THE AIRBORNE OPEN SYSTEM INTERCONNECTION DATA LINK TEST FACILITY

Richard R. Olson
Federal Aviation Administration
Technical Center
Atlantic City International Airport, NJ 08405

SUMMARY

This paper describes the activities of the Federal Aviation Administration (FAA) Technical Center in the joint government-industry Aeronautical Telecommunications Network (ATN) project. The ATN is defined as a network architecture that allows use of multiple communication subnetworks and provides a path for oceanic, international, and domestic Data Link services. A major goal of the design process is the separation of the user applications from the communications and interoperability among diverse Data Link subnetworks. This project is oriented toward the eventual provision of a world-wide packet switched architecture for the networking of International Organization for Standardization (ISO) Open System Interconnection (OSI) conformant host computer end systems and router intermediate systems.

INTRODUCTION

Today's existing air traffic control (ATC) system employs spoken instructions transmitted by very high frequency (VHF) radio. During peak periods of operation, especially in busy terminal areas, the available frequencies become overstressed to the point of saturation. This situation is getting worse as additional aircraft are placed into service and more frequent flights are scheduled.

Digital Data Link has the capability to alleviate this situation by removing routine communications such as transfer of control from congested voice frequencies. The ability to communicate using Data Link is not a new concept; studies have shown that an alternate means of air/ground communication could benefit airspace users by reducing the amount of VHF traffic.[1] If a reliable delivery system is available to all users, digital Data Link could become the primary communications medium in the future.

A wide range of Data Link technology, including satellite communications, VHF radio, high frequency (HF) radio, radar, and various optical links are available to the aviation community. However, these media are highly different in their operation, reliability, cost, and coverage when examined on an individual basis. A means to incorporate the advantages of each Data Link while hiding the underlying differences from the end users (air crews and controllers), will be required of a world wide aviation Data Link system.

The ATN is a research project funded by FAA Headquarters and managed by The MITRE Corporation, McLean, VA. The ATN is the name applied to the network architecture that will allow global packet data transfer between air and ground over various physically diverse communications links. While most of these communications links and the means to route information between them are evolutionary in their stages of development, the FAA is nearing the point of concept demonstration readiness. In order to bring ATN architecture out of the design stages, develop standards and learn about the operation and limitations of the network, a voluntary joint government/industry evaluation was initiated in 1990.

The FAA Technical Center, the research, test and evaluation center of the FAA located at the Atlantic City International Airport, NJ, is working with airlines, avionics vendors, and

(1) E.H. Hilborn, "Human Factors Experiments for Data Link," FAA-RD-75-170, Nov., 1975.

standards organizations to facilitate transition from the current non-Data Link environment to one which supports ATN. The program is designed to: (1) define new Data Link services and applicable operational procedures, and (2) collect and analyze end-user-to-end-user communications traffic supporting the new Data Link services.

NETWORKING BACKGROUND

Open Systems

The OSI standards describe the external behavior of systems by defining services and protocols. These international standards are based on a seven-layer model, commonly called a "stack." The seven-layer model can be described as a logical separation of functionality within the protocol stack wherein each layer provides services and primitives to the adjoining layers. The layers are normally identified as follows:

7 Application
6 Presentation
5 Session
4 Transport
3 Network
2 Link
1 Physical

ATN Networking

The ATN will consist of a series of interconnected local area networks (LAN's) on the ground and in the air to form one logical wide area network (WAN). Since the ATN will undoubtedly encompass equipment from multiple vendors, interoperability between these homogeneous systems becomes a major issue. In order to assure consistency between various hardware and software platforms, communication standards will be adopted and implemented. The OSI protocol suite was designed for interoperability in a heterogeneous network environment. The ATN requirements incorporate the essence of the OSI protocol standards to support interoperability.

Subnetworks

A network is simply a collection of subnetworks, connected by intermediate systems and occupied by end systems. A subnetwork can be a self-contained local area network, e.g., several personal computers or workstations connected by Ethernet over twisted pair wire. A point to point subnetwork connects two users or nodes, while a broadcast medium, such as radio, connects potentially many nodes. There are three main broadcast subnetworks being considered for air/ground Data Link within the ATN project.

Satellite Communications Subnetwork. The satellite communications subnetwork includes a geosynchronous satellite, a station on the ground, called a Ground Earth Station (GES) and an airborne station, called an Aircraft Earth Station (AES). Essentially, the satellite acts as a "mirror" by bouncing signals between the AES and GES. The satellite communications Data Link will be designed to exchange bit oriented data frames carrying network layer packets.

VHF Data Link Subnetwork. The current VHF subnetwork, called Aircraft Communications Addressing and Reporting System (ACARS) is a character-based demand mode system that has been in operation since the mid-1970's. Primarily used for airline company traffic until recently, ACARS, through cooperation of the FAA and Aeronautical Radio Inc. (ARINC), is being used to deliver pre-departure clearances, and soon, Automated Terminal Information Service (ATIS) reports to 30 major terminals in the U.S. The next generation of VHF Data Link, called Aviation VHF Packet Communication or AVPAC, is a higher capacity, bit oriented system that will support OSI protocols.

Secondary Surveillance Radar/Mode Select Subnetwork. The standard surveillance system used by civilian ATC is the ATC Radar Beacon System (ATCRBS). The system consists of ground-based rotating radar antenna and aircraft equipped with transponders. The ATCRBS site can request altitude and identification information, called Mode-C and Mode-A respectively, from each aircraft within coverage. Mode Select, or Mode-S, provides the capability to selectively address individual aircraft. This capability also allows for Data Link exchange to take place, on a "time shared" basis with radar surveillance, with properly equipped aircraft. The FAA plans to deliver most tactical ATC services by Mode-S.

Subnetwork Operation

OSI 8208 (X.25 packet layer protocol) is a common subnetwork protocol standard primarily used to connect LAN's to the wide area portion of a network.

The use of connection orientated 8208 has been mandated over the air/ground portion of the ATN. Typically, when X.25 establishes a connection, there is a call setup.phase, data transfer phase, and call disconnect phase. This is called a virtual call or virtual circuit (VC). The X.25 subnetwork can also support a permanent virtual circuit (PVC); there is no call setup or disconnect. The basic function of X.25, however, is to manage the connection between a peer pair of data terminal equipment (DTE) devices, i.e., the airborne router and the ground router.

The subnetwork dependant convergence function (SNDCF) translates the connectionless datagram messages from the internetworking protocol (IP) to the subnetwork, supporting any differences that may exist between the protocols. The SNDCF may also perform data compression to reduce the amount of overhead that may proliferate to limited bandwidth subnetworks.

Routing

A router is the name given to the device used to interconnect dissimilar networks. Routing is performed by the IP acting as the bridge between differing subnetwork protocol implementations. The ATN router will use the connectionless network service (CLNS) as defined in ISO 8473. The network layer allows for the redirection or routing of data traffic from the LAN to the WAN and back. Only traffic that is destined for remote systems will propagate, localizing the LAN's from unwarranted traffic. Routing functions simultaneously allow for the orderly transport of information between applications on end-systems through the LAN over the wide area backbone if necessary.

Inter Domain Routing Protocol (IDRP)

Routing allows for the interconnectivity between different subnetworks providing the cement that holds the various LAN's together. The ATN environment, however, has a need for more then the ordinary distribution of traffic to and from the subnetworks. Subnetworks and applications are "owned" by different organizations, but with the open systems concept, preventing unauthorized use of a subnetwork or application may be more of a challenge. The intelligent transfer of information based on various metrics such as "ownership," reliability, cost, and quality of service is required to support the ATN. To establish this, the ATN architecture will implement a gateway protocol called IDRP. Essentially IDRP manages the traffic over various networking domains to select routes by monitoring subnetwork availability, paths to remote end systems, and, most critically, the unique policy of each domain.

IDRP interfaces with the IP to offer the router the ability to make routing decisions based on a policy that will be defined for that router and its domain under a general framework of an overall network environment. Routers that offer this functionality are called Boundary Intermediate Systems or BIS's. These routers lie on the boundaries of the domain providing access to that domain based on its policy. This policy determines the decision process in order for the router to advertise its respective paths to the network and allowable access of data transversing that domain for applications in adjacent domains. As the network dynamically changes, IDRP will modify its routes to adapt to this changing environment.

Upper Layers and Addressing

The transport layer's main task is to provide reliable and cost effective communication between end systems. It is the conceptual line between network and system resources. The layers above transport mainly provide services to an application strictly in terms of the application and how data are presented to the system and the user. The logical interface between the transport and the network layer is where the network service access point (NSAP) is defined. The NSAP is merely the address where network services are accessed by a transport entity. A transport entity is anything that accesses the transport layer for service; for example an application seeking to open a connection to another application. When a transport entity requests the network to open a connection to a remote machine, it specifies the NSAP address to be called.

FAA PARTICIPATION IN THE ATN PROJECT

Airborne OSI Test Facility

The Technical Center is in the process of implementing an ATN compatible test facility capable of being installed on an FAA owned Boeing 727 aircraft (figure 1). This aircraft will be available to avionics vendors interested in a cooperative effort of testing and validating ATN compatible equipment before certification. The FAA's test facility will consist of the following:

1. The airborne portion of three broadcast subnetworks including a Mode-S transponder, airborne Data Link processor, satellite AES, and an ACARS management unit (expected to be replaced by an AVPAC unit when available).

2. A prototype ATN router. This prototype will be used for extensive recording, system performance, and shakedown testing and, thus, will contain expanded user interface and control capability. Production routers are not expected to include this expanded capability. This router will be replaced by commercial equipment when available.

3. A least two production Mode-S surveillance radars and associated ground Data Link processing with a network connection to a ground based ATN router.

4. A number of air traffic service applications, including automatic dependant surveillance, initial terminal ATC services, weather request/reply products via a gateway to non-ATN end systems and pre-departure clearance.

Cockpit Environment

ATN testing will progress into the human factors area with flight tests in the Data Link equipped 727. This aircraft will be configured with a center pedestal mounted control display unit, aural, and primary field of view visual alerting. Flight operations will be evaluated to asses the effects of dissimilar link characteristics, message transit times, and potential errors in data interpretation or procedures. Flights in restricted airspace will enable Technical Center evaluators to simulate the effects of the "quiet" cockpit in studying situational awareness and effects of loss of "party line" during Data Link operations.

CONCLUSIONS

There can be no question that the road ahead for the ATN will be a challenge. The transition from the current "speak and be spoken to" operations to a highly sophisticated internetworked computer-based environment will have to be performed, at first, in small steps. Each of these small steps, whether the replacement of a subnetwork with an improved version or the development of a new ATN compatible application, will bring the ATN closer to reality. The end state ATN, while not expected for a number of years, has the potential to provide capacity and performance benefits to the world's aviation community.

Most progress to date has been in the area of international standardization and definition of system requirements. Groups such as the International Civil Aviation Organization (ICAO), Airline Electronic Engineering Committee (AEEC), and RTCA, Inc. (previously known as the Radio Technical Commission for Aeronautics) have been active in the definition process. The next step, that of moving the ATN out of the theoretical arena and into prototype and preproduction implementations is practical today. Beginning with an emphasis on service definition, data collection, and fine tuning of the network parameters, this step will provide needed information to the potential suppliers and users of ATN compatible equipment. The FAA test facility described in this paper is intended to be utilized for ATN experimentation and can be made available for cooperative development by government and industry researchers.

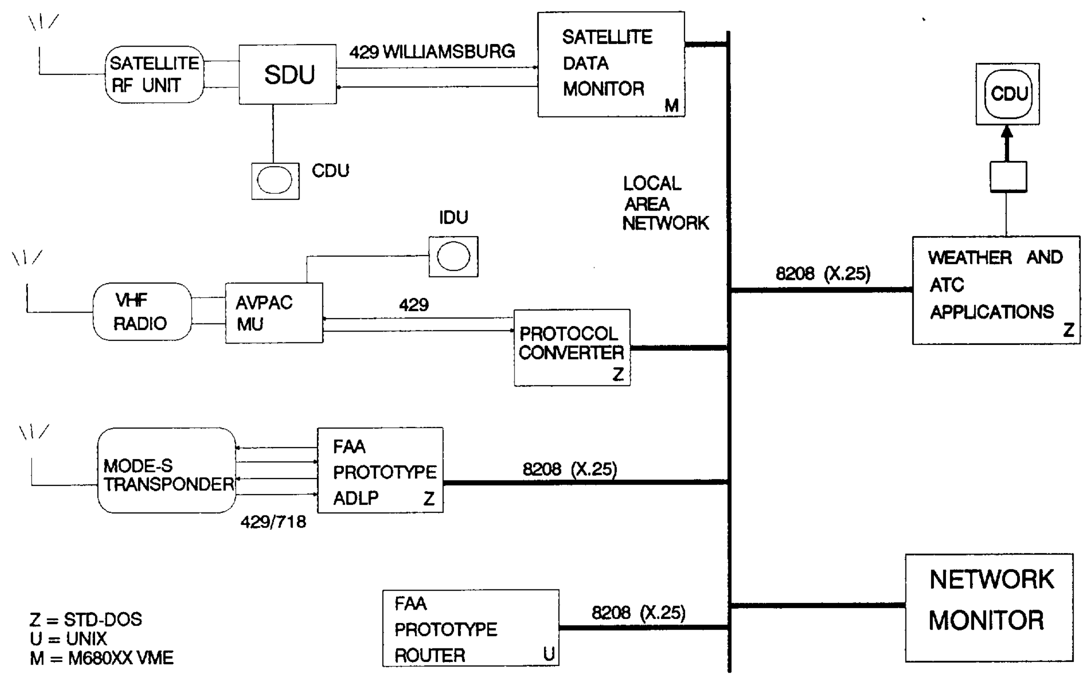

FIGURE 1. PROPOSED AVIONICS CONFIGURATION

(B727 Configuration)