AERONAUTICAL TELECOMMUNICATION NETWORK PANEL

Working Group 2 Meeting

Melbourne, Florida , USA 23 - 27 January 1995

Report of the First Meeting of ATNP WG2 Task Force 2 on CNS/ATM Package 1 Requirements

Prepared by F. Colliver
France

SUMMARY

This paper presents the results and conclusions of the first meeting of the ATNP Working Group 2 Task Force 2 (WG2/TF2). This Task Force was set up by WG2 to develop the specification for the ATN elements of CNS/ATM "Package 1" (i.e. the draft ATN SARPs) for validation by the second meeting of the panel.

REVISION HISTORY

Section	Date	Issue	Reason for Change
	20 January 1995	Issue 1.0	Document Creation
	23 January 1995	Issue 1.1	Modification of references to Appendix A, correction of date errors in actions list, addition of reference to identified problem in use of X.25 priority facility.
Change Marks	27 January 1995	Issue 2.0	Corrections based on meeting review of report.

TABLE OF CONTENTS

Report of the First Meeting of ATNP WG2 Task Force 2 on CNS/ATM Package 1 Requirements

SOF/FWC/D00102/CNA/95

Issue 2.0

Prepared by F. Colliver
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1. Introduction

1.1 Background

ATNP/WG2 has adopted a Task Force approach to the development of draft ATN SARPs. Accordingly, a task force has been set up to develop the specification for ATN "Package 1" i.e. the draft ATN SARPs for validation by the second meeting of the panel. The first meeting of this task force was hosted by the French Administration (DNA) in Issy-les-Moulineux (near Paris), during 14 - 15 December 1994.

1.2 Scope of this Report

This is a report of the first meeting of the Package 1 Task Force. It does not include the discussions that took place on Systems Management, as these took place in parallel to completion of the work on the Package 1 specification.

1.3 Attendance

The following ATNP members and advisors attended the meeting.

Name	Representing	Organization
Forrest Colliver	France	Sofréavia
Jean-Michel Crenais	France	CENA
Michel Perin	France	Thomson
Ken Crocker	USA	MITRE
Ted Signore	USA	MITRE
Greg Oliveau	SITA	SITA
Akhil Sharma	UK	CAA
Martin Adnams	Eurocontrol	Eurocontrol
Tony Whyman	Eurocontrol	MWA

1.4 Meeting Objectives

The subject deliverable for ATNP WG2/TF2 is described in the WG2 report as: "Develop CNS/ATM-1 Internet Package Definition (comprising PRL & definition of mechanisms to support optional non-use of IDRP) and, where necessary, Defect Reports and supporting draft Change Proposals required to support CNS/ATM-1 Package."

In order to produce this deliverable, the meeting focused on resolving differences in detailed architectural and Protocol Requirements List (PRL) proposals on which discussion had begun at the San Diego WG2 meeting. These proposals (primarily from UK, SITA, FRANCE and EUROCONTROL) are to be used to support the production of a joint CNS/ATM Package 1 PRLs document, taking into account as well appropriate aspects (i.e. those aspects related to Package 1) of US deliverable WG2-3 (made available 1 December 1994) . This part of the meeting was chaired by France, as the responsible party tasked with deliverable WG2-2.

Relevant ATNP/WG2 discussion papers considered at this meeting, as noted in the report cited above, include:

1. WG2/WP-25,
2. WG2/WP-35,
3. WG2/WP-37,
4. WG2/WP-12,
5. WG2/WP-19ApH,
6. WG2/Flimsy 1,
7. WG2/Flimsy 2,
8. WG2/Flimsy 3, and
9. WG2/WP-50.

In order to coordinate the work related to deliverable WG2-25 (Systems Management draft SARPs and Guidance Material for Package-1) and WG2-2, separate discussions were held on possible Systems Management (SM) functionalities to be used in CNS/ATM Package 1, as defined during the first part of the meeting. These discussions were chaired by SITA, as the responsible party tasked with deliverable WG2-25. These discussions focused on the choice of Managed Objects, Agent functionalities, SM communication profile and initial SM Applications, and are reported separately by SITA.

1.5 Meeting Agenda

The proposed agenda was as follows:

14 December 1. Introduction and Approval of the Agenda

14 December 2. ATN Internet Proposal for CNS/ATM Package 1

a) Review/Analysis of ATNP/WG2 Documents

b) Review/Analysis of New Input Papers and Deliverables

c) Resolution of Architectural and PRL Issues

d) Preparation of ATN Internet Draft Package 1 Proposal

15 December 3. Systems Management Proposal for the CNS/ATM Package 1 ATN Internet

a) Identification of Required Systems Management Elements

i) selection of initial applications (e.g. topology display, statistics, etc.),

ii) selection of MOs required to support these applications,

iii) selection of required Agent functions,

iv) selection of the supporting communication profile.

b) Preparation of Systems Management Draft Package 1 Proposal

15 December 4. Review and Approval of Draft Material

The agenda was approved as proposed.

Note: Due to the problems in completing the agenda for 14 December, a subset of the attendees continued the meeting on TF2 during 15 December.

2. Summary Report

The objective of the meeting was to agree on resolutions to the outstanding issues concerning the CNS/ATM Package 1 specification, so that a draft specification could be prepared for ATNP WG2. All issues previously identified by WG2 were discussed during the TF2 meeting based on the available input papers, with the main focus on References 1, 2 and 3 above, and many issues were resolved.

However, certain issues remained unresolved at the completion of the task force meeting, and the proposed PRLs draft (i.e. the content of Reference 3 above) was identified by the author (France) as requiring substantial editorial changes from its existing PICS format. Thus, it was suggested by France that the completion of the updated Package 1 specification and the updated PRLs document for review at the March 1995 meeting of Working Group 2 might be more practical, in order to take account of the resulting, possibly substantial, changes following WG2 discussions on these subjects during the January meeting.

Some discussion was expected regarding US deliverable WG2-3 at this meeting. As anticipated, the US provided this deliverable for consideration at the meeting, and the related US position statement is reported below.

During the resolution of the technical issues regarding the Package 1 proposals from France and Eurocontrol, and following the discussion of the US position statement in this regard, an alternative was devised by Tony Whyman to modify the proposed approach for the optional non-use of IDRP in the air/ground environment, in order to allow the use of ITU restricted subnetworks without requiring support for security, as required by the ATN Manual. If approved by the Working Group, this alternative could overcome certain US objections in this area; thus, Tony Whyman was requested to complete the description of this alternative for consideration during either the upcoming WG2 ad hoc meeting, or for consideration during the next full meeting of Working Group 2. An Appendix explaining this alternative as discussed during the task force meeting has been provided by Tony Whyman.

A number of deliverables for WG2 were agreed as objectives. These are:

1. Specification for the procedures employed air/ground when IDRP is optionally not supported over the air/ground subnetworks;
2. Guidance Material in support of Route Initiation including the optional non-use of IDRP; and,
3. A CNS-ATM Package 1 Profile for the ATN Internet support in ATN End Systems and Routers.

During the resolution of outstanding comments further issues came to light on the support of priority by the AMSS, which may also affect usage of Mode S. The problem concerns the fact that PTT X.25 networks are typically used to access the AMSS service and that some states similarly plan to use such networks for access to Mode S. It was reported to the meeting that such networks do not usually support the use of the priority facility and, even when they do, inconsistencies in its transfer have been reported. This compromises the ability of AMSS to support prioritized virtual circuits and may not permit the use of priority on AMSS networks within the Package 1 time frame.

3. Meeting Proceedings

Both Eurocontrol and France had submitted proposals for Package 1 to the ATNP/WG2 meeting in San Diego last October, on which discussion had begun. These were WP/25 (Eurocontrol), WP/35 and WP/37 (France). Further to this, Eurocontrol had prepared a paper identifying the differences between these papers which was submitted to this task force meeting. The US also submitted a position statement (deliverable WG2-3) which was presented to the meeting. The US statement was taken first, followed by the Eurocontrol paper.

3.1 US Position Statement

For the benefit of the meeting, the US position on the proposals discussed in San Diego was summarized as follows:

1. Support is required for ITU restricted networks, and thus a corresponding means for conveying "policy" for the air/ground and ground/ground path is required as well.
2. There must be no requirement or assumption in Package 1 for a globally interconnected ground ATN.
3. The proposal for the optional non-use of IDRP in the air/ground environment is supported.
4. Support for data compression on air/ground data links is required.
5. Package 1 should be validated.
6. Package 1 operational requirements must be documented.
7. The use of IDRP for ATN mobility support remains a US concern. Thus, an alternative strategy will be proposed to WG2 by the US as a "risk management" strategy, should the validation of the use of IDRP to support mobile routing reveal a failure to meet agreed operational requirements.

In discussion, it was agreed that 1, 2, 5 and 6 were common objectives and supported by the states and organizations present. Compression was discussed and once again, the resistance of avionics vendors to compression support was reported. However, it appears that while there is still considerable resistance to V.42bis compression, many vendors now seem willing to consider local reference compression. Given that compression was clearly desirable it was agreed to support the US position on this issue and to propose mandatory support for local reference compression in Package 1. It was believed that this would force any vendors with genuine problems to provide a clear statement of the problem.

Item 7 was noted as being more appropriately in the scope of formal Working Group meeting business, due to its far-reaching architectural and validation implications, and was thus agreed to be outside the scope of the WG2 Task Force 2.

3.2 Comparison of Eurocontrol and French Proposals

Forrest Colliver stated that France would withdraw its proposal for non-support of Capacity and non-support for priority at the Transport Service boundary, thereby resolving two of the outstanding issues. However, based on the long-standing tradition of the aeronautical communication community, this did not prevent a discussion of priority taking place. The following subsections document the conclusions reached on priority, and on the status of the remaining the issues identified in the comparison of the proposals from Eurocontrol and France.

Where agreements have been reached by the task force, the results will be incorporated directly in the draft ATN PRLs and procedural specifications for Package 1, to be prepared by France for the March meeting of Working Group 2. Where issues remain, these issues will be posed to the ad hoc ATNP Working Group 2 meeting to be held in January. If these issues are resolved in a timely fashion, it is

expected that the associated resolutions will be reflected either directly in the Package 1 specification/PRL material, or in appropriate defect reports.

3.2.1 Priority

The conclusion of the discussion on priority was that the ATN Manual is almost certainly defective in requiring not just a fixed relationship (independent of applications) between transport and network priority (Table A5-1 of the ATN Manual), but in also requiring that this mapping is explicitly implemented in the transport layer. The US had reported that the BSD UNIX implementation they were using permitted the specification of network and transport priority as separate parameters at the transport service boundary. This could meet the requirement of Table A5-1, sending data PDUs in the right order through the subnetwork, but did not meet the implementation requirements which, by themselves, have nothing to do with interoperability and appear to be over-specification. This in turn led to a discussion on the use of transport and network priority. It was agreed that the purpose of network priority was to identify the relative priority of data for transmission through the network and to determine access to limited resources. On the other hand, the purpose of transport priority in the ATN was to signal the relative priority of the transport connection between peer applications.

Given such thoughts, there is not necessarily any need for the strict relationship between transport and network priority given in Table A5-1. It was agreed that while Table A5-1 may be a sensible default, applications should be able to specify different mappings if desired.

Conclusion: It was agreed that appropriate defect report(s) should be prepared on this subject.

3.2.2 Security

Eurocontrol and France had proposed two very different approaches to Security in Package 1. Eurocontrol had proposed that support for Security (i.e. the use of Security Types to control routing over ITU restricted networks) be omitted from Package 1, in order to avoid certain near-term implementation problems, while France had proposed that support of Security should be mandatory for End Systems and Routers, with the only relaxation being that routers were permitted to disregard the Security Type. The French proposal would allow later improvement of network capabilities with no modification in end-system capabilities, but would force near-term modifications in commercial implementations. Both approaches implied a degree of partitioning and *a priori* knowledge in the routers in order to work and this aspect was strongly objected to by the US as it would cause problems with their ground topology.

The Eurocontrol position came from a view that support of security would require significant modification to existing End Systems software in order to work and would significantly add to the complexity in routers. Not including Security in the Package 1 specification would help ensure that existing commercial implementations fit more directly the Package 1 definition.

The French position came from a view that avionics development time scales meant that if security was not included in Package 1, it would be a number of years before this capability could be deployed, given design-freeze life cycles of between four and seven years. Therefore in order to ensure the availability of the function in the near to medium term, it must be included in Package 1.

The situation was thus a stalemate, with no obvious middle ground other than including the full ATN specification regarding Security in Package 1 with the associated risk this would entail for commercial product availability in the near-term. An alternative approach was then offered by Tony Whyman for meeting the requirement for controlling routing via ITU restricted subnetworks. The alternative used an addressing convention coupled with a specific routing policy rule. This approach offered the advantage that no special support in End Systems would be required and that only routers directly attached to ITU restricted subnetworks must include the additional policy rule. This approach on the other hand posed the problem of elimination of the existing and agreed security capability from the ATN for the foreseeable future. Background material descibing this alternative approach is outlined in an attachment provided by Tony Whyman in Appendix A.

The alternative approach to security in the ATN was well received, as it appeared on initial analysis to be readily implementable, to meet the requirement for routing control and offered a way out of the impasse. However, concerns regarding this alternative were expressed by several delegations, leading to a request to Tony Whyman to present a more mature form of this material to WG2 for its consideration at the ad hoc meeting to be held in January. If the alternative meets fully the existing ATN security and access control requirements, it may represent a long term replacement for the use of Security Types by the ATN.

It was understood that no change proposal on this subject need be raised in the near term, particularly prior to further consideration and approval of this approach by WG2. The development of a Security Concept is underway and a risk analysis is also expected. These activities may identify other requirements for use of the CLNP security field, in which case, the current approach, as specified in the ATN Manual, should remain the preferred long term solution. However, if no other requirements for use of the CLNP security field are forthcoming then the alternative approach may be a candidate to replace this part of the ATN specification.

The US stated that a similar mechanism had been implemented in a laboratory environment, and volunteered to provide more detailed information on this mechanism for consideration by the January meeting of Working Group 2.

Conclusion: It was agreed that a recommendation on this subject should be prepared by the January ad hoc meeting of Working Group 2, based on presentation of additional analysis and supporting guidance material.

3.2.3 Congestion Management

An urgent requirement was identified for an agreed network congestion management strategy. The ATN Manual currently suggests three alternatives, but does not recommend or mandate any specific approach. However, a congestion management strategy is believed to be necessary for Package 1. Furthermore, as congestion management will involve implementation of appropriate algorithms and protocol elements in End Systems including avionics, and as the development of Package 1 avionics has already started, agreement on the congestion management strategy is required during March 1995. It is hoped that Eurocontrol will be able to accept an action to undertake the selection of the appropriate strategy by using the already developed simulation models.

Conclusion: It was agreed that appropriate defect report(s) should be prepared on this subject.

3.2.4 Timer Settings

In WG2/WP-25, Eurocontrol had proposed that the ATN Manual recommendation for the setting of Transport Timers by applications should be mandatory for Package 1. This is understood to have reflected a user requirement from the ADS Panel. However, it was agreed that this requirement needs further investigation. Application specification of timer values may be in conflict with good network operations practice, and furthermore, it is not clear whether it is possible for an End System on the ground or in the air to support multiple applications with different timer requirements unless each such application includes its own instance of the transport protocol.

It needs to be determined whether the ADSP is intending to make use of the ISO 8072 Transport Service or is expecting to make direct use of the transport protocol. If the latter is the case, this may well be the reason why specific timer values are required. If ADS does make direct use of the Transport Protocol then this will have to be considered separately from general use of the ATN Transport protocol. Indeed, implementations of ADS may need to include a separate implementation of the ISO Transport Protocol specifically to support ADS.

Conclusion: It was agreed that a recommendation on this subject should be prepared by the January ad hoc meeting of Working Group 2.

3.2.5 The ISH PDU and Package 1

In WG2/WP-37, France had proposed that a conventional NSEL value of 0FFH in the router NET would signal non-use of IDRP. The Eurocontrol comparison paper commented that 0FFH is often conventionally used for broadcast addresses and perhaps should be avoided. Additionally, SITA had proposed (WG2/WP-50) that the ISH PDU version number be used to signal non-use of IDRP instead.

The issues were discussed and SITA withdrew their proposal. Given that 0FFH had been arbitrarily chosen, France agreed to change the proposed value to 0FEH.

Conclusion: It was agreed that this change should be directly incorporated into new material prepared on Package 1 procedures.

3.2.6 Other Issues

The other issues were resolved as proposed in the Eurocontrol paper, with the following exceptions:

1. Transport Layer QOS Mapping: this is related to the problems identified above with respect to priority mapping, and should be resolved in a similar fashion.
2. Minimum TPDU size: there are strong objections from avionics suppliers to a minimum greater than 512 octets, owing to the buffer size implications, and WG2/WP-25 did not relate this to any known User Requirement.
3. Support of identified IDRP mandatory features: Forrest Colliver asked for time to check with EURATN implementors why these features were proposed to be not supported before agreeing to their support. He will report the results to WG2 at the next meeting for resolution of this issue.

Conclusion: It was agreed that a recommendation on this subject should be prepared by the January ad hoc meeting of Working Group 2.

3.3 X.25 Fast Select

SITA questioned the requirement for Fast Select to be mandatory in Package 1. This was due to non-universal support for this facility in many existing PTT networks.

After discussion it was agreed to leave the ATN Manual specification unchanged as the ATN Manual only requires the use of Fast Select when it is supported by the underlying subnetwork. However, as the earlier discussion on priority indicated, the common perception of what constitutes an ATN subnetwork may often be wrong.

This is because an air/ground subnetwork, such as AMSS, is typically accessed using an X.75 gateway and a PTT X.25 network. Mode S may also be accessed similarly. From the point of view of the ATN router, the subnetwork includes both the AMSS air/ground network and the PTT access network. Only if a facility such as Fast Select or priority is supported by both networks is it supported by "the subnetwork".

Another issue identified is that many people will view requirements in the ATN Manual, such as the requirement to use priority if the underlying subnetwork supports it, as applying to a class of subnetworks rather than an instance. However, in practice and because of differences in access subnetworks, these requirements can only apply to each instance of such subnetworks. Airborne routers will need to apply *a priori* knowledge when, for example, logging on to an AMSS subnetwork, of whether it is possible to use subnetwork priority. This was identified as a potential defect in the ATN Manual specification for use of subnetwork priority.

Conclusion: It was agreed that a recommendation on this subject should be prepared by the January ad hoc meeting of Working Group 2.

3.4 X.25 Priority Facility

The discussion on X.25 Fast Select capabilities, and the associated problems of support within public data networks, led to a similar discussion regarding the X.25 priority facility.

The task force meeting concluded that similar constraints existed in this case, and that the propagation of this facility across both the access subnetworks and air/ground subnetworks was not certain in all cases.

Conclusion: It was agreed that a recommendation on this subject should be prepared by the January ad hoc meeting of Working Group 2.

4. Review of Work and Assignment of Actions

4.1 Summary of Work required for Completion of Package 1 Specification

It was noted that WG2/WP-37 provided example PICS in certain cases, rather than Protocol Requirements Lists, and it was recognized that the amount of editing work to turn them into PRLs would be prohibitive given the time scale initially proposed for deliverable WG2-2. In addition, it was recognized that certain open issues, such as the outstanding proposal for a change in approach to ATN access control and security mechanisms, precluded further detail work on the Package 1 specification and PRLs at that time. For this reason, the expected completion date for the WG2-2 deliverable was proposed by France to follow the January 1995 ad hoc working group meeting, to give the necessary time to complete the agreed extensive editorial changes, and to resolve the outstanding issues that await consideration by the Working Group 2. Based on this schedule, France agreed:

- to complete the specification for the optional non-use of IDRP, and
- to complete the Package 1 Profile specification for consideration by Working Group 2,

following resolution of the outstanding issues by the January 1995 ad hoc meeting of WG2.

To support this activity, Eurocontrol offered to make available to the Package 1 PRLs editor (France) certain ATN PRLs that had been prepared internally for a call for tender activity, but which are not considered commercially sensitive at this juncture.

4.2 Action List

Description of Action	Responsible	Date Due
1. Detailed proposal for alternative security and access control operations, using address selection and local policy measures, rather than the CLNP security option.	Eurocontrol	23 January 1995
2. Guidance Material in support of Route Initiation including the optional non-use of IDRP.	Eurocontrol	23 January 1995
3. Provide documentation on US implementation of an air/ground policy mechanism related to the alternative discussed in Appendix A to this report.	US	23 February 1995
4. Specification for the procedures employed air/ground when IDRP is optionally not supported over the air/ground subnetworks.	France	3 March 1995
5. CNS/ATM Package 1 Profile for the ATN Internet support in ATN End Systems and Routers.	France	3 March 1995

Appendix A: Background Material on Addressing Convention for Controlled Routing Over ITU Restricted Subnetworks

Prepared by A. J. Whyman

Eurocontrol

Note: This appendix provides background material to support the readers understanding ot the task force discussion on alternative methods to meet user requirements for ATN access control and security. This does not constitute a formal proposal to the Working Group.

1. The Requirement

The User requirement is to respect the ITU imposed restrictions on the type of traffic that may pass over subnetworks using free radiating media and frequencies that are assigned for a specific purpose (e.g. ATC). This means that data belonging to applications that do comply with the requirements imposed by the ITU must not be routed over such subnetworks.

2. The Addressing Convention

The Addressing Convention illustrated in Figure 1 is proposed as a mechanism for meeting the above requirement, together with the procedures for generation of routing information when IDRP is not used discussed below in 3, and the procedures for generation of routing information when IDRP is used discussed below in 4.

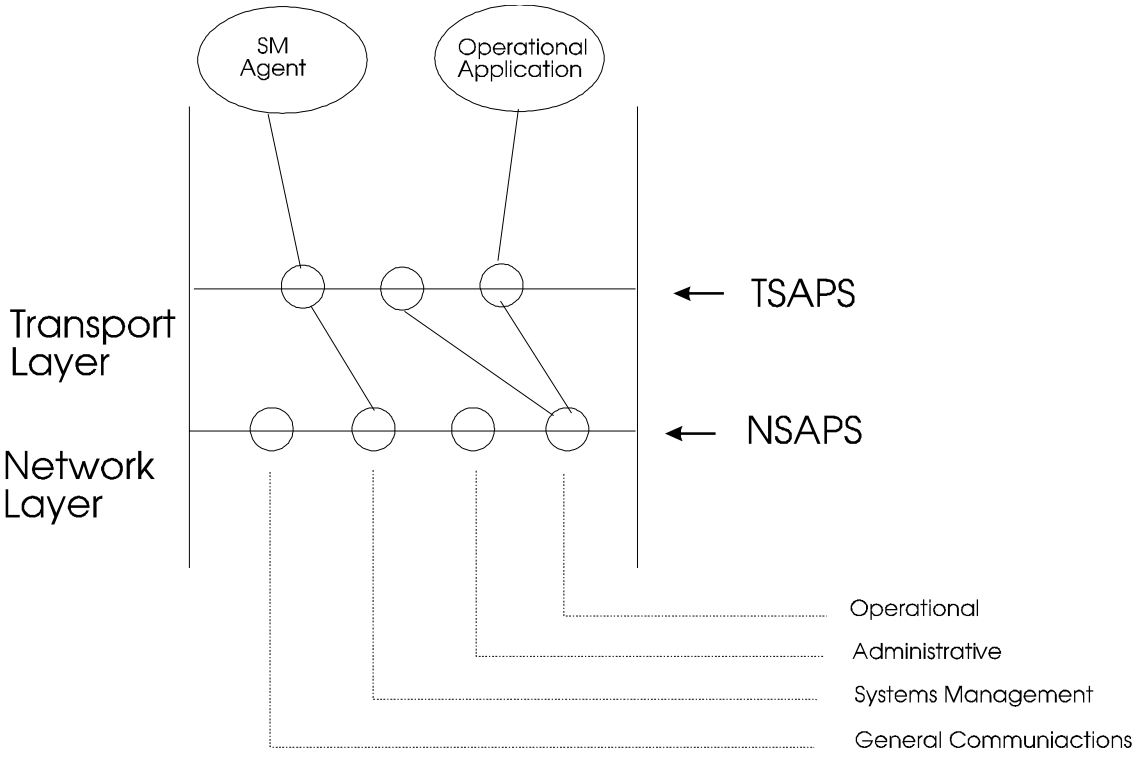

Figure 1 Address Assignment within ATN End Systems

The principle is that each Routing Domain has available to it four NSAP Address Prefixes for use in NSAP Address assignment. These prefixes must be syntactically related to each other, such that when one prefix is known, the others can be unambiguously deduced. This can be simply achieved by assigning, early on in the address syntax, a specific value for each such prefix. The four prefixes respectively represent:

- Operational Communications
- Administrative Communications
- Systems Management
- General Communications

i.e. each of the four Security Types currently identified by the ATN Manual.

Within each ATN End Systems there are then up to four NSAPs configured. Each such NSAP has an address assigned relative to each of the four above prefixes.

ATM Applications are then assigned addresses relative to the NSAP corresponding to the NSAP Address Prefix for their Security Type. For example, in Figure 1, an operational application is reached via a TSAP relative to the NSAP that has an NSAP Address assigned relative to the NSAP Address Prefix associated with operational communications. The result is that the transport address of each application effectively has encoded into it, its Security Type.

3. Controlled Routing over ITU Restricted Subnetwork with the non-use of IDRP

In Package 1, when IDRP is not used over an air/ground link, the ground an airborne routers must infer the routes available over such links from the NETs communicated by the ISH PDUs. The above addressing conventions is a natural extension of this mechanism.

When the ground router determines the NLRI for a route(s) reachable over an air/ground link, it derives the NSAP Address Prefix(es) from the airborne router's NET. When the above addressing convention is in place, the ground router must know *a priori* any ITU restrictions that apply to the air/ground link. When it generates the NLRI for the route, it must include within the route's NLRI an NSAP Address Prefix for the aircraft for each Security Type permitted to pass over that air/ground subnetwork. These can be derived from the NET as given one prefix, the rest can be derived.

When the airborne router determines the NLRI for a route(s) reachable over an air/ground link, it derives the NSAP Address Prefix(es) from configured information specific to that link. The configured information can and should identify routes and NLRI that reflect the ITU restrictions that apply to that link.

Note that when multiple air/ground subnetworks join an airborne and ground router, then the ITU restrictions that apply are the intersection of the restrictions, if any, that apply to the individual subnetworks.

4. Controlled Routing over ITU Restricted Subnetworks with IDRP

When IDRP is used over restricted subnetworks, as is anticipated after the Package 1 lifetime, the above convention requires a new routing policy rule to operate. This policy rule is applied to routes immediately before they are advertised over ITU restricted subnetworks. Under this policy rule, routes that contain multiple prefixes within their NLRI are broken up and considered as separate routes i.e. one route per prefix., for the purposes of apply this policy rule.

The rule itself is simple enough. If the Security Type encoded into the NSAP address prefix contained in the NLRI identifies a Security Type for data not permitted to pass over the subnetwork, then the route may not be advertised.

The result is that only routes to NSAPs hosting applications for which data may pass over that air/ground subnetwork, are advertised over the subnetwork.

5. Conclusion

The above is a natural extension to the optional non-use of IDRP. The only impact on the technical solution is on the administrative allocation of NSAP Addresses and the rules for generating the NLRI for routes over datalink for which IDRP is not used. The result is that the routes available properly reflect the Security Types of the applications that may use them and hence the requirement stated above is met. The convention may be readily extended to the later use of IDRP air/ground by the deployment of a routing policy rule only.

The gain for Package 1 appears to be considerable as:

1. The requirement is fully met
2. CLNP Security does not have to be added to commercial software

3. The use of Security Types does not have to be validated.

ATN IDRP related routing information is reduced by up to a factor of four affecting System sizing and performance and network bandwidth requirements.