IPv6 and Internet Technology for the Aeronautical Telecommunication Network
A New Networking Approach

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Abstract

Since 1996, The Eurocontrol Experimental Centre (EEC) has been involved in R&D activities dealing with Internet Telephony technology for innovative Voice Communication System (AudioLAN project) and with Internet's next generation protocol (IPv6 project) evaluation in the context of the Aeronautical Telecommunication Network. Today, COTS Internet Technology products are available to build aeronautical telecommunication mass-market based in an operational environment. After a description of the actual Aeronautical Telecommunication Network (ATN) status, this paper will undertake a technical discussion on an operational ATN based on Internet products, and will address benefits of such an approach for industrials and ATC community.

Keywords: Internet Technology, IPv6, ATN

Introduction

In the early 1980's, the International Civil Aviation Organisation (ICAO) recognised the increasing limitations of the present air navigation systems and the need for improvements to take civil aviation into the 21st century. ICAO established the Special Committee on Future Air Navigation Systems (FANS) with the task of studying, identifying, assessing new concepts and new technology, and making recommendations for the co-ordinated evolutionary development of air navigation for the next twenty-five years. From this, the ATN (Aeronautical Telecommunication Network) was specified in the ICAO Standards and Recommended Practices (SARPs). The ATN is a data communications inter-network that provides its users with a robust and reliable Air/Ground and Ground/Ground communications service.

The current ICAO standard for the Air Traffic data network is ATN; it is based on ISO's OSI)open Standard Interconnection) protocols, with adaptations specific to aeronautical applications. At the time of developing the ATN Standards and Recommended Practices (SARPs) the Internet Protocol (IPv4) was not capable of providing the facilities for the ATN to meet its objectives and was not expected to become the protocol of the future, OSI was expected to be the next generation protocol

In the meantime the Internet has grown at a phenomenal rate. It is touching every part of our lives from computers, play stations to mobile phones. It is now used as a marketing tool and it will soon be accepted as the norm for communication and is now accepted as the de facto industrial standard.

However the Internet has not been without its problems. For many years, the Internet community knew that IPv4 had many weaknesses that needed to be overcome. Only in the last few years, it has become necessary that these problems be solved quickly. The Internet Engineering Task Farce (IETF) established a working group to upgrade the Internet protocol, the IPNGWG (Internet Protocol Next Generation Working Group). [1] This working group has broadly specified a new version of the Internet Protocol, called IPv6 (IP version 6). At the moment it is not fully specified and standardised. However, there is strong interest in the Internet community for IPv6 with many experiments, developments of prototypes and integration tests for it to become a reliable and robust standard. Remembering that Internet development lifecycle is very fast, for example IP telephony took two years (1997) to become a commercial reality for the mass-market

The goal of this study is to provide an assessment of the adequacy of IPv6, and its ability to fulfil the requirements of aeronautical applications as set forth by ICAO documents such as the ATN/OSI SARPs. The interest of IPv6 for air applications is twofold:

- *IPv6 is an industry-driven emerging set of standards that are still being developed based on the needs of users and the actual implementation of new protocols and methods. Conversely, the ATN/OSI standards were completed before any implementation work was started.*

- *IPv6 are free, open standards and follow the technical evolution.*

The Aeronautical Telecommunications Network (ATN) [2]

In the early 1980's, the International Civil Aviation Authority (ICAO) recognised the increasing limitations of the present air navigation systems and the need for improvements to take civil aviation into the 21st century. In 1983 ICAO established the Special Committee on the Future Air Navigation Systems (FANS) with the task of studying, identifying and assessing new concepts and new technologies, and making recommendations for the co-ordinated evolutionary development of air navigation for the next twenty five years.

The need has been greatly influenced by two principal factors:

1. The present and future air traffic demands, with which the current system, by virtue of its limitations, will be unable to cope.

2. The need for global consistency in the provision of air traffic services during the progression towards a seamless air traffic management system.

The original FANS committee completed its task in 1988 with a system concept for communication, navigation, and surveillance (CNS) based largely on satellites, which would enable the evolution of Air Traffic Management. The concept is to enable civil aviation world-wide to overcome the well-known shortcomings of the present system, and to take advantage of modern technologies to meet aviation's projected growth into the 21st century.

It was recognised that to realise the concept it would take a high degree of international co-operation between civil aviation administrators, international organisations, service providers and users, ICAO established a new special committee among whose tasks was the development of a global co-ordinated plan. The FANS II committee held its first meeting in June 1990 and comprised members, advisors and observers from the Contracting States and other International Organisations. The Committee completed the global implementation plan in September 1993, which contains guidelines of the transition to the CNS/ATM systems, which are to be implemented in a timely and cost beneficial manner. The ICAO Council approved the plan in 1994.

One of the results from FANS was the specification and standardisation of the ATN and is specified in the ICAO Standards and Recommended Practices (SARPs)[1].

The ATN Objectives

The ATN is a data communications inter-network that is to provide:

1. A common communications service for all Air Traffic Services Communications *(*ATSC) and Aeronautical Industry Service Communication *(*AINSC) applications that require either ground/ground or air-ground data communications services,

2. Integrates and uses existing communications networks and infrastructure wherever possible,

3. Provides a communications service, which meets the security and safety requirements of ATSC and AINSC applications, and

4. Accommodates the different grades of service required by each ATSC and AINSC application.

As the ATN is to provide a common infrastructure for ATC applications, the marginal cost for introducing a new application should be small and concentrated on the specific functions that it implements; as the communications infrastructure will already be there. Therefore, the ATN has been specified to meet the requirements of the Civil Aviation Community and is expected to give the following benefits:

- *Use of the existing infrastructure*
- *High availability*
- *Mobile Communications*
- *Prioritised end-to-end*
- *Scalability*
- *Policy Based Routing*
- *Use of COTS Products*
- *Improved Communication*

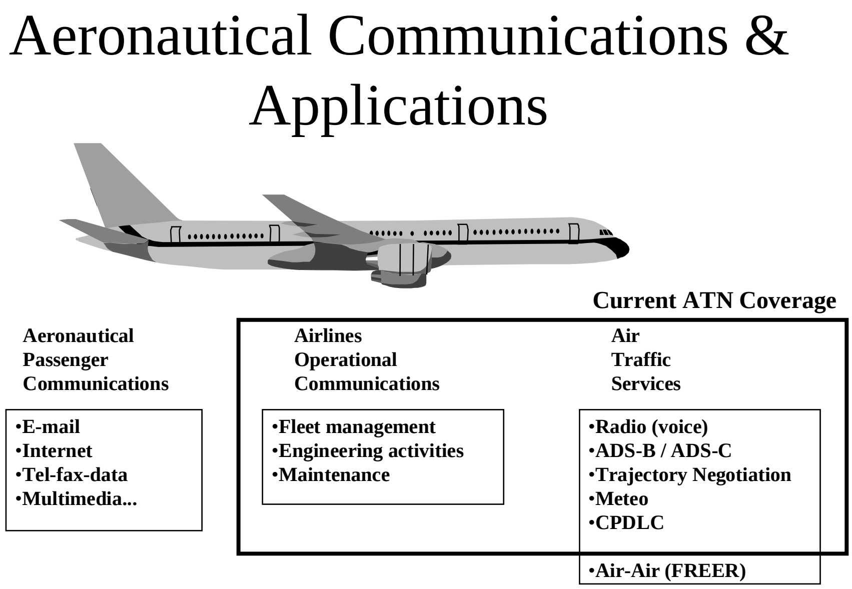
The ATN's Protocol

Currently the ATN is implemented using the OSI (Open System Interconnection) structure, and has, therefore, influenced the specification of the SARPs, especially with regards to the addressing scheme. Why the OSI model was chosen instead of TCP/IP was for three reasons:

1. **Historical:** When the ATN was first specified, many administrations had policies in place that required that public procurement required OSI communication protocols.

2. **Large Address Space:** The mobile routing strategy in ATN demands a large address space for its Addressing Plan and to accommodate its mobile routing strategy.

3. **Congestion Management:** The ATN utilises low bandwidth data links and an efficient congestion management strategy is essential.



ATN's Future Requirements

Currently the ATN is specified only to cover the following communications:

- *ATS (Air Traffic Services): Air-Ground and Ground-Ground Communication.*
- *AOC (Airline Operation Communications): Air-Ground and Ground-Ground Communication.*

However, it is foreseen that current communication requirements are limited and that airlines would be interested in expanding communications to include:

1. Expanding ATS to include air-air communication.

2. Aeronautical Passenger communications: This would include features such as e-mail, Internet, Telephone/Fax/Data and multimedia.

3. Ground-Ground Mobile Communication: This applies to mobile units on the ground at airports. It may include the aircraft and other mobile units at an airport.

The Internet and IPv6

The Internet Protocol (IP) has established itself as a primary vehicle for a global system of electronic commerce, enabling a vast array of client/server and peer-to-peer computing applications. Although IP has been successful, and is expected to continue expanding at a rapid rate, industry has just recently realised that the current IP version (IPv4) has not advanced in comparison to the advancement of computers and network applications that it supports.

In the future computer networks will benefit from the availability of many new technologies, including Asynchronous Transfer Mode, Gigabit Ethernet and virtual LANs. Because the Internet and many Intranets are based on IP technology it has to change to meet the new challenges. In anticipation for the need to upgrade IP, the Internet Engineering Task Force (IETF) has produced a comprehensive set of specifications (RFC 1752, 1883, 1886, 1971, etc.) that define the next generation IP protocol known as “IPng” or “IPv6”. Though IPv6 is based on much needed enhancements to the IPv4 standards, IPv6 is regarded as broad retool project to provide a much needed evolutionary re-architecting of today’s over stressed inter-networks.

IPv6 is considered both as near and long term concern for owners and service providers. On the one hand IPv6 products have already come on the market; and on the other hand, IPv6 will continue into the next decade as issues such as addressing performance, scalability, security, ease of configuration and network management are addressed.

Why IPv6?

The Internet has become a worldwide success and is expected to expand at a very rapid rate. The network architecture that is the cornerstone of the Internet is the *Internet Protocol Suite*, best known as TCP/IP. However, this protocol, in particular IP, was standardised in 1981 as version 4 (IPv4), and is therefore a little dated.

Users of the Internet [1]

	January 1990	January 1997	January 2000 Forecast
Internet Hosts	188,000	18,000,000	254,000,000
Internet Users	1,120,000	57,000,000	707,000,000
Electronic Mail Users	3,400,000	71,000,000	827,000,000

The basic function of IPv4 provides the facility of allowing the applications to de-couple from the transmission networks. It provides the user with the possibility to use their applications independently from the under-lying network technology. This allows IP to use different technologies in different parts of the network.

IPv4 achieves this by providing the following main characteristics:

Universal Addressing: each IPv4 network interface has a unique world-wide 32-bit address.

Best Effort: IPv4 performs its best effort to deliver packets, but it doesn't guarantee anything layers above in terms of percentage of delivered packets, nor in terms of delivery time.

These two characteristics have been points of strength for IPv4, but now they risk becoming its main limits and have forced the introduction of IPv6.

A new Addressing Scheme

The Internet is running out of addresses. IPv4 addresses are a 32-bit address, which means that there are about 4 billion addresses available, and as there are not 4 billion addresses in the world it is hard to understand why the Internet is running out of addresses. Currently it is not the address structure that is the problem but the assignment procedure, which causes a significant number of addresses to be unused. The problem of IPv4 address exhaustion was understood in 1991, as it was in that year that the requests for address assignments began to grow more rapidly than any expectation. It was at this time that the Internet started to become the global network for everyone. Because of this the IETF came up with a new policy of address allocation, and now the forecasts, which are uncertain, predict that the addresses will be exhausted between 2005 and 2015. Though this new addressing policy delayed the problem of address exhaustion it generates problems on routers, which are forced to maintain larger amounts of routing information and changes in routing policies.

Best Effort

IPv4 is a connectionless protocol, which transmits every packet independently, only specifying the source and destination addresses. The packets are neither marked as belonging to a flow or connection, nor marked in any other way. This means that it is not possible to correct errors at this level or know whether the packet has been delivered. This kind of service in IPv4 is called "Best Effort" and ensures that each node will perform its best to deliver the packet in the minimum time, but cannot guarantee if and when the delivery will happen. This protocol is easy to implement with a constant limited overhead, which has made IPv4 very popular.

With the availability of high speed Asynchronous Transfer Mode networks guaranteeing QoS (Quality of Service), as well as multimedia applications also requiring a guaranteed QoS, this has led to the question as to whether "Best Effort" would be good enough for IPv6. This lead to the IETF keeping IPv6 faithful to the connectionless model, but introducing the concept of flow as better way of integrating the QoS concepts.

IPv6 Requirements

The risk that the IETF considered when specifying IPv6 is the "second generation syndrome", which consists of adding everything users ask for at the expense of producing a slow, non-manageable, useless protocol. The question was then, which features from IPv4 were to be maintained, which were to be removed and which new are to be introduced. The following is summary of the features.

1. Larger Address Space: 128-bit address for IPv6. It is estimated that there would be 6.55×10^{23} addresses for each square metre of the earth's surface.

2. Multicast and Anycast Addresses: For applications that require group communication, such as video conferencing. Multicast ensures that the whole group receives the information, while Anycast ensures that only one member of the group that is closest to the source is to respond.

3. Unify Intranets and the Internet: IPv6 is to provide a unifying addressing overcoming the temporary solutions in IPv4..

4. Better Use of LANs: Currently when IPv4 operates on a LAN, it frequently needs to determine the relationship between an IPv4 address and a MAC (Medium Access Control) address, and vice versa. And uses broadcast transmissions that affect all stations. This is very ineffective and is corrected in IPv6 buy using a "neighbour discovery" method on the LAN that is more efficient than receiving all broadcasts.

5. Security: Currently all intrinsic IPv4 security problems are managed through particular computers or routers performing the role of *firewalls*. IPv6 was not expected to have security, but the IETF has defined a series of encryption and authentication procedures (IPSec) that will be standard in the IPv6 protocol from the very beginning.

6. QoS (Quality of Service) Support: This is needed especially that future applications are demanding it.

7. Routing: IPv6 routing is almost identical to IPv4 except that the addresses are 128-bit instead of 32-bit. With straightforward extensions, all of IPv4's routing algorithms can be used. However, IPv6 includes some routing extensions that support powerful functionality, which are:

    - Provider Selection (based on policy, performance, cost, etc.)
    - Host Mobility
    - Auto-Readdressing (route to new addresses)

8. Internet Structure: The Internet is organised into autonomous systems that exchange information on the reachability of networks of which they are composed. In IPv4 there is no relationship between the addresses and the network topology. Addresses are directly assigned to end-users. IPv6 will allocate addresses on a provider-based scheme as opposed to assigning them to end-users. This system will be based on the IPv6 Addressing Architecture, which is aggregable. In this scheme Direct Service Providers are assigned a set of addresses that it divides into smaller sets to be assigned to its users. Because the IPv6 address is longer, it can contain a new hierarchy level.

9. Mobility: Without specific support for mobility in IPv6, packets destined to a mobile node (host or router) would not be able to reach it while it is away from its home link. The protocol that allows a mobile node to move from one link to another without changing the mobile node's IP address is called Mobile IPv6. The movement of the mobile node away from its home link is thus transparent to the higher-layer protocols and applications. Mobile IPv6 is to be suitable for mobility across homogeneous media as well as across heterogeneous media..

10. Auto-configuration: IPv6 needs auto-configuration (plug and play) mechanism for addresses that change in the long run and especially for mobility. It will also allow the auto-configuration of hosts and subnetworks, the learning of default routers, and through the interaction of the DNS (Domain Name Service) the automatic configuration of host names.

11. Transition from IPv4 to IPv6: Migrating from IPv4 to IPv6 is a huge task considering the size of the Internet, and that many organisations are becoming more and more dependent on the Internet for their daily business. It was recognised that the migration from IPv4 to

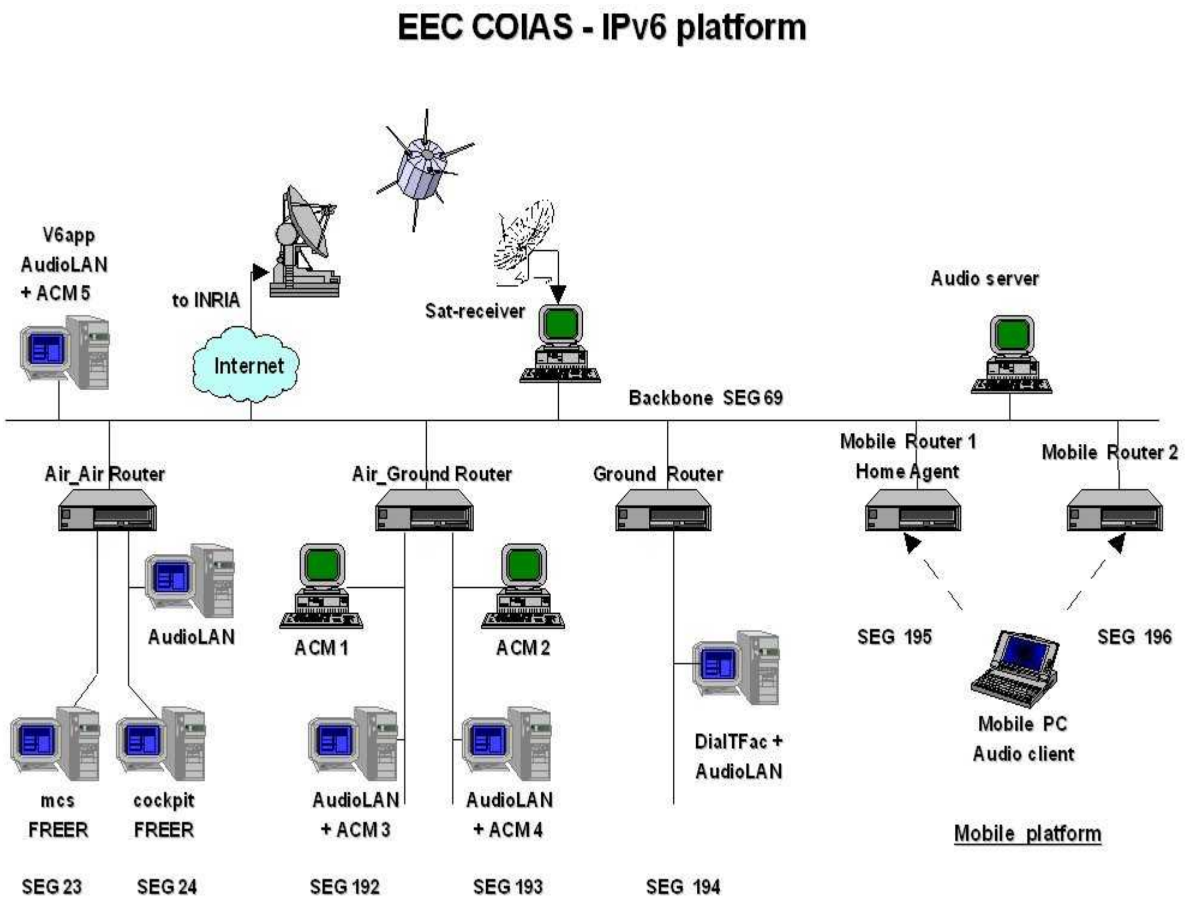
IPv6 cannot happen overnight and should be implemented on a node by node basis using the auto-configuration procedure as described earlier. This way IPv6 hosts do not need to be configured manually and users can immediately benefit from IPv6 while maintaining the possibility of communicating with other IPv4 users or peripherals.

The key goals that the migration must meet are as follows:

- IPv6 and IPv4 must inter-operate.
- The use of IPv6 hosts and routers must be distributed over the Internet in a simple and progressive way with little interdependence.
- Network administrators and end users must think that migration is easy to understand and migrate.

core standardised, it is rapidly growing and will certainly become a mature and robust standard for the future. With this there is not only support from educational and research establishments but also from industry. Within the industrial sector this is not confined to the traditional network and computer manufacturers (SUN, CISCO, Microsoft, etc.), but also other sectors such as Mobile Phones, Digital Television, and Satellites. IPv6 also offers the following advantages:

- *Linked with emerging technologies*
- *Large industrial investment*
- *COTS Products*
- *The IETF co-ordinates activity with other standards bodies (e.g. ASYNCHRONOUS TRANSFER MODE Forum [4]).*
- *Industrial implementations*



Status of IPv6

Since July 1996, IPv6 has been making massive leaps from the implementation of a project to a standard. Though IPv6 is still in its infancy, with its

- *Transition Mechanism*
- *Mobile Telephones*
- *CORBA*

- *Java/Jini*
- *WAP (Wireless) for mobile phones*

IPSky

The IPSky team at the EEC recognised that the emergence of IPv6 could have a profound affect on aeronautical communications and that it could in fact replace OSI as the protocol for the ATN, as it fulfils the general requirements of ATN. It also has the added advantage of being open and evolving with many experts all around the world contributing to it.

The IPSky team is involved in experimenting, evaluating and implementing Internet technologies, especially IPv6, with regard to the aeronautical environment, and is actively in many projects:

The COIAS project aims at developing and demonstrating the new generation of Internet protocols based on IPv4 and IPv6 above ATM (Asynchronous Transfer Mode) and satellite. It will take into account the main features for the Information Society: performance, quality, mobility, reliable multicast and security, to be used in the ATC community.

It will use existing ATM and satellite technologies. Focusing on developing, implementing and evaluating IPv4/v6 software as proposed by the IETF standards on:

- *Security (IPSec)*
- *Integrated Services (IS)*
- *Mobility*
- *IPv6-over-ATM*

EEC COIAS Platform Hardware/Software Structure

Applications	Machine/Hardware	Operation System/Software	IPv6 Stack
AudioLAN	SUNW, SPARCstation-5 (SS5)	Solaris 2.5.1	Release 5.3 of IPv6 for Solaris 2.5.1
DialTFac	SUNW, SPARCstation-5 (SS5)	Solaris 2.5.1	Release 5.3 of IPv6 for Solaris 2.5.1
MCS/FREER	SUNW, ULTRASPARC station-10/20	Solaris 2.5.1	Release 5.3 of IPv6 for Solaris 2.5.1
ACM	PC	Windows NT4 SP4	MUSICA-IP version 4.5 from Detexis-Thomson-CSF
Traffic Generator	PC	Windows NT4 SP4	MUSICA-IP version 4.5 from Detexis-Thomson-CSF
Audio Client/Server	PC	Windows NT4 SP4	MUSICA-IP version 4.5 from Detexis-Thomson-CSF
Routers (not mobile)	PC (Multi-homed)	Windows NT4 SP4	MUSICA-IP version 4.5 from Detexis-Thomson-CSF
Mobile Routers	PC (multi-homed)	FreeBSD3.2	KAME/INRIA from the KAME Project (Japan) & INRIA (France)
Mobile PC	Lap Top PC	FreeBSD3.2	KAME/INRIA from the KAME Project (Japan) & INRIA (France)
6Bone Router (not on diagram)	PC	FreeBSD3.2	KAME/INRIA from the KAME Project (Japan) & INRIA (France)

COIAS

COIAS an IPv6 project for the European Commission (DGXIII)**.** The EEC is a member of the COIAS consortium of which the other members are: University College of London, (UK), INRIA (FR), Thomson-csf Detexis (FR), British Telecom (UK), Secunet (G). [5]

At the EEC, a platform has been constructed to evaluate the following IPv6 features in relation to Air Traffic Control, Air Navigation and Passenger applications.

QoS (Quality of Service): Air Traffic Services require different QoS and bandwidth. It is important that the scheduling mechanism is efficient over the different media.

Security : Air Traffic Services, radio and the airlines own applications require a high level of security.

Reliable Multicast : This is needed for applications that require group conferencing

To evaluate these features the EEC has several applications that it is using to simulate the appropriate components in the ATC environment. The applications used are :

FREER (Free Route Experimental Encounter): This is an advanced air component based on the Multi-aircraft Cockpit Simulator/Experimental Flight Management System.

DialTFac (Dialog Test Facility) : Is a ground component and is the ground part for FREER.

AudioLAN : Radio Telephone Voice Communication System.

ACM: Is a basic ground component and is a LAN-oriented, multi-player aerial simulator.

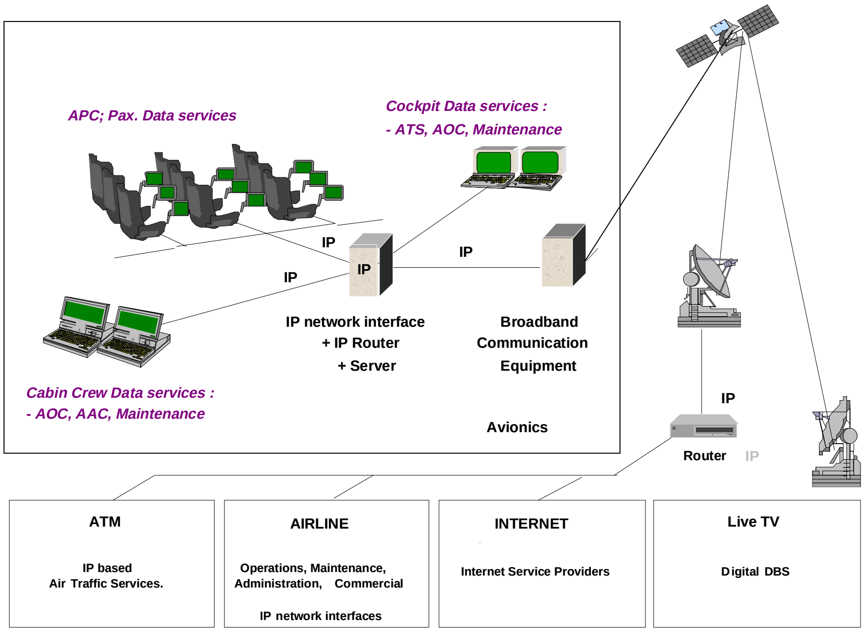
NATACHA

NATACHA (Network Architecture and Technologies for Airborne Communication of Internet High-bandwidth Applications) is European Commission project under its 5th framework for Sustained Growth in the area New Perspectives in Aeronautics. It has consortium consisting of EEC, DASA Airbus (G), KID Systeme (G), Thomson-CSF Sextant (F), Thomson-CSF Communication (F), Ramline (SF) and Cebe Network (G). It is also actively supported by ASTRA by providing satelite services and ESTEC (ESA) .by providing space and satellite expertise.

The project will last 30 months with the objectives being:

- *To develop an on-board transmitter and receiver technology for high bandwidth bi-directional digital data communication via satellite.*
- *To explore the application of the Internet Protocol (IP) for information transfer between the air and ground, and between on-board systems.*
- *To develop a unified on-board data communication as an IP based Intranet with routers and severs.*
- *To implement example application services from every domain for evaluation.*

The project focuses on the on the airborne part of the communication between air and ground via a satellite link. The innovation is combination of mobility, interactivity and high bandwidth.



NATACHA Platform

PRIMA

PRIMA (Projet de réseau IP mobile ad hoc) is a French funded project that the EEC is taking an advisory role. It aims at prototyping an autonomous mobile network based on IP. It will study the conception, perform simulations and build a demonstration of such a network.

The partners in this project include EUROCONTROL, MATRA Systemes & Information, INRIA and COMATIS.

It will be a network without an infrastructure (i.e. an ad-hoc network) that is to be deployed rapidly with all functionality being distributed amongst all the nodes of the network The topology of the network will evolve according to the mobility of the nodes and the quality of the connections.

Different technologies will be integrated around IP, which will provide the transmission of data, the routing, multicast, reliability, adaptation to the constraints of radio transmission and multiple access to radio channels.

ATN's Slow Start-up

Though the ATN has objectives that everyone in the aeronautical community can identify with, it still has not been implemented as quickly as many had predicted after many years of development, trials and experimentation. The ATN has been very slow to move from specification to a system and the enthusiasm for it is very subdued. There are many factors that have hindered the progress of the ATN.

- **Costs versus Benefits***: One thing that is certain is that the ATN will cost airlines, but from the point of view of a business it is not clear how the benefits would improve its performance. They would have to recuperate the costs either by increasing prices or cutting profit margins, which the airlines are very reluctant to do in a highly competitive market.*
- **ATN's Development Cycle***: The development cycle is very long winded and the specifications are ratified before any experimentation is done as to whether the protocols specified are feasible or not. If during implementation it is found that what is specified is practical then the whole process is started again. This in complete contrast to the IETF (Internet Engineering Task Force) where a draft specification must be implemented and connected with two or more sites and shown to work before it proceeds to becoming a standard.*
- **ATN over OSI***: The choice of OSI for ATN at the time appeared to be the right choice. However, OSI has failed to replace IP and in fact IP has become the open standard that OSI strived for. Also during the time of specifying the ATN, IP has evolved and adapted to new technologies whereas OSI has remained stagnant.*
- **Limited Industrial Investment:** *Because ATN is based on OSI and the long development cycle, Industry (Computing and Networking) has been reluctant to invest in this niche market.*
- **Lack of COTS:** *As a result of the above points there are no products for ATN that are COTS (Commercial Off The Shelf) products, but completely bespoke which means lack of variety and competition leading to high costs.*

Conclusions

When OSI was chosen for the ATN, it was the only network protocol at the time that could meet most of the ATN requirements. However, the problem with OSI is that within the commercial environment there is little interest for OSI, and therefore, minimal investment in OSI products. In fact, OSI has not fulfilled that expectation that it would replace TCP/IP as the new standard. This has meant that the aeronautical community has to assist in financing the development of ATN products, which has had the result that advancement in ATN products are slow and that these products are not COTS products but bespoke.

It is recognised that aeronautical communications needs to be a more up-to-date and sophisticated. To achieve this the ATN needs to be implemented over a protocol that will help meet its goals, IPv6 is that protocol.

Though IPv6 is still in its infancy the commercial sector is actively participating and investing in its development and evolution. Not only are networking companies interested in improving the Internet, but telecommunication companies, with regards to mobile communication, cable television networks, and satellite TV are also looking to the Internet to expand their markets. It is predicted that these markets will move closer together offering similar facilities but all using the Internet protocol. [6] IPv6 gives them, the potential to realise their ambitions.

With all this interest and activity in IPv6 it is important that it is not overlooked. There is a vast amount of commercial investment being made into IPv6, especially with its interface to other technologies, such as, satellite, Asynchronous Transfer Mode, mobile telephones, television, wireless LANs, Java, multicast, and mobility, that these technologies should not be ignored. It is essential that IPv6 be evaluated as it continues to evolve and standardise, for it, and all the technologies surrounding it, will bring benefits to the aeronautical community.

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