CEC TEN-T ATM Task UK/96/94

ACCESS

ATN Compliant Communications

European Strategy Study

Ground/Ground Subnetworks

Document Reference	: ACCESS/DFS/204/WPR/002
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Revision Number	: 1.0
Date	: 4 April 1998
Filename	: D002I1-0.DOC

DOCUMENT CONTROL LOG

Revision Number	Date	Description of Change
0.1	19 July 1997	first draft containing only Chapter 2
0.2	21 September 1997	inclusion of NATS and STNA comments and other material
0.3, 0.4	October 1997	internal versions
0.5	5 January 1998	inclusion of Eurocontrol and DFS comments; oriented to the “option 1 routing architecture”
0.6	30 January 1998	editorial changes as a result of STNA comments (mainly sections 2.2.3, 3.2 an 3.3); additions necessary for an “option 2 routing architecture, Sections 2.6 and 3.7.
1.0	4 April 1998	first published version; based on Version 0.6 including some editorial changes

EXECUTIVE SUMMARY

The document provides a description of the ground subnetworks to be used for interconnection of ATN intermediate and end systems.

It consists of two main parts:

- a description of general principles to be used in selecting ATN subnetworks and
- proposals for implementation of subnetworks connecting the ATN routers and end systems defined in WP203.

Together with the results of Work Packages 203 and 205 the document defines the ACCESS architecture for the ATN, targeted for the 2010 time-frame.

The recommendations made in this document are dependent on the ACCESS routing architecture defined in WP 203 and are intended to be compatible with the decisions made there. These include the possibility of an “option 1” architecture based on a route server concept and of an “option 2” which may necessitate a high-capacity core subnetwork.

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1. Introduction

1.1 Scope

The document covers a range of topics considered relevant to ground subnetworks to be used for implementing the European ATN.

1.2 Purpose of Document

Together with the results of Work Packages 203 and 205, the document defines the ACCESS architecture for the ATN, targeted for the 2010 time-frame. It provides a description of the ground subnetworks to be used for interconnection of ATN intermediate and end system and provides criteria for making choices in individual cases.

1.3 Document Structure

The document is divided into two main parts:

- First, general principles relating to the use of ground subnetworks are discussed (Chapter 2).
- Secondly, applying these principles, and based on the routing architecture defined in WP203, recommendations are made for the choice of subnetworks in implementing the European ATN (Chapter 3).

The way in which these two parts relate to the results of other Work Packages is shown below in Figure 1.

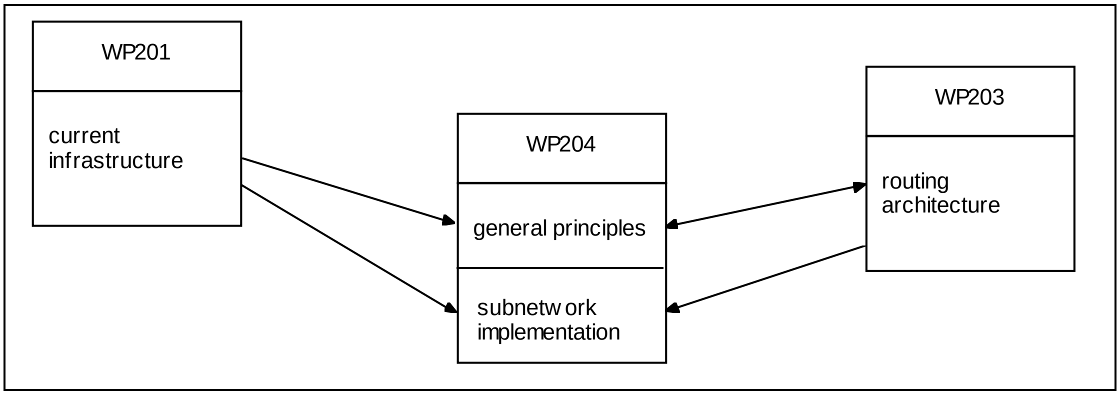

Figure 1: **Relationship of the parts of this document to other WPs**

The level of detail provided here is dependent on the information given in WP201 and WP203. It is assumed that the information on current infrastructure is complete. Uncertainty is associated however with the future developments in national infrastructures leading up to the implementation of the European ATN. The routing architecture defined in WP203, currently based on a “route server” concept (Option 1), is determined to a large extent by the results of WP202 and WP205. In turn it provides the “boundary conditions” for the treatment of ground networks in this document. The discussion here cannot extend beyond the framework set up in WP203 and a greater level of detail would be of little value.

1.4 References

Reference	Title
[Axxx]	ACCESS WPxxx
[EAT16]	Report of EATCHIP COMT Drafting Group on the Feasibility of ATSO Data Network Service Integration, undated (June 1997 ?)

2. Principles for the Choice of Subnetworks

In this chapter, basic principles for the choice of ground subnetworks to be used in the implementation of the ATN are discussed.

2.1 Use of Existing Infrastructure

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 the associated investments in them are unavoidable.

2.1.1 Common Use of Subnetworks

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 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 - see Figure 2 - 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.

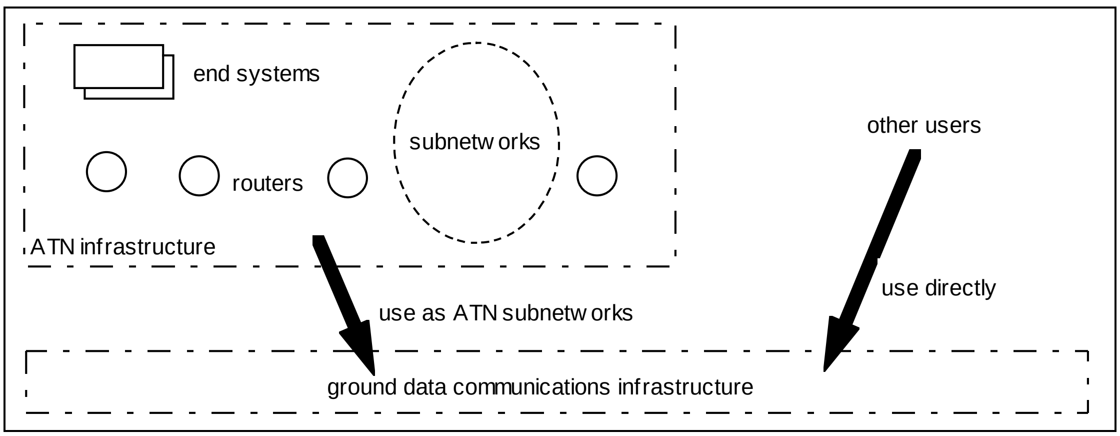

Figure 2: The common use of data communications infrastructure (schematic)

ATSOs and Aircraft operators have in recent years placed considerable investments in ground data communications, as described in WP201. These organisations cannot be expected to set up an additional subnetwork infrastructure dedicated to the ATN.

This common usage of ground data communications infrastructure by the ATN simultaneously with other users is only possible with network technology which allows multiplexing. This is true of most network types including, for example, packet switched networks and LANs which provide a network service inherent to the network. It is not true of leased lines where the link and network levels are implemented by the (non-ATN) user. Without additional multiplexing equipment, it is not possible to let multiple systems use leased lines.

2.1.2 Recommendation

During the early stages of the ATN implementation, the utilisation of ground subnetworks by the ATN is likely to be low. It also appears unlikely that ground-ground applications might “drive” the development of the ATN. For the reasons described above, subnetworks which allow simultaneous use by the ATN and by non-ATN applications should be preferred to those dedicated to the ATN. This implies the use of existing infrastructure where possible. Later, when the ATN has developed further, the use of subnetworks dedicated to the ATN may be more easily justifiable.

2.2 Predominance of Packet Switched Networks

As described in WP201, the majority of national and regional data networks currently maintained by ATSOs is based on packet switched technology which appears to be ideally suited to use by aeronautical applications.

2.2.1 Properties

Some of the advantages of packet switching in this environment are:

- mature technology with standardised network access protocol and addressing
- possible network service provision to many users simultaneously,
- high availability and robustness and adaptable to varying network loads,
- switched connections which make flexible usage possible,
- equivalent service available from other, e.g. public, service providers for backup, and
- appropriate service in terms of data rates, data integrity, etc.

However the successful and economical use of PSNs is subject to a number of restrictions which are outlined in the following.

2.2.2 Will Packet Switched Networks still be Predominant in 2010?

Packet switching is already an old technology: the X.25 recommendation has a history of 20 years and major manufacturers of data networking equipment have gone through several generations of systems supporting the standard. The question as to whether packet switching will still be technically relevant in 2010, the time frame for the ACCESS target architecture, is valid.

The answer to this question appears to be affirmative for the following reasons:

- Aeronautical applications (with the possible exception of radar message transfer) are not particularly demanding with respect to bandwidth: data rates which can be handled by PSNs are currently sufficient.
- Over ten years have passed since the original deployment of national aeronautical PSNs. Current planning is projected into the coming five years. With few exceptions, there are no plans for the implementation of aeronautical WANs based on other technologies.
- The upgrading of PSNs to more modern WAN technologies such as Frame Relay and ATM is offered as migration options by suppliers of PSN networks. Alternatively, more modern network technologies can be made backward compatible to PSNs by providing X.25 based services. This fact tends to make PSNs even more ”future proof” removes handicaps to their deployment.

Further, X.25 as a data communications interface is well incorporated into the ”ATN culture”, being used, for example on the A/G datalink. However the inability to cope with higher data rates is one aspect which must be considered carefully – see the following section.

2.2.3 Restriction on Data Transmission Rates

Data transmission rates which can be handled by packet switching technology are inherently restricted. This is due to the relatively large amount of processing (of packets, frames) in the network nodes due to the functionally rich link and network protocols. The processing overhead, when compared with the transmission time, becomes increasingly unfavourable when data rates increase. At data rates above 512 kbps, packet switching no longer remains viable: window sizes must be increased drastically and the quality of the physical transmission must be very high in order to take advantage of the higher data rate. This would appear to be a very inefficient use of packet switching technology.

For higher data rates, other switching technologies (frame switching (frame relay) and cell switching (ATM)) must take its place. The question arises as to whether this represents a serious restriction on the use of PSN as ATN subnetworks.

For current aeronautical data applications 512 kbps appears to be a very generous upper limit on data transmission rates. However this is, no doubt, partly due to the fact that when applications were designed, no higher capacities were available. It cannot be ruled out that in the time up to the implementation of the European ATN considered within ACCESS (2010) ”bandwidth-hungry” data applications may come into existence for which this restriction is serious. In addition, subnetwork connections must potentially be able to handle the traffic associated with a number of parallel applications (or application associations).

On the other hand, it would not, at this stage, appear feasible to propose the introduction of new network technologies if the concrete need has not been demonstrated. The only current example of high speed connections is the coupling of LANs with frame relay. However this does not qualify as an ”ATN application”. In addition, voice applications are not foreseen for the ATN. Any ”bottleneck” restricting data transmission rates is more likely to be found in the routers than in the subnetworks. Problems in the network capacity can be more easily circumvented by planning more subnetwork connections and subnetwork resources rather than a change in technology.

For these reasons it is concluded that the data transmission rate inherent in packet switching technology does not represent a serious restriction. If, as proposed in the EATCHIP Comms Strategy, there is a need to anticipate a tenfold increase in traffic requirements, then the restriction may have to be avoided by the use of other switching technologies. However there will be smooth upgrade possibilities to these.

2.2.4 Quality of Service

The ATN internet makes, in principle, rather low demands on the quality of service provided by its subnetworks (subnetwork service): the necessary high level of service quality end-to-end is provided at the transport level. To a certain extent, the quality of service provided by PSNs is wasted when they are used in a purely national environment as ATN subnetworks since the quality of service is supplied again at a higher level. This represents a waste of resources (mainly processing resources).

This is considered to be the price which has to be paid for the standardisation and general usability of PSNs. While a PSN is used as an ATN subnetwork, it can be used in parallel in a non-ATN way. As a consequence, the all important economies of scale – see section 2.2.6 below - come about. This conclusion is different in the case of internationally interconnected PSNs – see section 2.3.

2.2.5 Importance of Network Node Location

It is important to note that the advantages of packet switching technology in the aeronautical environment listed in Section 2.2.1 above are of value only when the PSN access node is close to its user application. In the ATN context, this means that an ATN router using a PSN as a subnetwork should be in the vicinity of the PSN access node. Otherwise, as shown in Figure 3, case (b), the disadvantages of dedicated leased lines arise. Then there is probably little advantage in using the PSN when compared with the alternative of connecting routers with leased lines.

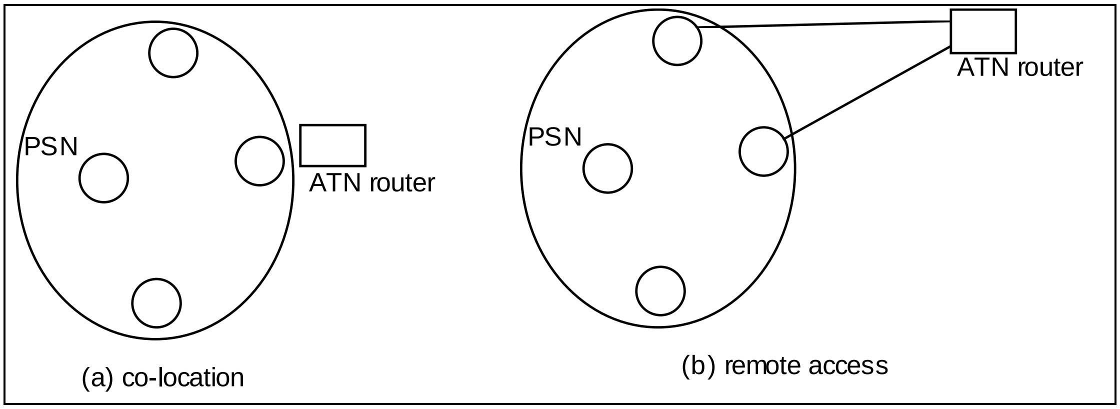

Figure 3: Access by an ATN router to a PSN

A recommendation of a PSN as an ATN subnetwork, is only appropriate when the PSN access node is in the vicinity of (better: is co-located at) the ATN router being supported. The use of long leased lines for PSN access should be discouraged.

2.2.6 Economies of Scale

Notwithstanding all its advantages, data communication via PSNs causes a significant amount of processing and transmission overhead associated with the handling of packets and frames and is, in general, more costly than the use of networks of leased lines, assuming that these can be utilised to a high degree. Packet switching becomes economically viable only when a certain minimum amount of traffic is carried by it. The economic advantages become most apparent when the applications, each of which would not be able to consistently utilise dedicated resources, generate traffic in a stochastic fashion. This is likely to be the case with PSNs as ATN subnetwork because of the application mix. At the same time, there is the possibility of their use by non-ATN applications.

The common use of PSN by the ATN (as subnetworks) and by other users supports the network designer's goal of attracting as much traffic as possible away from dedicated leased lines onto a PSN. On the other hand, the geographical extension of PSNs so that they can support the ATN as subnetworks must be investigated on a case-by-case basis. For example, the extension shown in Figure 4 would - on the face of it - not appear to be a sensible use of the PSN as an ATN subnetwork: the use of dedicated leased line might be more appropriate. There is apparently a trade-off between the need to locate PSN nodes close to their main users (e.g. ATN routers) and the need to avoid dedicated extensions to PSNs.

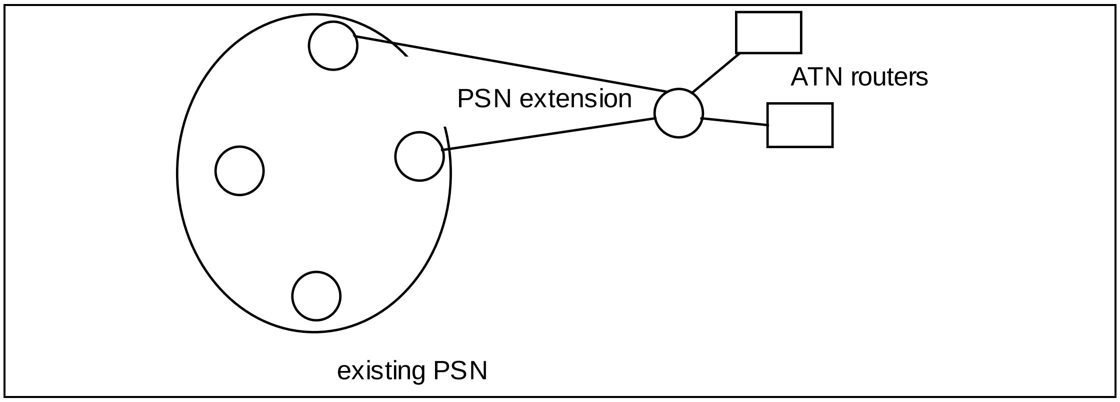

Figure 4: Unsuitable PSN extension to provide subnetwork service to ATN routers

2.2.7 Recommendation

The discussion in this section shows that, where possible and subject to a number of caveats, ATN IS should be connected within countries by means of existing national PSNs. In some cases this may necessitate the extension of the existing networks, however this is considered preferable in general to the introduction of new networks. The suitability of PSNs for providing a subnetwork service internationally is considered in the next section.

2.3 Interconnection of Packet Switched Networks

With the operation of PSNs by an increasing number of European ATSOs, the question of interconnection of the PSNs has been ”on the agenda” of States for a number of years. It is relevant to the selection of ATN subnetworks.

2.3.1 The two Interconnection Possibilities

Standard interfaces to PSNs exist only on the boundaries of the networks as X.25 and X.75: interfaces internal to the network between network nodes are proprietary and not standardised. For the interconnection of two or more national PSNs two general possibilities exist:

- if two PSNs are made up of equipment from the same supplier and use identical internal protocols between nodes, the two networks can be merged and treated as though they were one network (case (a) in Figure 5); the requirement that the protocols be identical refers to production protocols, administration, network management, etc.;
- PSNs can be connected on their boundaries by means of the protocol X.75 which, as a symmetric version of X.25, is primarily intended for this purpose (case (b) in Figure 5); a common addressing scheme, e.g. X.121, is necessary.

By means of these interconnection possibilities, two or more PSN can be combined to form a larger PSN which could function as a larger ATN subnetwork. The interconnection of the constituent PSNs using ATN routers is not considered here because, in this case, each PSN forms an ATN subnetwork in its own right - see section 2.3.3.

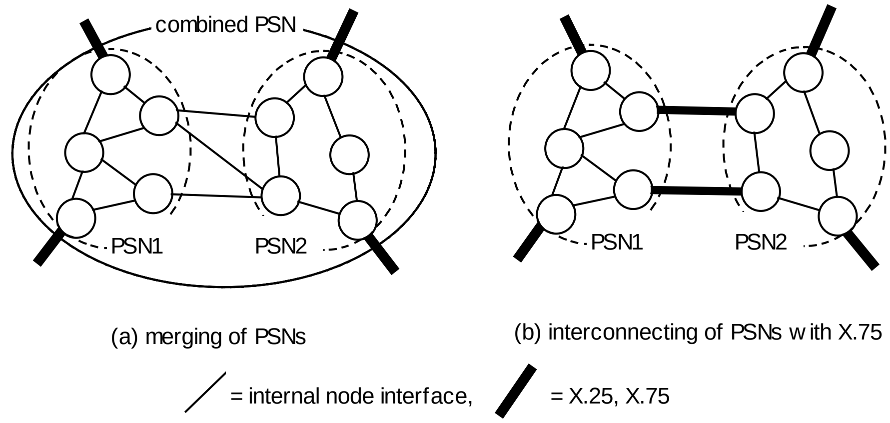

Figure 5: Two general methods for interconnecting PSNs

2.3.2 Comparison

The implementation of RAPNET which is made up of merged national (+ Eurocontrol) PSNs corresponds to case (a). The merging is possible because all equipment is based on Nortel DPN100 products. Because of the high level of meshing between the two PSNs, the functionality and the quality of service provided by the combined PSN is equivalent to that provided by each of the PSNs individually.

Other existing and planned interconnections in Europe correspond to case (b). In general, the functionality and the quality of service provided by the interconnected networks are inferior to that of the individual networks. For example, only limited meshing is possible (2 connections in Figure 5) and so the availability of virtual calls traversing the two networks is not as good as with a properly meshed network; no *automatic* rerouting by the networks is possible should one of the X.75 connections go out of service. X.75 (as a symmetric version of X.25) has no means of conveying information about virtual calls on other links. However each PSN can automatically configure its routing tables and when the X.25 virtual calls are re-established by its users, the networks can use alternate X.75 links.

X.75 gateways are known to be ”bottlenecks” with limited throughput in many PSN implementations.

When more than two PSNs are interconnected in this way, these properties tend to become amplified since the probabilities of outages increase. In this case, an intermediate PSN, say, in a chain of three PSNs might have to transport transit traffic, making network dimensioning difficult and introducing other institutional issues.

The use of merged or X-75-interconnected PSNs as ATN subnetworks is logically equivalent to the use of any single PSN. In the case of merged PSNs, no additional considerations have to be made concerning the quality of service provided by the subnetwork; in the case of interconnected PSNs, the suitability would have to be decided on a case-for-case basis. In both types of interconnection, ATN traffic is carried between ATN routers on specific virtual connections which, in principle, do not interfere with other virtual connections being used simultaneously for other network applications.

2.3.3 Interconnection of PSNs with ATN Routers

Although not directly relevant to a choice of ATN ground subnetworks within the ATN router architecture, it is interesting in this context to compare the PSN interconnection technique with the internet approach followed by the ATN for providing European-wide data networking capabilities.

2.3.3.1 Comparison with Interconnected PSNs

Current activities aimed at interconnecting national networks are intended to satisfy urgent operational requirements with short-term solutions. Such requirements stem, for example, from the need for additional international OLDI/SYSCO connections without implementing leased lines. The planning is being performed by an EATCHIP COMT working group [EAT16]. It is interesting to note that the working group is coming up with many questions which will have to be dealt with within the scope of ACCESS (administration, security, management, …).

Because of the short-term nature of that planning, no considerations are being made on the ATN. One significant consequence is that the network solutions being investigated use PSN merging and interconnection as discussed in this section. This approach can be described as a ”connection-oriented” solution because data transfer between applications is performed within the context of network connections.

In strong contrast with this, the ATN is based on a ”connectionless” network service in which network data units are passed independently through the network: a connection context, if necessary, is established on the transport level. The ATN can take advantage of PSN interconnection as described in this section by using the interconnected PSNs as subnetworks. However apart from this, the two approaches have little in common.

National PSNs can be integrated *by means of ATN routers* rather than the *ATN routers using the connection-oriented PSN interconnection* as currently being planned and widely implemented. In this case, the users of the network service have to be implemented according to ATN SARPs in ATN end systems, requiring a migration of existing applications.

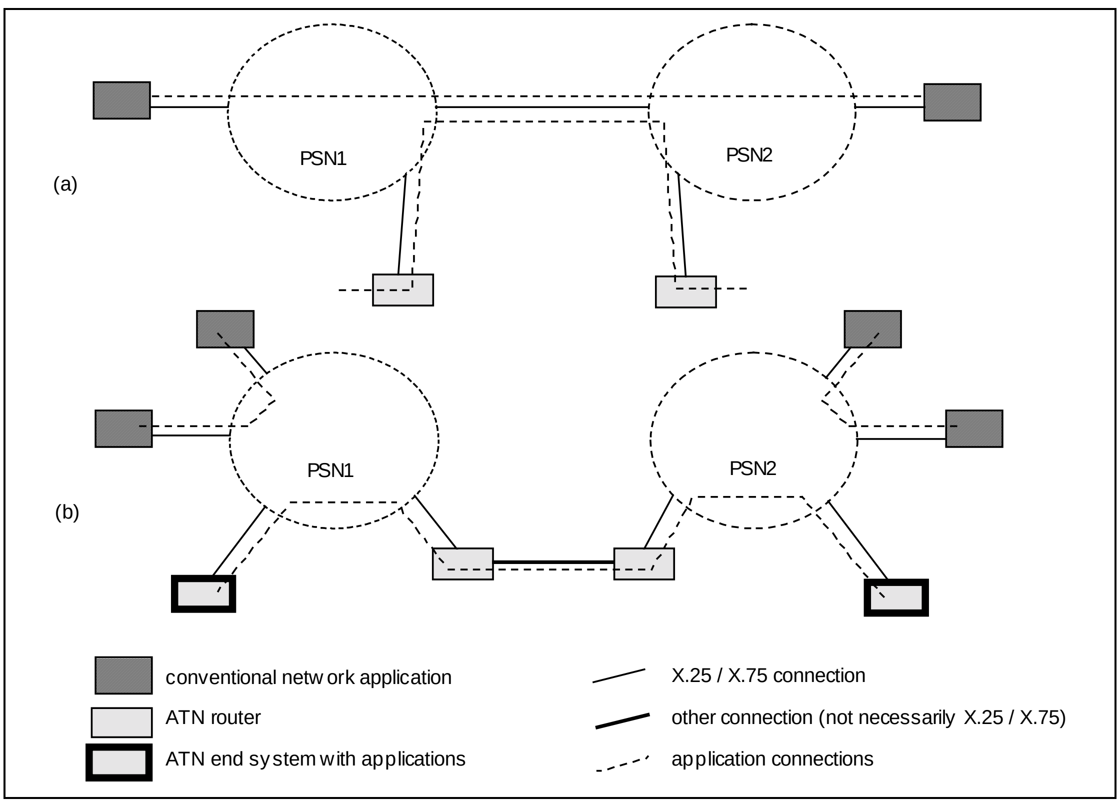

Figure 6: PSN interconnection by means of ATN routers (b) and the current approach (a)

The two approaches are compared in Figure 6. Case (a) shows two conventional systems, e.g. computer systems implementing OLDI, communicating via interconnected PSNs. Also shown here is the way in which the interconnected PSNs can be used as a subnetwork to connect two routers. Thus a leased line used for the PSN interworking is also used indirectly for connecting the routers. In case (b), the PSNs are not connected directly and each remains a separate subnetwork from an ATN point of view. The physical connection between PSNs is replaced by the physical connection (subnetwork) connecting the two ATN routers. No changes are necessary for conventional applications using just one PSN. However those which span the two PSNs have to be implemented in ATN end systems. Note that, from a technical point of view, one ATN router would be sufficient in case (b). However two might be required for institutional reasons. During a transition period there will likely be a mix of the approaches (a) and (b), in particular for interfacing among regions using different techniques.

The so-called ATN approach, considered as a long-term solution for the interconnection of remote ground sites, is probably technically superior to the connection-oriented approach. However, the PSN interconnection can perfectly be integrated in an ATN network and is already well advanced in the ACCESS region in support of communications between existing applications. In the so-called ATN approach, all this environment would have to migrate rapidly, this being a major effort driven only by technological constraints rather than by applications' requirements.

2.3.3.2 Rationale for Proposing the Use of Interconnected PSNs

The interconnection of PSNs by means of ATN routers is rejected here as the possible primary approach for building up an ATN subnetwork infrastructure in the ACCESS region.

This is partly due to the benefits to be gained from the ACCESS routing architecture (Option 1) defined in WP203 in connection with the route server concept. In addition, the following points should be taken into consideration:

- PSN interconnection is already extensively deployed and in use.
- Native X.25 based applications will continue to exist and there should not be a requirement on these to migrate to the ATN.
- Investment in PSN interconnection must be protected, i.e. continued to be used.
- Interconnected PSNs can be used by the ATN: there is no need to set up an additional subnetwork infrastructure.
- The superiority of the interconnection via ATN routers is perhaps more theoretical than practical. It may take a long time before the ATN routers have the same switching performance as the existing X.75 gateways.
- The means used in the ATN to detect the failure of links, i.e. IDRP, is not necessarily superior to those employed in PSN interconnection. IDRP as specified by ISO is not designed to react very quickly to faults. In the ISO10747 standard, the faults are detected thanks to the expiration of the KEEPALIVE timers; this means that link or adjacent equipment failures are normally detected only after some times when no answer has been received from the adjacent equipment.

The situation *outside of the ACCESS region*, e.g. in northern or eastern Europe may well be different: a well established PSN infrastructure may not be available there and the appropriate strategy may not involve PSN interconnection.

2.3.4 Possible Migration to Higher Capacity Switched Networks

It has been concluded above that (interconnected) PSNs are ideally suited for ATN ground subnetworks. The only major uncertainty concerning their usefulness is their overall throughput.

Other switching technologies, Frame Relay (frames) and Asynchronous Transfer Mode (cells), are available to upgrade the PSNs favoured in this analysis. The fact that the quality of service provided by these technologies (cell/frame loss, data integrity) is inferior to that of PSNs is not significant because of the rather low quality demands made by the ATN internet on its subnetworks.

Preconditions for the usefulness of such networks as ATN subnetworks include:

- The locations requiring high capacity connectivity are all served by the network. In the case of international WAN that will result from the interconnection of national PSNs, this includes all national gateway locations.
- In the case of switched services, the probability that calls can be set up is high.
- The quality of service with respect to cell/frame loss and data integrity is sufficient.

Networks which might satisfy these requirements are currently in the planning phase.

2.3.5 Recommendation

PSNs should be used where possible for international subnetwork connections among ATN routers. This recommendation is valid without restriction for merged and X.75-connected PSNs. In the case of X.75 interconnected PSNs, the quality of service provided must be carefully considered.

2.4 LANs

LANs form an important part of data communications infrastructure operated by ATSOs and Aircraft operators and are necessarily candidates for ATN subnetworks.

2.4.1 Importance

Almost every computer installation makes use of LAN technology for interconnecting various computer systems and peripherals over distances up to several hundred metres. If ATN routers are foreseen at more than one location at such an installation, then the LAN would, in addition to its other modes of use, e.g. with IP - see next section -, have to provide an ATN subnetwork service.

Because of their limited geographical coverage (by definition), a LAN is restricted to one physical location and questions of interconnection such as those discussed in Section 2.3.1 do not arise with the same importance. LANs will also only find their way into the ATN on its ”periphery”, i.e. will not be found on major trunk routes such as on a backbone. Decisions on the choice of LANs as subnetworks therefore do not have the same strategic significance as those for wide area subnetworks and are not of central importance to the ACCESS architecture. Such decisions can be taken by individual States without having to be co-ordinated with other States.

2.4.2 Interfacing the ATN with TCP/IP Networks

LANs are standardised up to the level of their link protocols. On top of these, the TCP/IP protocol suite is used almost universally. Applications are likely to be distributed on different computer systems linked by a LAN. Depending on which protocol suite (ATN or TCP/IP) is run by these computer systems, two implementation scenarios are possible as shown in Figure 7. In this figure, the “ATN transport gateway” converts at the transport level between ATN protocols and TCP, the “conventional end systems” are systems using TCP/IP for communication but interacting with remote end systems on the ATN.

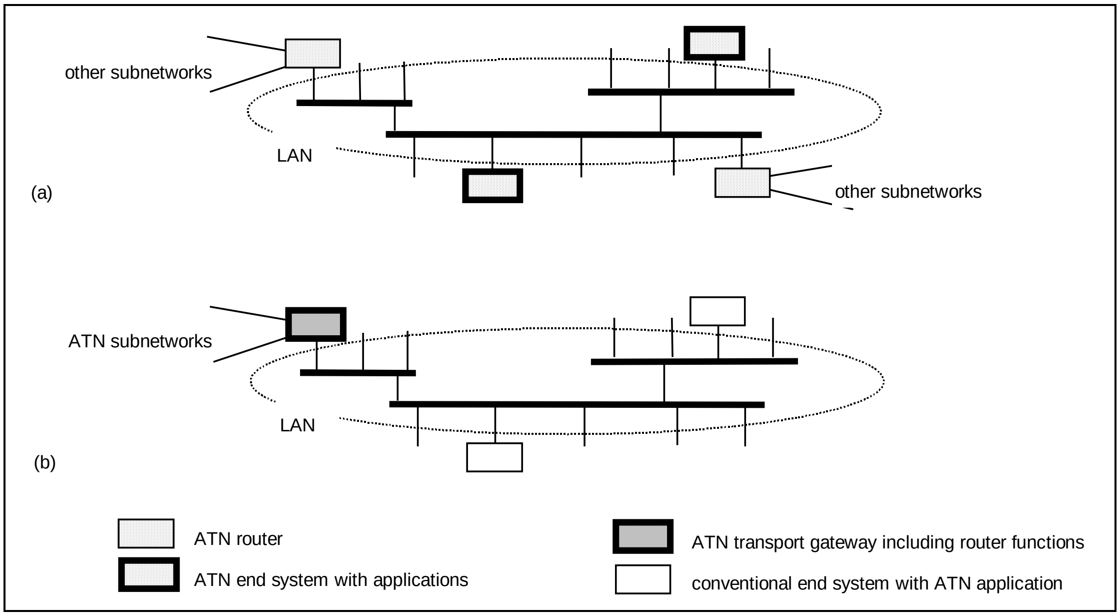

Figure 7: LAN as an ATN subnetwork (a) and a transport gateway to the ATN (b)

In those cases where applications are run over TCP/IP, the use of an ATN/TCP/IP gateway is required if interoperability with remote ATN End Systems is necessary. The protocol architecture of an ATN-/TCP/IP transport and/or application gateway is shown in Figure 8.

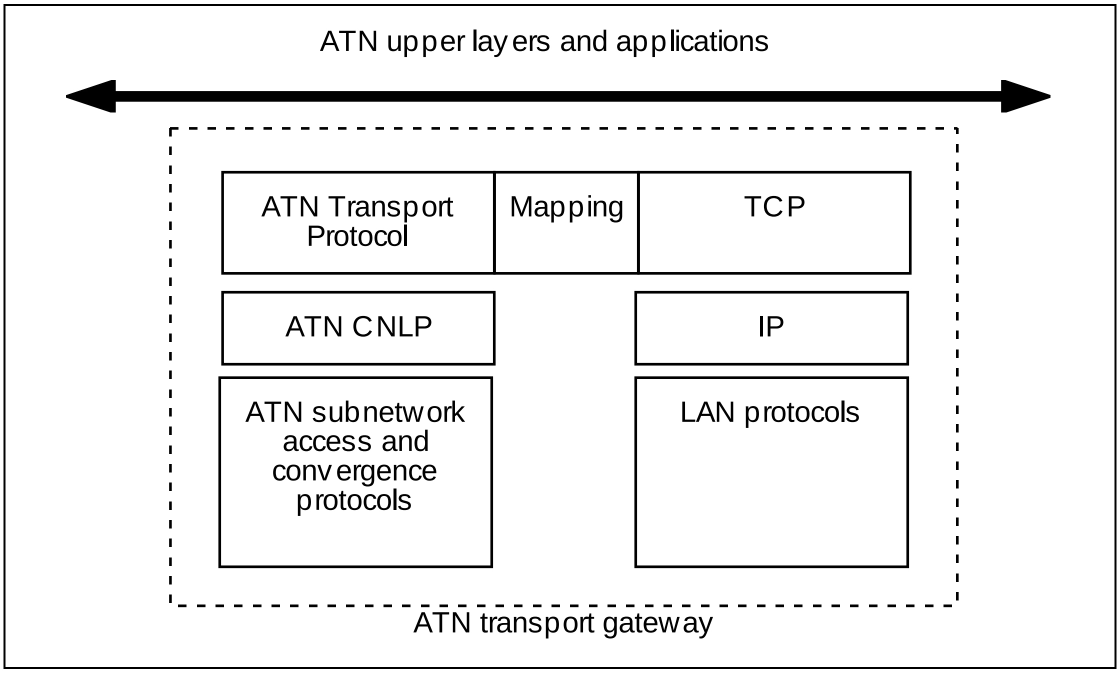

Figure 8: Protocol architecture of an ATN/TCP/IP transport gateway

2.4.3 Recommendation

Depending on the local area communications infrastructure in the various countries, LANs of different types will be necessary as ATN subnetworks. However choices on these do not play a strategic role to the same extent as for wide area networks. In some circumstances, it may make sense to convert between ATN protocols and TCP/IP in a transport and/or application gateway.

2.5 Dedicated Leased Lines

In the preceding sections, the importance of simultaneous use of networks directly by conventional applications and as ATN subnetworks has been underlined. However there may be cases when the use of leased lines is justified.

2.5.1 Indications for Using Leased Lines

The term "leased line" is used to mean a permanent or dial-up point-to-point connection with a well defined quality of service and leased from a telecommunications provider. A dial-up line would have to be semi-permanent in the sense that connection establishment is rapid, e.g. less than or of the order of 0.1 seconds.

Only the interface and the quality of service provided by the supplier is relevant to the discussion here because the user normally has no influence on the way the connection is implemented in the supplier's network. Quality of service includes the availability of the connection, perhaps also correlated with the availability of (an) other connection(s).

Connections implemented via satellite also fall into this category. However in the European context they are considered to be of little importance.

Leased lines have the disadvantage, that without additional multiplexing equipment, they cannot be used simultaneously by different applications. Their use may not be easy to justify during the early life of the ATN when traffic levels are low. Further, leased lines possibly represent single points of failure in the routing architecture and appropriate means of back-up would have to be implemented. However the following situations may be indications for their use:

- 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.

2.5.2 Protocols

The protocols to be run on the leased lines between a pair of routers would have to be chosen suitably. A candidate would be LAP-B/HDLC, assuming it can be supported by the routers.

2.5.3 Leased Line Back-up

Figure 9 shows three means of backing-up a dedicated leased line:

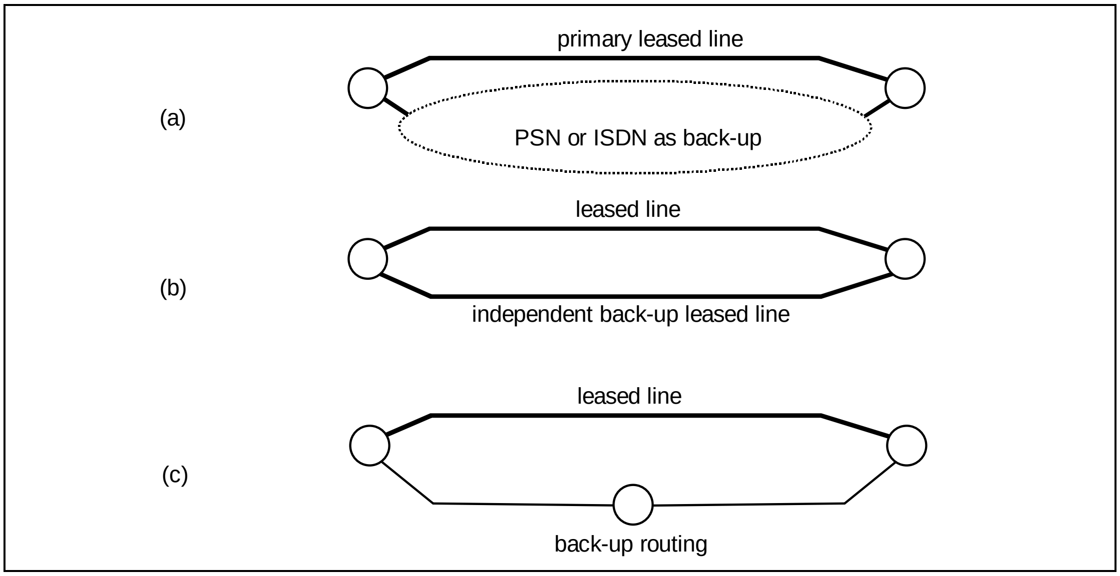

Figure 9: Methods of backing-up leased lines

The three methods are:

- case (a) shows back-up by means of switched connections on a PSN or ISDN with automatic switchover;
- case (b) shows leased lines in parallel; here there would have to be a guarantee from the provider of the lines that they follow completely separate paths through the network or at least that the probability of failures on both lines together is acceptably low;
- case (c) shows how the low availability of leased lines can be allowed for in the router architecture; router and line capacity would have to be able to cope with traffic with one line outage.

Combinations of these methods are possible.

Figure 10 shows the common use of a leased line using a multiplexing technique. Such a configuration might be feasible if a leased line network with free capacity is available.

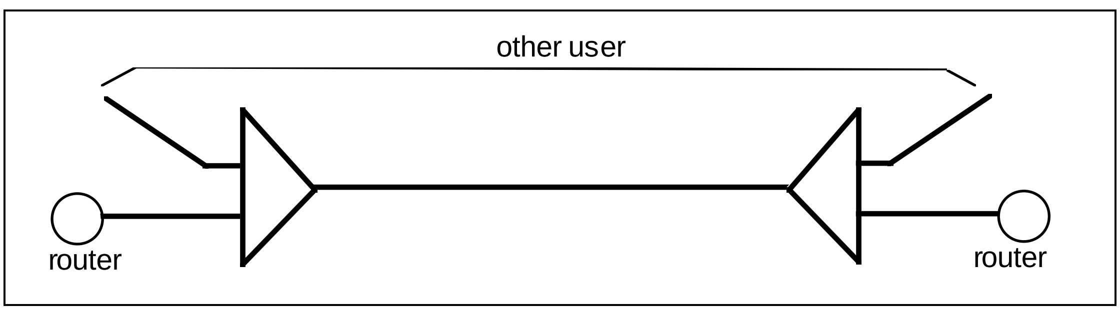

Figure 10: Possible use of multiplexers in connection with leased lines

2.5.4 Recommendation

When one or more of the indications or possible advantages listed in this section are present, the use of dedicated leased lines with suitable subnetwork protocols and possibly with multiplexers should be considered. However it is important to take into account the relatively low availability and reliability of fixed point-to-point connections.

2.6 Possibilities for a Core Subnetwork

The discussion above has treated all possible subnetworks as being equally important for the ATN as a whole, i.e. as being of the same status or on the same network hierarchical level. However it may be advisable in some circumstances to implement a “core subnetwork” as described below.

2.6.1 Definition

The term “core subnetwork” in this context is taken to mean the following[1]

- The subnetwork is “central”, i.e. a core, in the sense that other, more peripheral subnetworks are connected to it via routers,
- It is a principal purpose of a core network to interconnect other (more peripheral) subnetworks rather than providing subnetwork points of connection for End Systems. The possibility of the latter is, however, not excluded.
- The core network should attract as much traffic in the ATN: any traffic which could usefully be passed through the core network, thus reducing the load on peripheral subnetworks, should be routed in this way.

Although this is by no means a formal definition, it is sufficient to characterise this special class of subnetwork as shown schematically in Figure 11. Note that interfaces between the ellipses of Figure 11 are implemented by ATN routers and end systems.

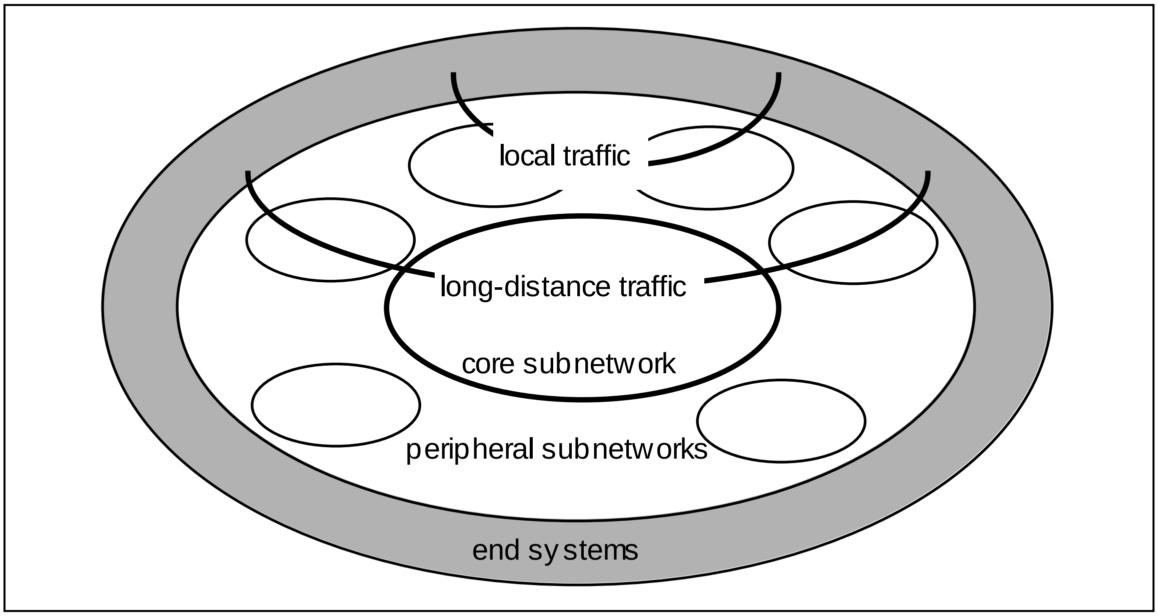

Figure 11: Schematic representation of the function of a core network

2.6.2 Requirements

The following is a list of requirements which would apply to a core subnetwork:

1) **provision of subnetwork service:** This obvious requirement follows from the fact that the core subnetwork is an ATN subnetwork and must conform to ATN SARPs. The

[1] The term “backbone” would obviously have been preferable; however it is already in use in connection with the routing architecture and it would have lead to confusion here.

level of service provided must be appropriate and it must be possible to define and implement the access protocol in ATN routers.

2) **possible stepwise expansion:** It is likely that the core subnetwork will have to be a “green fields” implementation which - partly because of the requirements listed here - cannot be derived from existing or currently planned subnetworks. For this reason the initial implementation will probably be small and it will have to be expandable in small steps.

3) **possible expansion to high capacity:** Because of the role and importance of the core subnetwork as evident from Figure 11, no inherent limitations in the transmission capacity are tolerable.

4) **extremely high availability:** The availability requirements are due to the central importance of the core subnetwork: the long-distance functioning of the European ATN may depend on it. All possible threats to the availability must be considered (technical, natural catastrophes, terrorism)

5) **not restricted to data transmission:** In order to set up a business case for the implementation of a core subnetwork, it may be necessary to consider the transmission not only of data traffic on it. Economies of scale may have to be taken advantage of and these may not be possible only with data transmission. The provision of voice transmission services, although not within the scope of the ATN (and therefore not a mandatory requirement), could be an effective way of achieving economies of scale.

6) **use of future proof, modern technology:** The decision to implement a core subnetwork dedicated, in part, to the ATN would be a cornerstone of a long term European aeronautical communication strategy. The technology chosen for the core subnetwork would have to have a foreseeable lifetime of (say) at least 20 years.

These requirements are derived from general considerations. They would apply to the Routing Architecture (Option 1) in those areas where no other ATC WAN possibilities exist. In the case of the Routing Architecture (Option 2), the core network has more of a backup function and not all of these requirements need apply.

2.6.3 Technical Options

Four network technologies are considered below as options for the implementation of a core subnetwork in the light of the requirements listed in Section 2.6.2.

2.6.3.1 Packet Switching

This technology has been dealt with at length in this document and must be considered a candidate for a core network.

1) **service:** The X.25 access protocol is a well-established option for the ATN

2) **expansion:** Packet switching networks are well adapted to this requirement.

3) **capacity:** Significant restrictions apply to the maximum feasible speeds of individual virtual connections - see section 2.2.3. However such restrictions do not apply to the PSN as a whole and sufficient capacity could be provided for a core subnetwork.

4) **availability:** Availability can be provided up to any given level at reasonable cost.

5) **voice transmission:** Packet switching is (by definition) a data networking technology and, although possible, is economically not suited to voice transmission.

6) **future proof:** In section 2.2.2 it was argued that packet switching is future proof up to a time frame of 2010. However this is probably not true for longer time frames and it would seem to be too much of a risk basing an ATN core subnetwork on packet switching.

2.6.3.2 Frame Relay

Frame relay, in some senses a successor to packet switching techniques, currently enjoys enormous success in the implementation of corporate networks. For this reason alone, it must be considered a candidate for a core subnetwork.

1) **service:** The Frame Relay service (at link level) is a well-established solution for subnetworks between routers in general. It could therefore be a suitable option for the ATN.

2) **expansion:** Frame relay does not suffer from any significant restrictions in this respect although the minimum size network is larger than in the case of packet switching.

3) **capacity:** No restrictions are apparent.

4) **availability:** The possible maximum availability of individual connections is, in general, not as good as for packet switching (depending on the techniques used internally in the frame relay network). However this can be allowed for at the level of the ATN internet since the possible overall availability of a frame relay network is sufficient.

5) **voice transmission:** Frame relay is well suited to voice transmission.

6) **future proof:** Frame Relay technology is very likely to be available for about 20 more years and therefore meets this criterion.

2.6.3.3 Subnetwork of leased lines

The possible use of leased lines as subnetworks has been considered in section 2.5. However there the emphasis was on their isolated use, e.g. for backup purposes. The intensive use of leased lines in a core subnetwork might justify the setting up of a carrier network based, for example, on SDH or other proprietary multiplexer technology.

1) **service:** An appropriate link level protocol should be chosen and implemented on top of the basic (physical) transmission service.

2) **expansion:** The implementation of subnetworks of leased lines on all scales is obviously no problem.

3) **capacity:** No restrictions are apparent.

4) **availability:** This criterion presents problems for individual connections but not for the whole leased line network assuming that it is configured appropriately.

5) **voice transmission:** Basic transmission is independent of the type of information being transmitted.

6) **future proof:** Transmission technology such as SDH will certainly be available up to and beyond the ATN time horizon.

2.6.3.4 Asynchronous Transmission Mode

ATM has been claimed to be an important network technology for the future because of its adaptability to a wide range of user situations.

1) **service:** A wide range of suitable network access interfaces is normally available on ATM switches.

2) **expansion:** ATM networks can be expanded in small steps. However minimal configurations are relatively powerful and correspondingly expensive to implement.

3) **capacity:** There are no relevant capacity limitations for the ATN environment.

4) **availability:** ATM networks can be configured to provide any given level of availability.

5) **voice transmission:** The contents of the ATM cells are independent of the type of information being transmitted.

6) **future proof:** ATM will probably be available up to and beyond the ATN time horizon.

2.6.4 Recommendation

ATM, Frame Relay and subnetworks of leased lines are network technologies which satisfy the requirements discussed above for a core subnetwork.

One possible problem with ATM is the high relative cost of minimal configurations which would be necessary in the initial stages of the network development.

In the case that a core subnetwork based on Frame Relay or ATM is chosen, leased lines cannot be neglected, firstly, as part of the infrastructure between switches and, secondly, for the possibly long access paths between users, i.e. ATN routers, and subnetwork switches.

It is therefore recommended to use a combination of either Frame Relay or ATM and dedicated leased lines to implement a possible core subnetwork.

3. Ground Subnetwork Implementation

Based on the principles established in Chapter 2 and on the results of ACCESS WP203 and WP205, recommendations are made in the following for the implementation of subnetworks for the various types of IS-IS interconnection required. Six different interconnection cases can be distinguished.

3.1 Interconnection of National IS and ES

According to recommendation 2.2.7, national PSNs should be used for the interconnection of national IS and ES. In isolated cases, leased lines according to section 2.5.4 are acceptable. Within closed areas such as ACCs, interconnection may be via LANs according to section 2.4.

In those cases where an extensive, infrastructure based on LANs with TCP/IP is in operation, the use of an ATN/TCP,IP gateway might be considered for a transition period.

3.2 International Pairwise Connection of BIS

WP203 identifies the possible continuing need for some direct interconnection of BIS across national borders leading to a requirement for direct interconnection of BIS between national RDs. To accommodate these needs, interconnected national PSNs are suitable according to recommendation 2.3.5. If direct connectivity via the interconnection of the national PSNs is not available, leased lines according to section 2.5.4 are acceptable.

3.3 The European-wide Backbone

According to the WP203 option 1 report, in order to benefit from the advantages made possible by a Route Server in the ATN backbone, the backbone BISs must be connected to the same common WAN. Additionally, if other (non-backbone) BISs are also connected to the same common WAN, the advantages of the route server concept are extended to the whole set of ATN routers connected to this WAN. According to recommendation 2.3.5, this WAN should be made up of internationally interconnected national PSNs.

According to that, in the European areas where an international ATC WAN is (or will be) available, it is of interest that the backbone BISs 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, it will be of interest to interconnect the backbone BISs and the route server to another common WAN; in such a case, the deployment of a high capacity backbone subnetwork according to section 2.3.4 may be advisable.

3.4 Aircraft Operators' BIS and ATSO BIS

BIS within the backbone of the airlines' European Homes RDC need to be connected with BIS of the European Region ATN Island Backbone. For this, the services of an IACSP; e.g. SITA, will be necessary.

The subnetworks used within the European Homes RDC are out of scope of this study.

3.5 Other Organisations and ATSO BIS

Other non-ATSO organisations such as MET, airports and military need to interconnect with IS of ATSOs of their country of location. In some cases the connection will be of the form ES-IS if the ATSO is willing to support them from its RD. Otherwise a BIS-BIS interconnection will be necessary.

In general, the national PSN according to recommendation 2.2.7 will be suitable since ATSO switching nodes are located at the other organisation's site. In isolated cases, leased lines according to section 2.5.4 are acceptable.

3.6 Data Link Processor and Ground BIS

In general, the location of the data link processors of the mobile VDL subnetworks as recommended in WP205 will not be co-located with their associated BIS: the former are likely to be at antenna locations and the latter in ACCs. For connecting the two, national PSNs are unlikely to be suitable since the data link processor location, in general, is not served by PSN nodes.

Either leased lines between data link processors and ACC or, alternatively, access lines to a PSN node in conjunction with the PSN will be necessary.

3.7 Implementation of a Core Subnetwork

The implementation of a core subnetwork may be advisable for the following situations:

- There is a large volume of long distance traffic (including routing protocol traffic) which traverses more than two PSNs or other subnetworks.
- The availability requirements placed on individual long distance connections provided by interconnected PSNs cannot be satisfied.
- There is a possibility of economically transmitting types of traffic other than ATN data traffic, e.g. voice, between ATN router locations.
- The coverage made possible by PSN interconnection is not sufficient.

For the implementation, a combination of either Frame Relay or ATM and leased line transmission technologies are recommended in section 2.6.4. It is assumed here that for economic and operational reasons only one core subnetwork would be implemented.

Figure 12**,** Figure 13 and Figure 14 show a possible migration path of a core subnetwork serving a hypothetical configuration of four BIS using ATM technology. It is apparent that this is a far from trivial design problem due to connectivity and availability requirements [2].

1) uses a configuration of simple and multiplexed leased lines,

2) introduces a pair of ATM switches and

3) provides interconnection by means of an ATM subnetwork infrastructure.

[2] Note, for example, that the problems of achieving sufficient availability when accessing a meshed network are the same in the case of an ATM network as with a PSN - see section 2.2.5 and Figure 3.

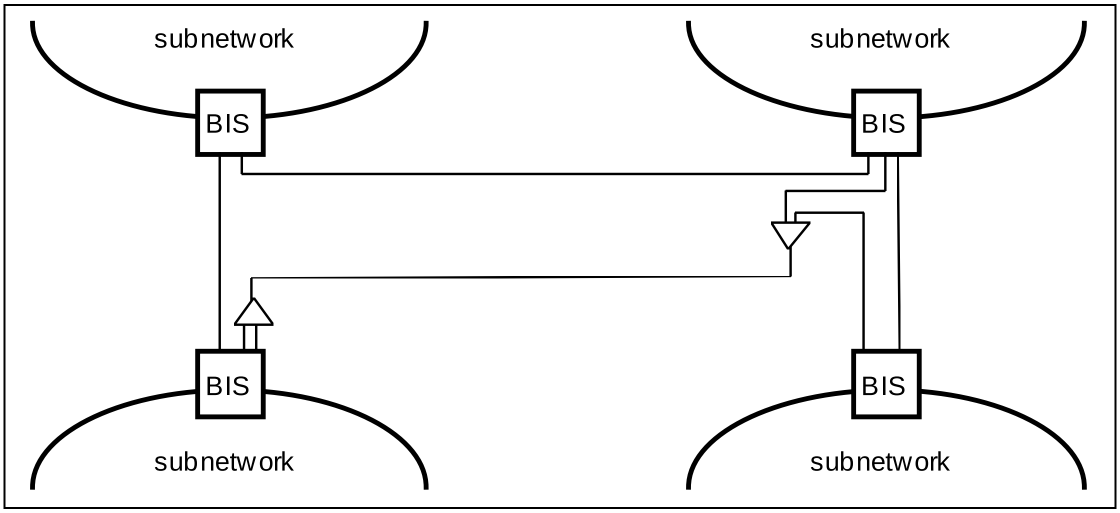

Figure 12: Possible migration path for a core subnetwork (1)

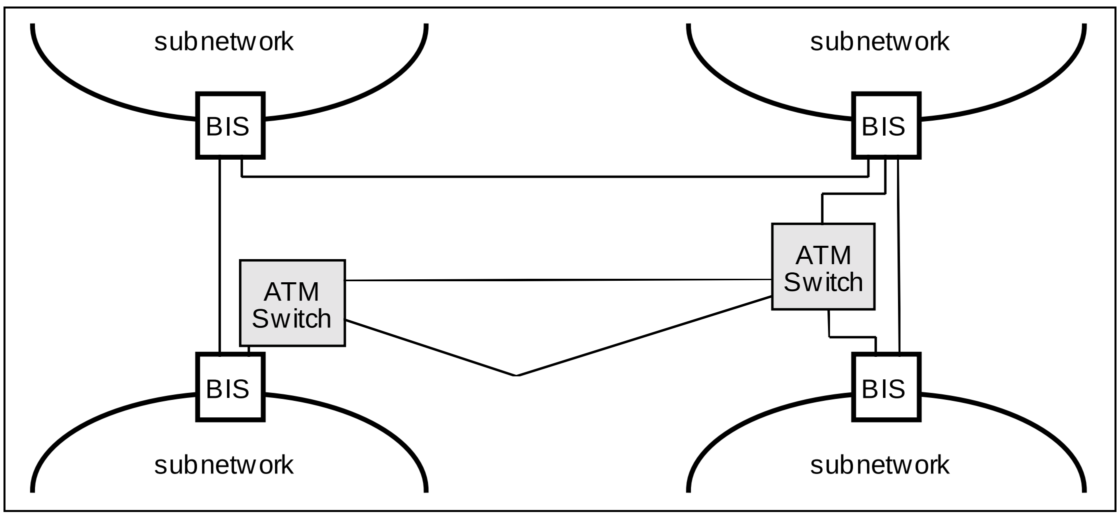

Figure 13: Possible migration path for a core subnetwork (2)

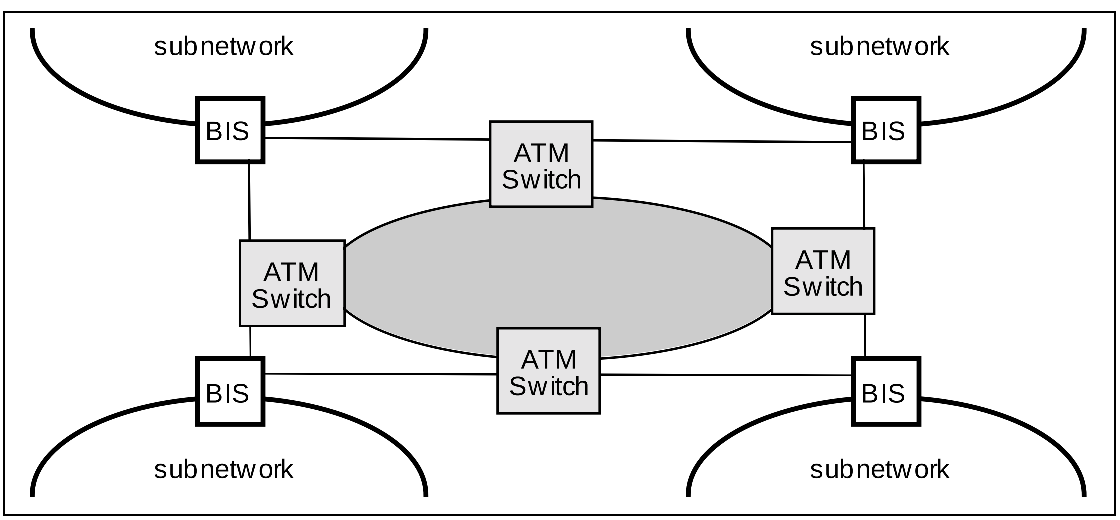

Figure 14: Possible migration path for a core subnetwork (3)

It must be emphasised that a decision to implement a core subnetwork would have to be taken and supported by all participating bodies in the ACCESS Region: the advantages, in particular the economies of scale, would not be worthwhile without a commitment from all participants before implementation begins. This fact is obviously associated with a number of important institutional issues such as ownership, financing, operation etc. of the core subnetwork.

The return on investment of a core subnetwork would be difficult to estimate. The implementation would be a new undertaking dedicated to the development of the European ATN and (by comparison with the use of PSNs by the ATN in addition to their use by existing applications) would require significant investment “up front”. The risks associated with this investment would have to be estimated.