CEC TEN-T ATM Task UK/96/94

ACCESS

ATN Compliant Communications
European Strategy Study

Selection of Routing Architecture

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1. Introduction

1.1 Scope

The ACCESS (ATN Compliant Communications - European Strategy Study) Project, which is part funded by the EUROPEAN Commission, is being undertaken by NATS, STNA and the DFS. Part of this project involves the design of a target ATN Architecture for a core European Area in the year 2010. Whilst working on the Routing Architecture Work Package for this proposed ATN Internetwork, two options for the Routing Architecture were developed. A meeting was held to enable European ATN Routing experts to discuss the pro's and con's of each option and then to select the preferred Routing Architecture for Europe.

1.2 Purpose of Document

This document will provide a summary of the two routing options and an overview of the issues raised during the Routing Workshop. The selected Routing Architecture will be recommended in the Final ACCESS Report to the European Commission. Further, the selected Routing Architecture will be passed to the ATNI-TF for adoption by EUROCONTROL and the European States

1.3 Background to Routing Workshop

The Routing Workshop was held at the EUROCONTROL Headquarters in Brussels on the 03/06/98. The attendees are listed below and included a representative from each partner of the ACCESS consortium and the authors of the proposed routing options.

Attendees:

Brian Cardwell (BC)	NATS	Stephane Tamalet (ST)	STNA
Michael Coughlin (MC)	NATS	Ian Nicholls (IN)	For DFS
Jean-Michel Crenais (JMC)	STNA	Klaus-Peter Graf	For Eurocontrol

The agreed agenda for the meeting is reproduced at Appendix A.

Prior to the workshop a list of selection criteria was developed to assist in the selection of a preferred architecture. The criteria included factors such as cost, ease of deployment and political acceptability. The list of selection criteria is reproduced at Appendix A.

2. Routing Architecture Options

2.1 Introduction

This section provides a high level summary of the two routing architecture options and addresses some of the issues regarding their suitability not only for the core European states but states 'lying' on the periphery of this core.

2.2 Summary of Routing Architecture Option 1

This option is proposed as the target architecture for the ACCESS Region in 2010.

Option 1 proposes a routing architecture centred around a European ATN Island containing a high level backbone that will carry both routing and data traffic. The European ATN Island can be further divided into smaller ATN sub-Islands containing backbones which will connect to the high level backbone. This option proposes locating the Aircraft Home Routing Domain Confederation for European Commercial Air Transport Operators outside the European ATN Island. The impact of these proposals is an optimisation in the routing performance by minimising the routing traffic.

The internal architecture of the ATN sub-islands includes a route server for sub-islands where more than three backbone BISs are required. This will minimise route convergence delays and reduce the number of ‘hops’ for data packets moving through the backbone. The route server architecture requires the use of a common subnetwork.

2.3 Option 1 Feasibility

This option is not feasible as a first step deployment, however it does as intended address the likely long term routing requirements for the ACCESS area and provides valid, practical solutions. The Island / Sub-Island concept ensures the architecture can evolve as the number of users and traffic level increase. Issues regarding transition to this ‘end state’ will be addressed in work package 240 ‘Transition’ and are briefly discussed in section 4 of this document.

2.4 Summary of Routing Architecture Option 2

This option is proposed as the minimum architecture required to satisfy known routing requirements in the EUR Region. It may develop as the ATN in Europe evolves, in particular if routing and connectivity requirements increase. It is not proposed as a target architecture for 2010, as Option 1, but as an evolutionary first step.

Option 2 proposes a routing architecture centred around a European ATN Island in which the backbone acts as a large central routing information base, providing a default route to all aircraft in the event that no other routes are available. Air Traffic Service Operators (ATSO) are assumed to deploy ATN systems or contract out ATN Services which will generally provide direct routes to the aircraft within the ATSO’s area of responsibility. The ATN Island backbone will not be the optimum route and will be limited to one BIS only, hence there will be no need for a route server. The option assumes that a large portion of future ground-ground data communications will be characterised by data exchange with centralised pan-European bodies e.g. CFMU, and there will be no requirement for a fully interconnected structure. IDRP connections would be established between ground BISs to enable identified g-g data traffic to be directly routed rather than via a backbone infrastructure. The tendency is towards a star type topology. This option also proposes the locating of the Aircraft Home Routing Domain Confederation outside the European ATN Island, for the same reason as mentioned in section 2.2 above.

2.5 Option 2 Feasibility

This option provides an appropriate architecture for States with limited existing data communications infrastructure, i.e. no access to a core transit network. It is a first step in an evolutionnary process towards Option 1 in those areas which choose to implement a core transit network for inter-organisation data exchange. It is anticipated that the transition from an Option 2 architecture towards an Option 1 architecture would occur once the volume of data exchanged in the area will have reached a certain level (to be determined with experience). At that time, a more distributed Backbone built upon a core transit network for inter-organisation data exchange may be required, such as the one proposed in Option 1.

2.6 Issues Affecting Selection

This section provides a summary of the main issues raised during the Routing Workshop and deemed important to the selection procedure. There was, however, general consensus that there are many similarities between the two options with Option 1 being an 'End State' solution, and Option 2 being more evolutionary in nature, requiring modification as more users come 'on line'.

2.6.1 Definition Of The ATN Backbone.

In Option 1 the backbone will provide transit facilities for both routing information and data packets between islands, sub-islands and individual organizations. In Option 2 the backbone is primarily perceived as a route information pool, providing a default route for mobile users in the event that no other route is available; the backbone would not be implemented to provide ground-ground data transit services inter-organizations, but will be used for ground-ground communications with central pan-European facilities, such as CFMU, EAD, and other information pools which are expected to be implemented in the frame of advanced ATM concepts. This is considered to be the most likely initial deployment scenario for the ATN given the existing and proposed data communications infrastructure within the European region.

The choice of the routing architecture is therefore very dependent on the role that is expected to be played by the ATN backbone : Option 2 is not the most appropriate architecture, if the ATN backbone has to convey ground-ground data (production) traffic between organizations. Conversely, Option 1 is an over-dimensioned architecture if the role of the ATN backbone is limited to the provision of default (backup) routes for air-ground communications.

2.6.2 Cost Of Building A Transit Backbone

It may be difficult to justify the cost of building a transit backbone to enable ATN deployment within Europe. However, Option 1 would provide a suitable architecture for the States which already have access to a core network; this is the case for most of the States in the ACCESS Region (There are developments under way to provide connectivity between the European X.25 networks owned by ATSOs). Initially the routing and data traffic levels would not justify the route server architecture and only one or two backbone BISs would be required. It would be relatively easy to transition to the route server architecture as the number of BISs increases. Option 1 describes a target architecture for the European ATN of year 2010. Option 2 provides an appropriate architecture for States with limited existing data communications infrastructure, i.e. no access to a core transit network, and a first step in an evolutionnary process towards Option 1 in those areas which choose to implement a core transit network for inter-organization data exchange.

2.6.3 Development Of Route Server

The development of the route server option (Option 1) would require the IDRP NEXT HOP parameter to be mandated in a standard ATN air/ground router. This is the 'next hop' facility; it allows the route server to process only route selection and to not participate in the forwarding of data.

3. Routing Architecture Conclusions

1. Option 1 is a suitable 'end state' target architecture for the European region covered by the ACCESS study, provided that :
   - the traffic levels and user demand are sufficient, and
   - a common core transit network is available or being established.

   The use of an architecture with smaller sub-islands and a router server in other parts of Europe needs to be validated.
2. Traffic levels and user demand permitting, Option 2 could be developed into the 'end state' architecture proposed in Option 1.
3. The transition issues raised from (1) and (2) above will be addressed in the ACCESS Transition work package.
4. Option 2 would be an appropriate architecture for States who have no requirement for a core ATN backbone supporting the exchange of production traffic.
5. There are currently plans to provide connectivity between X.25 networks owned by ATSOs, e.g. CAPSIN and RENAR. This has the potential to provide a common core subnetwork for the States in the ACCESS geographical area. This will 'tie in' with the architecture proposed by Option 1.
6. Agreement will need to be reached as to the status of the ATN Island backbone; is it a default route for mobile users or a core network forwarding routing and data packets ?
7. Both options require the backbone equipment i.e. route server (Option 1) and backbone BIS (Option 2) to have a very high availability.

4. Transition Issues

4.1 Introduction

The results of the workshop concluded that Routing Option 1 is the recommended target architecture for the ACCESS region and Routing Option 2 could be an evolutionary first step towards this target architecture or provide an alternative approach where limited traffic requirements or communications infrastructure exist.

In the discussion of the two options, it became necessary to clarify the transition issues pertaining to the evolution of the European ATN from an Option 1 Routing Architecture initially deployed in the core ACCESS States, to the complete deployment of the ATN in the whole European Region. The concern was to demonstrate the extensibility of the routing Option 1 from the core ACCESS area to other parts of Europe.

Although these transition issues were initially foreseen to be considered in the scope of the Transition Work Package (WP240), it was felt useful to anticipate the answer to any possible questions on the applicability and suitability of the Option 1 routing architecture for the Northern and Eastern parts of Europe.

The objective of this section is therefore to provide complementary information on the Option 1 architecture addressing transition issues and extensibility of the proposed solutions to the whole European Region.

4.2 Overview of the Option 1 architecture proposed for the ACCESS area

The Option 1 architecture considers that ATS Organisations will generally not offer their ATS-dedicated ATN networks to serve as a **transit** network for AOC or long distance ground-ground ATSC traffic (i.e. ATSC traffic between non-adjacent ATSOs), and will more likely rely on an ATN backbone and/or on existing international subnetworks for multi-national communications. The backbone is then perceived as a key element for the global routing performance within a region, and Option 1 assumes that European ATSOs will intend to be directly interconnected with this backbone.

Option 1 recommends to optimise the performance of the backbone by using 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 benefits of a route server include optimal routing, the minimisation of the number of router interconnections and it avoids the routing stability problems inherent to meshed topologies.

As a baseline proposal, Option 1 recommends the use of a route server in the backbone for the distribution of routes to backbone routers. The proposed routing architecture within a European subregion (such as the core ACCESS) area is illustrated by Figure 1.

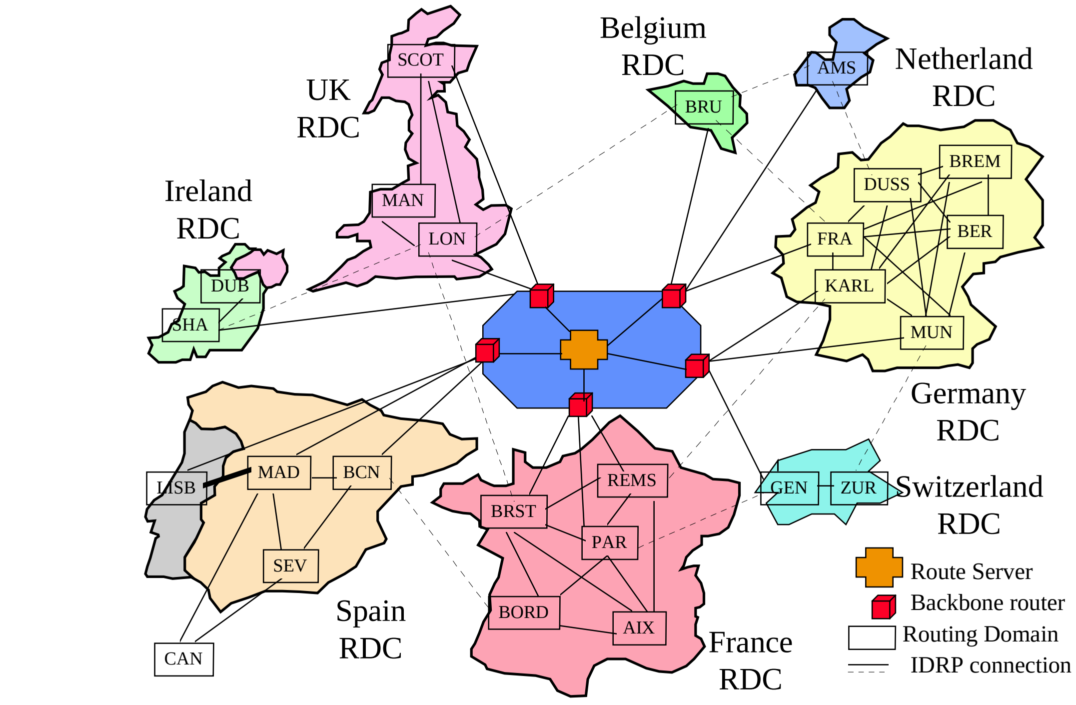

Figure 1: Option 1 proposal for the basic ATN architecture in the core ACCESS area

The use of a route server will allow the deployment of backbone routers close to (within) the national domains, and consequently it will allow 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 deterrent point of the Option 1 backbone architecture is that the use of a route server necessitates the availability of common multiple access subnetwork interconnecting the route server and all client backbone routers. In the Western part of Europe, this proposition is practical, considering that a common international X.25 network (resulting from the interconnection of the national ATSO networks) will soon be available.

4.3 Extensibility of the Option 1 architecture

4.3.1 General

The concern that may arise from the deterrent point mentioned in the paragraph above, relates to the suitability of this architecture in the European areas where a common international subnetwork is not available, and to the possibility of expansion of the European ATN beyond the core ACCESS area.

It is proposed to address this issue through a case study: it is assumed that the ATN has been deployed in the Western part of Europe according to the Option 1 recommendation, and as represented in figure 1 above; the case of another European country, outside the core ACCESS area (e.g. Norway), and willing to implement an ATN infrastructure interconnected with this Western European ATN can then be considered: it is assumed that this country implements ATN routers (i.e. BISs) and is willing to interconnect one or several of these BISs to the existing European ATN backbone. It is additionally assumed that this country has no direct access to the common international X.25 subnetwork in use in the core ACCESS area.

4.3.2 Scenarios for the expansion of the European ATN

4.3.2.1 Introduction

The objective of this section is to study how a European country could be interconnected to the ATN infrastructure already deployed in the Western part of Europe according to the Option 1 architecture.

Four possibilities exist for achieving the interconnection of a new European country to the European ATN infrastructure already in place:

1. Direct interconnection of a BIS of the country with an existing backbone BIS via a leased line or any existing subnetwork.
2. Extension of the ATN backbone : implementation of a new backbone router close to the new country, and interconnection of this backbone router with a BIS of the country.
3. Extension of the international X.25 subnetwork and interconnection of a BIS of the country with the ATN backbone, using this subnetwork.
4. Interconnection of a BIS of the country with a BIS of another country already participating in the European ATN.

The following sections describe each of these different possible scenarios.

4.3.2.2 Solution 1 : Interconnection of a BIS with an existing backbone BIS

With the Option 1 architecture, the European ATN backbone provides transit facilities for application traffic as well as routing traffic.

If it is assumed that such a European ATN backbone is available in the core ACCESS area, the access for a new country to this ATN network becomes very easy : a simple interconnection of a BIS of the country with one of the backbone BIS is sufficient for providing ATN internet connectivity from any ATN systems of the country to any other ATN systems in Europe or in the world.

This interconnection scenario is depicted in figure 2.

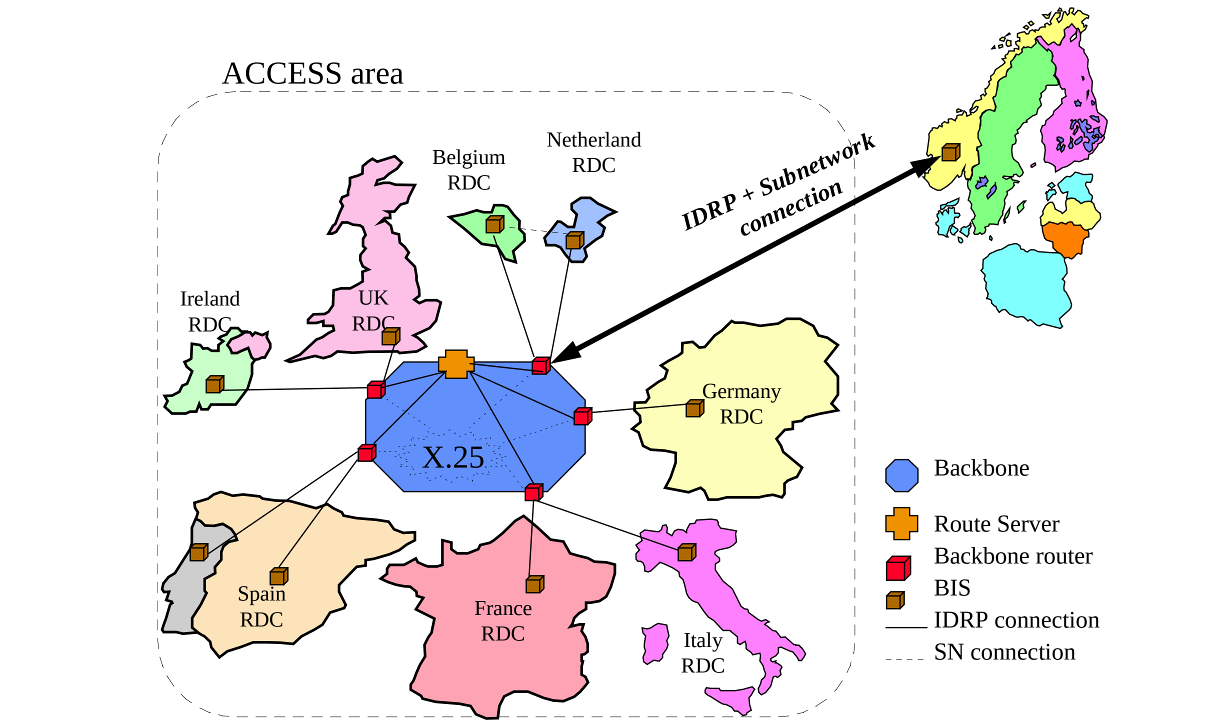

Figure 2 : connection of a new country via Solution 1

The interconnection between the router of the new country and the backbone router necessitates the attachment of both routers to a common subnetwork. If no suitable existing subnetwork is available, a possible solution is to use a leased line, which will then be dedicated to the ATN traffic between the 2 routers. Other solutions may be appropriate: e.g. use of a CIDIN connection, public X.25 networks, etc...

4.3.2.3 Solution 2 : Extension of the ATN backbone

If a group of ATSOs, external to the core ACCESS area, is willing to participate in the ATN, it may become of interest to extend the geographical dimensions of the backbone to the part of Europe where these ATSOs are located. This is depicted in figure 3.

This solution consist in installing a new backbone router close to the set of ATSOs to be interconnected to the European ATN. The new backbone router must be interconnected with one of the backbone routers located in the ACCESS area.

The interconnection between the new backbone router and the backbone router in the ACCESS area necessitates the attachment of both routers to a common subnetwork. If no suitable existing subnetwork is available, a possible solution is to use a leased line. Other solutions may be appropriate: e.g. use of a CIDIN connection, public X.25 networks, etc.

This approach may reduce the cost of the interconnection of a group of ATSOs to the European ATN : it avoids multiple long-range BIS-BIS interconnections between every new ATSO participants and the European backbone, by sharing a backbone segment over which will be multiplexed the ATN traffic of the different ATSOs.

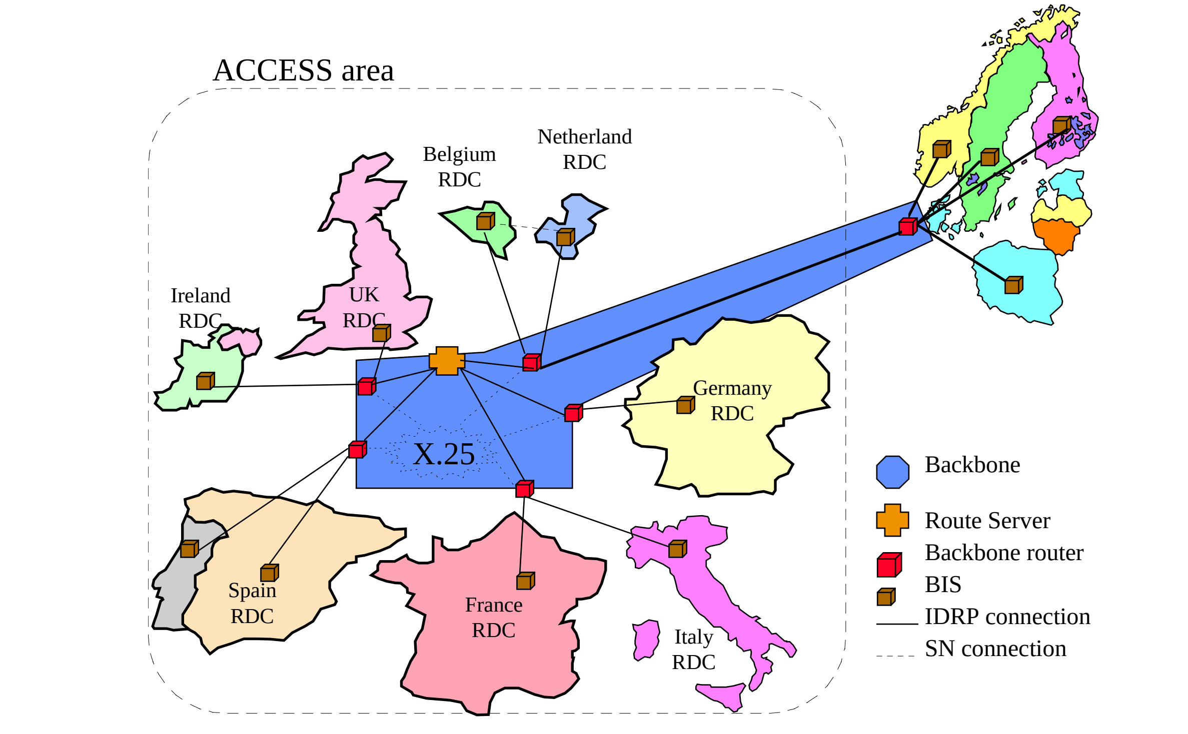

Figure 3 : connection of a new country via Solution 2

Note : the resulting backbone would then be different to the backbone defined by Option 1 since all backbone routers would not be directly connected to the Route Server via a single international X.25 subnetwork. However, this does not preclude it to play its role.

4.3.2.4 Solution 3 : Extension of the international X.25 subnetwork

The approach presented in the previous section allows several ATSOs to share a subnetwork infrastructure which is dedicated to the transport of ATN traffic.

The extension of the international X.25 subnetwork would allow these ATSOs to share a subnetwork infrastructure, used for the transport of the ATN traffic, but also for any other types of traffic (e.g. native X.25 traffic between non-ATN applications, TCP/IP, others).

With the extension of the international X.25 ATSO network, the 2 previous scenarios (i.e. solution 1 & solution 2) may be envisaged for the interconnection of the ATSO to the ATN:

a) The X.25 subnetwork extension can be used to support the interconnection of the ATSO's router with one of the backbone routers existing in the ACCESS area (Fig. 4), or

b) the X.25 subnetwork extension can support the extension of the ATN backbone and the installation of a new backbone router in the new area where the ATN is being deployed. (Fig. 5).

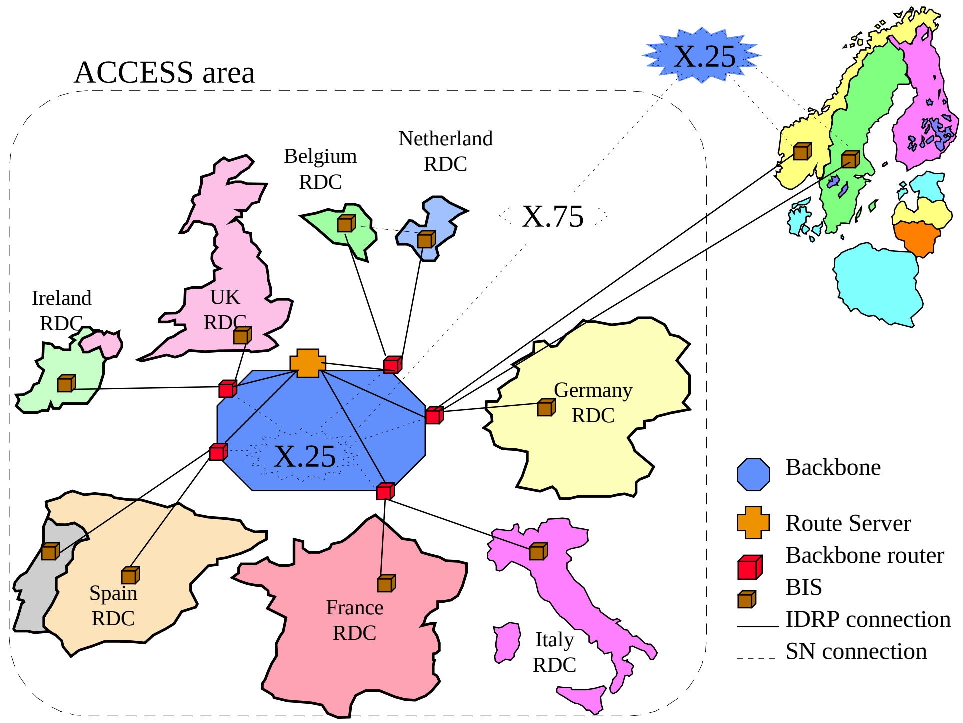

Figure 4 : connection of a new country via Solution 3.a)

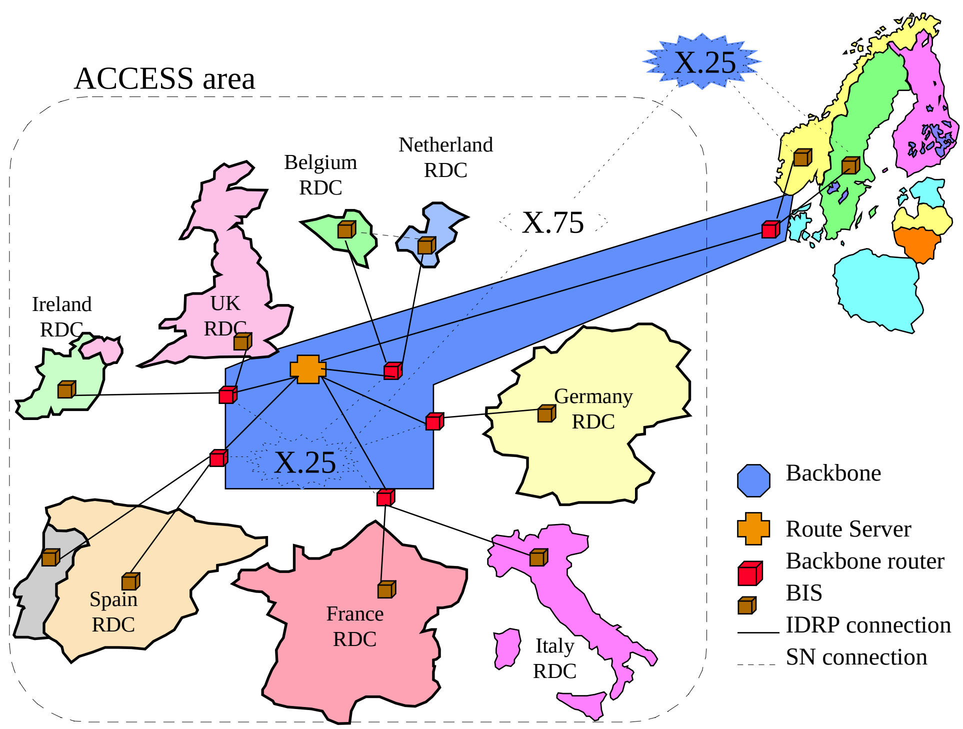

Figure 5 : connection of a new country via Solution 3.b)

The implementation of the ATN within a country cannot justify alone the deployment of an X.25 infrastructure. The extension of the X.25 international ATSO network must only be envisaged if requirements for international communications between non-ATN applications exist and if it is impractical to migrate these applications to the ATN.

4.3.2.5 Solution 4 : Interconnection with a non-backbone BIS of another country

Another possibility for the extension of the European ATN outside the core ACCESS area, is the attachment of new participant ATSOs thanks to their interconnection with the ATN router of an ATSO participating already in the European ATN (see figure 6).

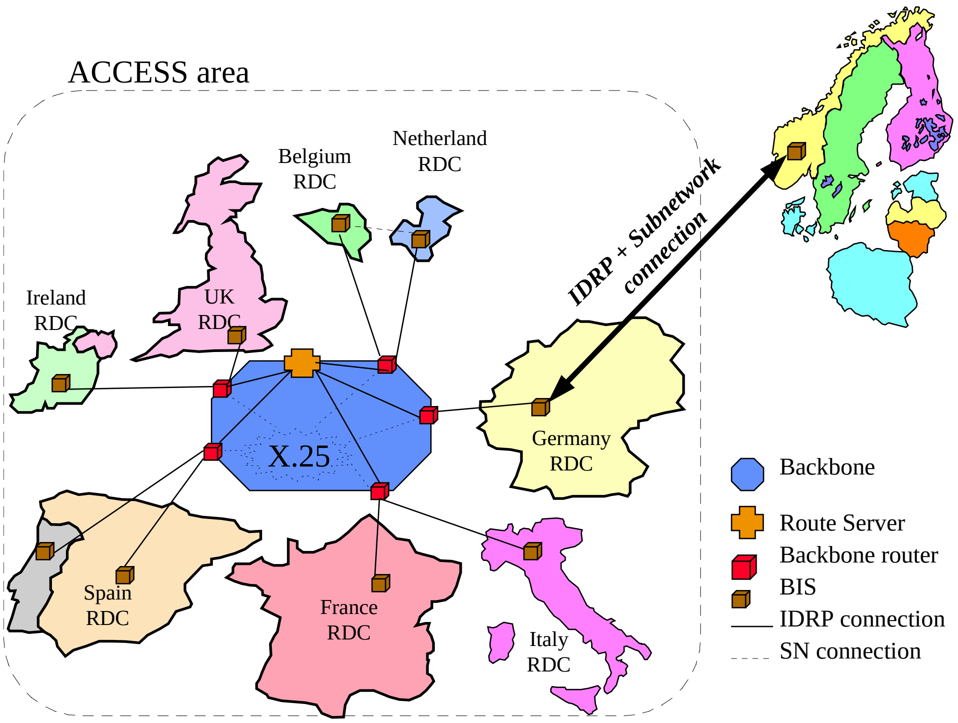

Figure 6 : connection of a new country via Solution 4

With this solution, the new ATN participant is not directly attached to the ATN backbone. Its international ATN traffic transits through the ATN infrastructure of the adjacent ATSO to which it is interconnected.

4.4 Conclusion

The Option 1 routing architecture does not prevent any extension of a core ATN infrastructure in the ACCESS region to the other parts of Europe: there are numerous possibilities for the interconnection of other European ATSOs to the initial European ATN.

The are no preferred scenarios for the interconnection of new ATN participants; the selection of one of the possible solutions has to be performed on a case by case basis, taking into account the existing networking infrastructure, and the ATN implementation plans of the adjacent countries.

It must be noted that the interconnection of a new ATSO to the European ATN is likely to increase the routing and data traffic handled by the ATN backbone routers. With time, and with the interconnection of several additional ATN participants, the increase of traffic may require modifications to the ATN backbone infrastructure. These modifications may consist of the replacement of backbone routers with higher performance systems; they may also consist of the re-organisation of the ATN backbone into a hierarchy of smaller backbones and the partitioning of the European Island into several SubIslands. These solutions for a mature European wide ATN are presented in the Option 1 report.

5. Further Reading

The following reports are recommended for readers wishing to gain a more detailed understanding of the concepts associated with the two routing options discussed in this report:

1. ACCESS WP203 'Definition of the European ATN Routing Architecture Option 1' Issue 2.0 - 05/03/98 Doc Ref: ACCESS/STNA/203/WPR/009

2. ACCESS WP203A 'Definition of the European ATN Routing Architecture Option 2' Issue 1.0 - 09/06/98 Doc Ref: ACCESS/NATS/203A/WPR/045

6. Appendix A : Routing Workshop Agenda

1. Workshop Introduction
2. Review of proposed agenda and time allocations
3. Overview of Routing Architecture Option 1
4. Overview of Routing Architecture Option 2
5. Review of proposed selection criteria
6. Development of proposed/additional selection criteria
7. Application of selection criteria to Options 1 and 2
8. Summary of selection discussions
9. Agree selection of recommended Routing Architecture
10. Next steps / further work (if applicable)

7. Appendix B : Routing Workshop Selection Criteria

1 Scaleability of Architecture

- Number of BIS - BIS Connections per Router

2 Routing Updates

2.1 Per flight (ATC and AOC)

- A/G exchanges
- G/G exchanges
- Trans-national A/G exchanges
- Exchanges with adjacent Regions

2.2 Ground Applications (ATC and AOC)

- G/G exchanges
- Trans-national G/G exchanges
- Exchanges with adjacent Regions

2.*3 Speed of Convergence*

3 Impact on the use of Routing Policies

- Aircraft Operator Homes (commercial / GA)

4 Failure Modes

- Distribution of routing information
- Re-advertisement of routes
- Speed of re-convergence
- Knowledge of network failure conditions (e.g. line failure)

5 Compliance with IDRP standard / availability of suitable routers

6 Impact on avionics complexity

7 Ease of Deployment

- ‘Big-bang’/Phased/Evolutionary
- Availability of required ground infrastructure

8 Relative Costs

- Of the routers
- Of the routing traffic
- Use of a backbone versus point-to-point links

9 Political

- Location/ownership of routers