets of the NSAP addresses are very dependent on the internal routing architecture of each organisation. Some guidelines are provided in the ACCESS report but a general common approach cannot be specified and does not have to.

2.5.3 Guidelines for the naming and addressing of application in European ATN systems

Each application hosted in an ATN End System is assigned an application name and an ATN address. A tutorial on how application names and addresses are defined in the ATN is provided in ACCESS.

The European ATC applications will have to follow the following naming and addressing schemes:

1. For non AMHS-based applications (i.e. all air-ground applications and ground ICC applications)

   The ATN address is composed of an NSAP address identifying unambiguously the end system within the ATN environment and a TSAP selector identifying the application within the scope of the end system. The structure and contents of the NSAP address shall follow the recommendations provided in the previous section. In addition, ACCESS recommends that the TSAP selector be locally assigned for all applications except the CM application in case a logical application address is needed for CM.

   The ATN application naming scheme defines an application name assignment procedure based on the geographical location of the system hosting the application and on the type of the application (see Sub-Volume 4 of the ATN SARPs). Therefore, as no possibility of customising the application names is given to the system administrators, ACCESS does not provide any guideline on the way the application should be named.

2. For AMHS based applications

   The ATN address of these applications is composed of an NSAP address and three selectors identifying in turn the Transport, Session and Presentation service-users. The structure and contents of the NSAP address shall follow the recommendation of the previous section. The value assignment for the selectors is considered as a local matter for organisations responsible of AMHS systems.

   Application names are needed to identify the application entities participating in the AMHS as well as the final AMHS users. Application names for AMHS application entities shall conform to the naming scheme defined in the ATN SARPs Sub-Volume 4 based on the location of the systems. Application names for AMHS users shall at least support the naming structure "XF-address" described in the SARPs when communications with AFTN users are foreseen. No particular constraint is put on the AMHS administrators to define their user names. However, as AMHS communications may be eased by the adoption of common naming rules, a European AMHS naming scheme is required. The European project SPACE (Study and Planning of AMHS Communications in Europe) will address this issue.

2.6 Performance Analysis and Dimensioning of ATN Components (WP207)

2.6.1 Introduction

The objective of the Work Package 207 was to set up a framework for analysing, predicting and planning the quantitative parameters of the network. The following section provides the results of this task.

2.6.2 Results

Of the vast amount of work which has been performed to date on the ATN (including that done within the ACCESS study), most of it can be classified as “qualitative” or “logical design”. The ACCESS study took a quantitative look at the network.

The primary goal was to set up a framework for specifying quantitative parameters of network components of the ATN in the ACCESS area depending on a number of “boundary conditions” and the time frame under consideration. Because of the lack of suitable existing material on the subject, it has been necessary to carry out original research. It has become apparent that there is little if any research nor experience in dimensioning data networks similar to the ATN in a consistent way.

The problem of predicting and analysing ATN performance and specifying parameters of ATN components is a multidimensional design task which seeks to optimise a number of mutually conflicting aspects:

- topology,
- throughput capacity,
- transit delay times,
- accuracy,
- availability and
- costs.

The particular problems encountered in the design task are due to the unique technical and administrative characteristics of the ATN. Although the Internet, as the world's largest (inter)network, has many similarities to the ATN, studying the Internet is no help in a quantitative analysis of the ATN. This is due to the history and development of the Internet and to the radically different demands placed on it.

Any quantitative analysis of the ATN is necessarily confronted by a large number of assumptions which have to be made. Within the ACCESS context, much valuable work has been done in narrowing down this inherent uncertainty in the "environment" of the European ATN. The initial requirement in terms of applications, architecture, locations and subnetworks has been defined in the ACCESS Work Packages 202 to 205. However the authors have chosen not to restrict themselves only to the ACCESS environment because of the general lack of quantitative ATN investigations. Therefore the results presented here are valid for the ATN in general and not just for the ATN in the ACCESS area. This approach has the advantage that the methods developed will be useful not just in the initial design stages of the European ATN and not just within the European Region.

Given the above facts, it is evident that this area is a necessary basic research topic, and all methods must be specified in the absence of supporting external research. It would seem that the ACCESS study is starting from scratch in a number of senses, and can only outline procedures to progress the ATN design, but cannot yet actually produce the design itself because of insufficient information. The intent was therefore to set up a framework for analysing, predicting and planning the quantitative parameters of the network.

The framework consists of a series of activities to be carried out when performance analysing and dimensioning the ATN. There are two distinct ways of approaching this task:

- assume a topology, and analyse it to dimension the components accordingly, and
- assume only the requirements (throughput, time delay, etc.) and compute an optimal cost topology.

It is concluded that the topology must be input to the task as a given and that it is unrealistic to expect the analysis to yield a topology: it is felt that this is best carried out manually. This is in keeping with the ACCESS methodology: WPs 203, 204 and 205 provide the necessary input. The framework does therefore not propose a method for designing specific topologies.

The framework contains analytic and simulation activities. The analytic approach, which is emphasised in the report, will be fast, but not totally reliable because certain dynamic aspects of the ATN cannot be analytically modelled (e.g. interaction between routers). For this reason, the analytic methods should be verified by either a simulation model or by a pilot implementation. There are three tasks which must be carried out prior to using the analytic approach of the framework:

1. establish the application data traffic overhead for each class of application which the ATN must handle;
2. obtain the throughput and transit delay characteristics, MTBF and MTTR of each subnetwork and router product proposed for use in the ATN;

3. specify (in terms of locations, subnetworks etc.) the ATN topologies which are to be analysed.

In addition, the following information must be determined:

- application analysis - a survey to identify each end system's location and the applications it supports,
- for each application supported by an end system, the number and average/peak length of data items it will generate for transfer through the ATN,
- the priority setting and classification for each application,
- a detailed survey of ground subnetworks involved,
- a detailed survey of air/ground subnetworks involved,
- topography (geographic locations) of end systems and any constraints on location of routers, connectivity of subnetworks, subnetwork traffic types,
- analysis of profiles of traffic due to mobile hosts.

Assuming that the above information is available, the calculations in this framework can be used to determine appropriate subnetwork, router and communications circuit sizes and the associated costs. This analytic approach may be used to eliminate obviously undesirable designs prior to running simulation tests on those designs which seem acceptable.

The results must, however, be interpreted in the light of the following restrictions:

- The designs will indicate the minimum requirements of routers, subnetworks, switches and communications links which are able to handle peak traffic loads, under the assumption that all of the ATN components operate at their most efficient. The requirements must be multiplied by a factor to ensure that abnormal loads and component outages can be dealt with;
- The designs do not take into consideration the requirement for duplications of ATN components to minimise the impact of component failures. Appropriate duplications must be included in the design of any proposed ATN topology;

As a result of this investigation, the following recommendations can be made:

1. Manually design trial ATN topologies and test them with the analytic tools outlined in this report;
2. Subsequently test the designs by simulation;
3. Develop analytic tool based on spreadsheet models for the ATN;
4. Use existing proprietary tools for subnetworks and routers where they are available;
5. Initiate research into actual application requirements in terms of expected data traffic flows, peak data volumes, transit time peak maxima and timings and other parameters for each application. Determine the overall constraints for each application. This is a significant and large task, the results of which are used in both analytic modelling and in simulation.
6. Initiate research into the availability of subnetwork capacity and router capacity available from the market, and determine their throughput/transit time delay characteristics;
7. Establish an Operational Context for the ACCESS region which specifies precise throughput, scope and transit time delay requirements;
8. Establish a framework for allocation of target parameter values (e.g. maximum allowed transit time delays) among the ATN operational authorities.

3. Future Work In ACCESS Part 1

The ACCESS phase 2 - part 1, second sub-phase will study various ATN implementation issues not addressed in the first sub-phase. It will consist of the following Work Packages and last from March 1998 to August 1998.

Work Package Number	Work Package Title
WP209	Selection of Routing Architecture
WP210	Analytical Modelling
WP220A	Air/Ground Subnetwork Deployment Scenarios
WP220	Third Party Service Provision
WP221	Operational Scenarios
WP222	Security Issues
WP223	Safety Assessment/Certification
WP224	Institutional Issues
WP225	Accommodation of FANS-1/A
WP226	Life Cycle Costs
WP227	System Management

The outcomes of this phase will be presented in the ACCESS Interim Deliverable 2.

4. Conclusion

In this first phase, the ACCESS project allowed to generate fundamental technical discussions on the architecture of the future European ATN between some of the main actors of the European ATC (NATS, DFS, STNA, Eurocontrol) and to build a number of concrete proposals as regards the design of the Target ACCESS ATN. Although it was difficult to get firm conclusion on every aspect, it is expected that a consensus on open issues (e.g. routing organisation, possible VDL deployment scenarios) be reached between ACCESS participants, as well as in the scope of the ATN Implementation Task Force (ATNI-TF), before summer 1998. This will then result in a complete proposal for the architecture of the target ATN network for year 2010 in the ACCESS region.

ACRONYMS

AAC	Aeronautical Administrative Communications
ACARS	Aircraft Communications Addressing and Reporting System
ACC	Area Control Centre
ACCESS	ATN Compliant Communications European Strategy Study
ADS	Automatic Dependant Surveillance
AFTN	Aeronautical Fixed Telecommunication Network
AIDC	ATC Interfacility Data Communications
AIS	Aeronautical Information Service
AMHS	ATS Message Handling System
AOC	Aeronautical Operational Communications
ATC	Air Traffic Control
ATCC	Air Traffic Control Centre
ATIS	Automatic Terminal Information Service
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
CIDIN	Common ICAO Data Interchange Network
CM	Context Management
CPDLC	Controller Pilot Data Link Communications
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
FIS	Flight Information Services
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
ODIAC	Operational Development of Initial Applications of A/G data Communication
PSN	Packet Switched Network
RD	Routing Domain
RDC	Routing Domain Confederation
RVR	Runway Visual Range
SARPs	Standard And Recommended Practices
SIGMET	Significant Meteorological Information
VDL	VHF Digital Link
WAN	Wide Area Network

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[A202]	ACCESS/STNA/202/WPR/002 - Define geographic area + Services - ATN Data Link Services in the ACCESS Area - Version 2.0 (5 March 1998)
[A203]	ACCESS/STNA/203/WPR/009 - Define Network Topology - Routing Architecture - Definition of the European ATN Routing Architecture - OPTION 1- Version 2.0 (5 March 1998)
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