OSI-Compatible Protocols for Mobile-Satellite Communications: The AMSS Experience

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ABSTRACT. *The protocol structure of the international aeronautical mobile satellite service (AMSS) is reviewed with emphasis on those aspects of protocol performance, validation, and conformance which are peculiar to mobile services. This is in part an analysis of what can be learned from the AMSS experience with protocols which is relevant to the design of other mobile-satellite data networks, e.g., land-mobile.*

1.0 INTRODUCTION

This paper reviews material presented to the Aeronautical Mobile Satellite Services (AMSS) Panel of the International Civil Aviation Organization (ICAO) regarding the protocols for the planned international aeronautical-mobile data service. Particular emphasis is placed on the datalink protocols and some of the work being done at the Communications Research Centre (CRC) in this area.

2.0 OVERVIEW OF AMSS AND OSI

One underlying premise of the AMSS is that it is constructed in manner which is consistent with Open Systems Interconnect (OSI) principles and in particular that it uses the seven-layer protocol stack illustrated in Figure 1. The work of the AMSS panel is concerned with the bottom three layers of this model: the physical, the datalink and the network layers. However, the AMSS is viewed as representing a satellite subnetwork within a much larger Aeronautical Telecommunications Network (ATN), which includes numerous other subnetworks among which are VHF datalink networks, radar communication networks and fixed data networks. One conception of the ATN is illustrated in Figure 2. The prime motivation for adopting the OSI model as a guide in developing the AMSS is this view of AMSS as part of a much larger ATN.

Among the attractions of the OSI model are the belief that it leads to more interoperable systems both intranetwork and internetwork, and the standard protocols available for the different protocol layers: protocols which have been to some extent validated and thoroughly tested. A further attraction of this approach is that the communication system is kept independent of the application, implying a much easier maintenance and upgrading of application software.

The drawback of the OSI model is that it is inherently designed for medium and wideband data networks. In mobile systems, power constraints imply that data rates range from hundreds of bits to a few kilobits per second, which is one to two orders of magnitude lower than the typical minimum data rate one would find in fixed data networks. Consequently, the overhead due to the use of seven layers of protocols can use proportionately more of an already scarce resource. Minimizing the message length at the application layer only eases this problem slightly, because at some point the contribution of the protocol overhead to the total message length becomes dominant.

The single example of Automatic Dependent Surveillance (ADS) messages illustrates many of these aspects of an OSI system which are important in mobile applications. ADS reports are aircraft position information derived from on-board navigational aids and are a potentially important air

traffic control application of AMSS. At the application layer most of the redundancy is removed from these messages leaving a standard message length of 88 bits. However, after passing through the top five OSI layers one calculation [1] shows that the message length presented to the data link layer is 248 bits; the majority of this additional overhead is due to the 128-bit Network Service Access Point (NSAP) address standard for the ATN (128 bits) [2]. However, the greatest overhead (most of which is not attributable to OSI) occurs when this message is converted to the 1368 bits which are transmitted over the channel. This latter figure includes the bits needed for a burst preamble and synchronization, and also includes the rate 1/2 coding applied to all information bits. On the other hand, designing to OSI principles means that changes in the content or the length of the ADS report can be made without requiring any change in the delivery system. The interconnectability offered by the ATN means that the ADS report can be automatically delivered over the best of a number of communications alternatives, e.g. satellite, VHF data link, or possibly Mode S surveillance radar.

This example clearly illustrates the important consideration that must be given to the protocols in the design of a mobile data network where there is limited bandwidth available at the physical layer. Opportunities for improving performance exist at all the different layers. For example, at the network layer an NSAP address of 128 bits[2], in principle, allows over 10^{38} destinations to be directly addressed, which is an extremely large amount of flexibility. It would be very advantageous if the network-datalink protocol convergence function limited the amount of flexibility through the use of some default addressing or other forms of address compression.

On the other hand there may be areas where the potential improvements are limited. For example, at the physical layer the very nature of the mobile network implies a necessity for some form of random access strategy and its inherent inefficiency. Ideally one would minimize the use of a random access scheme once the mobile is logged on the system, performing subsequent accesses using some form of controlled access. However, in an OSI
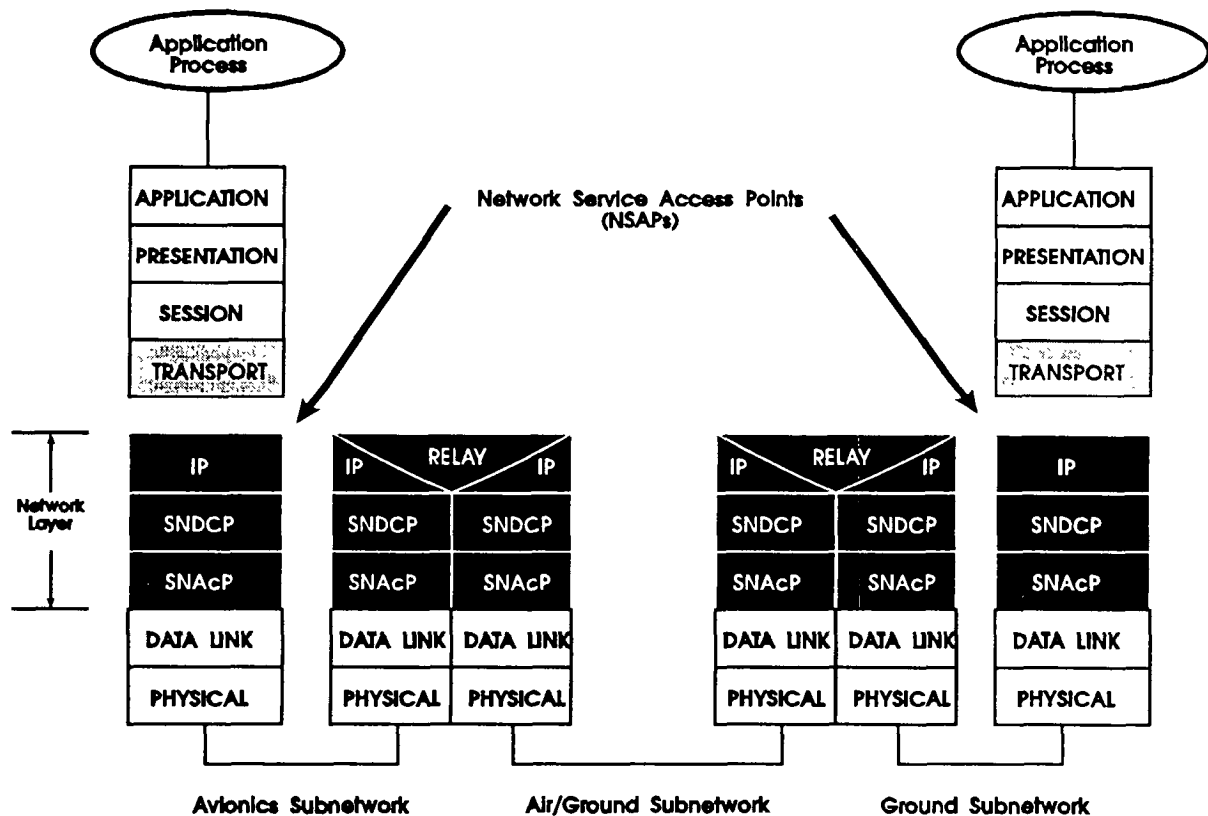

Figure 1. The ATN protocol architecture[2]. (Legend: IP - Internetwork Protocol; SNDCP - Subnetwork Dependent Convergence Protocol; SNAcP - Subnetwork Access Protocol)
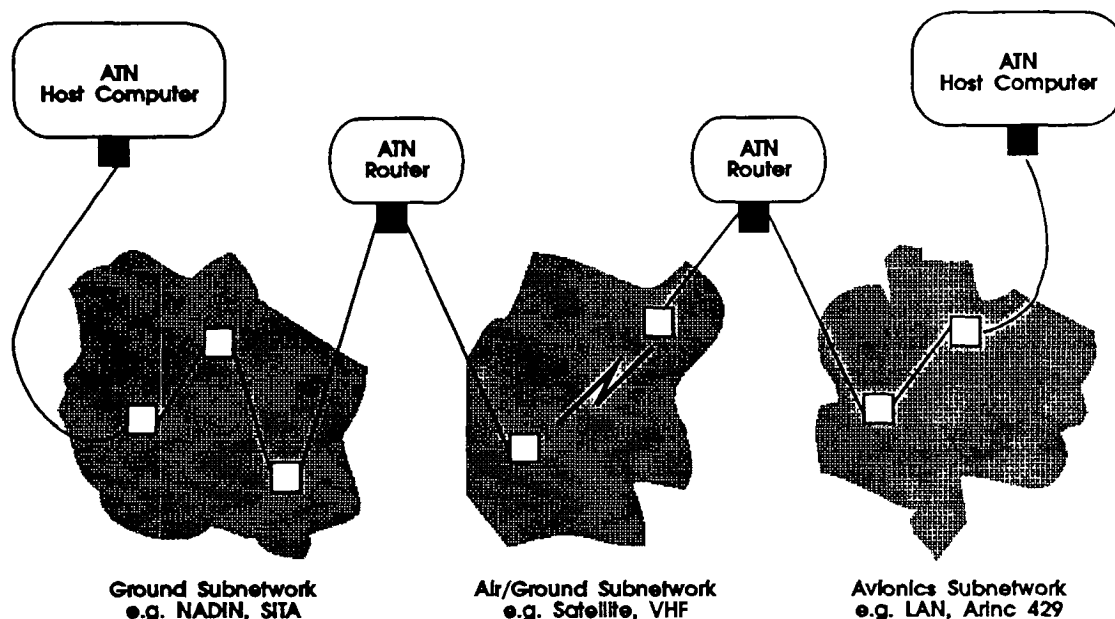
Figure 2. Conception of ATN composed of a number of interconnected subnetworks [2].

system the communications cannot be tailored to the application and as a result some inefficiencies are irreducible. However, there is ongoing research in the area of improving random access schemes [3], and other areas where the transmission media can be used more efficiently.

The OSI layer which is most directly concerned with the physical communications is the datalink layer, and it is at this layer that there is the most opportunity to optimize the performance of the limited physical resources. This is the layer that the remainder of this paper will concentrate on.

3.0 DATALINK PROTOCOLS

There are a number of services which the datalink layer must provide[4], and from the datalink protocol proposed by INMARSAT for the AMSS the most important of these relevant to mobile systems are:

— priority queuing of messages,
— message segmentation and re-assembly, and
— error detection and re-transmission.

The combination of priorities and message

segmentation, breaking long messages up into short packets of uniform length, prevent a long low priority message from hogging the narrow bandwidth datalink and causing excesssive delay to higher priority messages; and it also allows low priority messages to be interrupted by high priority messages and then to resume without the need to be completely re-transmitted. Message segmentation also allows the selective re-transmission of those portions of a message which were corrupted or lost, a situation which is not uncommon due the generally relatively poorer quality of mobile data links.

In the case of AMSS, considerable time and effort has been spent by INMARSAT to develop a datalink protocol which attempts to optimize the physical resources available. The underlying assumption being that with sufficient optimization at the datalink layer, standard ISO protocols such as ISO 8208 (X.25), ISO 8473, and ISO 8073/8602 can be used at the network, internetwork, and transport layers, respectively[2].

However, even within OSI there are interlayer conflicts. For example, the priorities used by the datalink layer are derived from the standard priorities attached to all aeronautical communications by the Radio Regulations of the

CCIR. However, priority is not a standard Quality of Service (QOS) parameter for an OSI datalink layer, in particular, it is not a standard QOS parameter passed by the standard X.25 network protocol. Priorities could be passed as part of the facilities field in the X.25 protocol, but this reduces to some extent the benefits of using a standard network protocol.

A detailed analysis of the datalink protocol for the AMSS will not be performed here but we will concentrate on some system level concerns about the protocol which are shared with land-mobile networks.

4.0 ASPECTS OF DATALINK PROTOCOLS

4.1 Performance

The main performance criteria placed on a data communications system are average message delay, maximum message delay, and reliability, as a function of message priority. The verdict is still out on the what performance is expected to be provided by the AMSS. One conclusion is clear, initial service will be slow because of the low data rates available and the large overheads associated with the data. However, this is acceptable in initial AMSS which serves oceanic and low-density areas [5] where the response time is, for the most part, not critical. However, there have been suggestions that AMSS may be used for air traffic control applications in en route areas, where the required response time is significantly shorter. In this latter case a detailed simulation of the protocols will be necessary to determine if the performance requirements can be met.

4.2 Protocol specification and validation

As with the introduction of any new protocol there is a need to carefully specify and validate the protocol to insure that it performs the required functions, and that it does so efficiently and without error. Protocol validation is not a new problem, but it becomes increasingly important problem as the size and complexity of a communication network grows. Although protocol validation is not a new problem, there does not appear to be a well defined solution.

The approach taken with the AMSS datalink protocol is to specify it using the standardized

formal description language SDL. Languages of this type are designed to allow the user to express all the details needed to specify an implementation[6]. In that sense they are not a minimum description of the protocol required to prove correctness and insure interoperability. While these languages are in a sense more complete, it has been our experience that at times they can also be ambiguous.

Among the several approaches that can be taken to the problem of validating a protocol are the following [6]:

— formal verification methods
— implementation of the protocol and testing the implementation,
— simulation of the protocol, and
— in a few cases, it is possible to construct automated design procedures that can be proven to produce correct designs, but this an area of current research.

Formal verification methods refer to the specification of the protocol as a transition system or the equivalent of communicating finite state machines. Then the state space of such system is exhaustively searched for undesired properties such as unmatched communication events, deadlocks, and infinite loops. Although such an analysis can be automated, the state space of such a system may grow so large with the number of messages and the number of machines present that such a verification becomes infeasible, although protocol validation for systems containing up 10^7 states have been proposed in the literature[7]. For example, the X.25 protocol has been partially verified by such an analysis.

By choosing to specify the AMSS datalink protocol in SDL, simulation/implementation appears to be the only the available method of protocol validation, until a transition system description is available. There are several levels on which the protocols can be validated by simulation/implementation. Current work being performed at CRC is validating the performance of the datalink protocols using a minimum subset of the system, one AES and one GES, together with simulated channel conditions. Validation of the protocols in a more complete system is a desirable second step in this process, but it is not clear if this can be done without either performing an in-service validation, or simplifying the simulation and possibly missing some of the protocol interactions.

4.3 Conformance testing

After a protocol has been validated, there remains the problem of insuring that all manufacturers conform to the standard. In theory, one would like to access to all interfaces between the different OSI layers, however, cost and manufacturer's design usually make this impractical. Furthermore, the goal of a standard is interoperability of different manufacturers' equipments rather than explicit specification of an implementation. This has the consequence that there are a limited number of standard test points available for testing protocol conformance. For example in the ICAO standard for AMSS, the only test points available for testing conformance are the interfaces at the network layer and the interface at the physical layer, that is, the signal-in-space as shown in Figure 3. As a consequence, the approach to testing equipment conformance will in general be very different from validating the protocol. In the latter, one can isolate the different OSI layers and validate each independently; while with the former, end-to-end conformance may be the only test available. Since the number of variations can increase exponentially with the number of layers combined, the latter may perform a far greater testing problem, and the only approach would appear to be insertion of the equipment in a simulation test suite where a equipment conformance can be tested over a wide range of standard scenarios[8]. The one saving grace is that this type of test only needs to done once for each implementation, and that there are a limited number of manufacturers.

A potential future problem is the correction of problems found in the protocol after the system has gone into service. There may be questions as to whether implementations must go through a formal test procedure with each upgrade or whether in-service testing can be sufficient. Another consideration is that, because of its size and the number of users, the complete system will not be upgraded simultaneously and thus each upgrade should be backwardly compatible.

5.0 CONCLUSIONS

In this paper several observations have been made about the development of the AMSS communication protocols and their implementation, emphasizing those areas which are relevant to other mobile systems. The OSI approach offers great flexibility and interconnectability to data communications with the penalty of significant protocol overhead. The implication is that in a narrowband system, such as mobile-satellite networks, great care should be taken to minimize these overheads at all layers. At the datalink layer, in particular, there is the opportunity to optimize the use of the available physical resources. However, it is clear that protocol validation should be performed as early as possible in the design process, and that each subsequent design change should be validated; in that way, the cost of correcting errors is minimized.
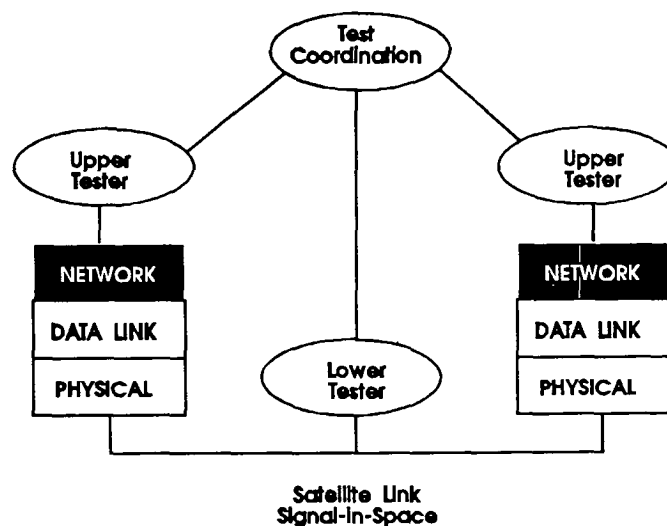

Figure 3. Illustration of test points available for protocol conformance test.

REFERENCES

[1] V.Foose et al, "Preliminary estimates of data link transmission overhead for ADS messages", WP-36, *3rd Panel Meeting of ICAO AMSS*, February 1990.

[2] F.Colliver Jr., "The Aeronautical Telecommunications Network", WP-37, *3rd Panel Meeting of ICAO AMSS*, February 1990.

[3] S.N.Crozier, "Sloppy Slotted ALOHA", *IMSC'90*, Ottawa, Canada, June 1990.

[4] "Reference Model for Open Systems Interconnection for CCITT Applications", *CCITT Rec. X.200*, 1984.

[5] Report of the Special Committee on Future Air Navigation Systems of ICAO, *FANS/4 Report*, Montreal, Canada, May 1988.

[6] B.Pehrson, "Protocol Verification for OSI", *Computer Networks and ISDN Systems*, vol. 18, pp.185-201, 1990.

[7] G.J.Holzmann, "On Limits and Possibilities of Automated Protocol Analysis", *IFIP Int. Conf. on Protocol Spec., Testing and Verif. VII*, Zurich (North-Holland, Amsterdam, 1988).

[8] R.J.Linn, "Conformance Testing for OSI Protocols", *Computer Networks and ISDN Systems*, vol.18, pp.203-219, 1990.