AERONAUTICAL TELECOMMUNICATIONS NETWORK PANEL
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Protocol Overhead in the Aeronautical Telecommunications Network (ATN)

SUMMARY

CAASD has applied its ATN simulation to investigate the percentage of protocol overhead on an air/ground subnetwork. The protocol overhead studied in the simulation included only routing, transport, and internetwork protocols. With a mix of the Automatic Terminal Information Service (ATIS) and Controller/Pilot Data Link Communication (CPDLC) applications, more octets of overhead than user data are sent over the air/ground link. For communication from aircraft to the ground, where application messages are especially small, 13 to 25 octets of protocol overhead were sent for every octet of user data. The connection oriented transport protocol contributes most of this overhead. The ATN community should reconsider whether the benefits of a connection oriented transport protocol over the air/ground link are worth the cost. The Interdomain Routing Protocol (IDRP) contributes up to 15% of the total traffic.

1.0 INTRODUCTION

Because the Aeronautical Telecommunications Network (ATN) will use very low bandwidth air/ground subnetworks, much effort has gone into minimizing the amount of protocol overhead on those subnets. CAASD has applied its ATN simulation to investigate how well those efforts have paid off. The protocol overhead studied in the simulation included only routing, transport, and internetwork protocols. The simulation did not investigate additional overhead from upper layer protocols.

With a mix of the Automatic Terminal Information Service (ATIS) and Controller/Pilot Data Link Communication (CPDLC) applications, more octets of overhead than user data are sent over the air/ground link. For communication from aircraft to the ground, where application messages are especially small, 13 to 25 octets of protocol overhead were sent for every octet of user data. The connection oriented transport protocol contributes most of this overhead. The ATN community should reconsider whether the benefits of a connection oriented transport protocol over the air/ground link are worth the cost. The Interdomain Routing Protocol (IDRP) contributes up to 15% of the total traffic.

2.0 DESCRIPTION OF EXPERIMENT

These experiments simulated a portion of the Federal Aviation Administration's (FAA's) ATN infrastructure. To keep simulation run times reasonable, the simulation included only aircraft with connections to Kansas City (ZKC), Denver (ZDV), Albuquerque (ZAB), Fort Worth (ZFW), and Houston (ZHU). One ATN router was located at each of these ARTCCs. (An ARTCC is an en route control facility, sometimes referred to as a "center.") Each ARTCC was its own routing domain. The ground routers were interconnected by the NADIN Packet Switched Network (PSN), the FAA's national X.25 network.

An average of 53 aircraft were in each domain's airspace. Aircraft flight times in an ARTCC's airspace were exponentially distributed with a mean of 27 minutes. The minimum time in an ARTCC's airspace was 60 seconds. Transport connections were set up as soon as an IDRP connection was established after takeoff or after entering coverage of the next center. The applications were notified when a transport connect confirm was sent or received. The applications began generating messages upon receipt of this notification. CLNP headers were compressed as specified in the ATN Manual. IDRP keepalives were sent every 400 seconds.

The model included two applications, ATIS and CPDLC. For ATIS, the aircraft periodically sent a 7-byte request to a ground end system at the aircraft's destination. The ground end system sent a 400 byte response back to the aircraft. For CPDLC, either the ground or the aircraft could initiate a request/reply transaction. Each downlink message was 4 octets. Each uplink message was 15 octets.

The amount of application message traffic strongly influences the amount of protocol overhead. Results are presented below for two cases, a low application traffic case and a high application traffic case. The low traffic case uses the expected interarrival times for early ATN [1, 2]. Table 1 lists these message interarrival times and the approximate number of transactions during an aircraft's flight through a single ARTCC's airspace. For the high traffic case, the message interarrival times were divided by 6. Table 2 shows the utilization of the air/ground subnetwork for each traffic level.

Table 1. Mean Message Interarrival Times - Low Traffic

Application	Transactions per ARTCC Traversal	Mean Msg Interarrival Time (sec)
ATIS	1	1628
CPDLC, ground initiated	10.8	150
CPDLC, aircraft initiated	1.3	1252

Table 2. Subnetwork Utilization

	Uplink Utilization	Downlink Utilization
Low Traffic	9%	7%
High Traffic	37%	23%

The simulation included a detailed model of the connection oriented transport protocol, ISO 8073 [3]. Parameters that affect end-to-end delays were set as shown in Table 3. The window time determines how often transport keepalives are sent.

Table 3. Transport Timers

Parameter	Value
Acknowledgment time (AL)	2 sec
Retransmission time (T1)	203 sec
Keepalive time	657 sec
Max. Number of transmissions	5

The acknowledgment time is how long a transport entity may wait before acknowledging a receive packet. The retransmission time is the length of time a transport entity waits before retransmitting an unacknowledged packet. A retransmission time of 203 seconds seems somewhat large but was necessary to prevent transport connections from timing out in the scenario with heavier traffic load. Somewhat smaller values may be better; further study would be needed to determine an optimal value. Selective acknowledgment was used. Transport acknowledgments were sent as keepalives when a transport connection was idle for 657 seconds.

Table 4 lists the sizes of protocol packets and headers in the simulation.

Table 4. Packet and Header Lengths

Packet or Header	Size (octets)
IDRP Open length	82
IDRP Update length	126
ISH length	30
Uncompressed CLNP header length	60
Compressed CLNP header length	6
Transport protocol:	
Connect Request	53
Connect Confirm	55
Disconnect Request	10
Disconnect Confirm	9
Data packet header	9
Acknowledgment	34

3.0 RESULTS

Tables 5 and 6 list the number of octets sent in each direction for applications and several categories of protocol overhead. The tables also show the percentage of the total traffic contributed by applications and each type of overhead. The results in Table 1 are for the low level of application traffic; Table 2 is for the higher level of traffic. Figures 1 - 4 display the results graphically.

The “TP4 Connection Est” category includes Connect Requests and Confirms and Disconnect Requests and Confirms. The “TP4 Acks” category includes acknowledgments used to update the sender’s transmit window and acknowledgments sent as keepalives.

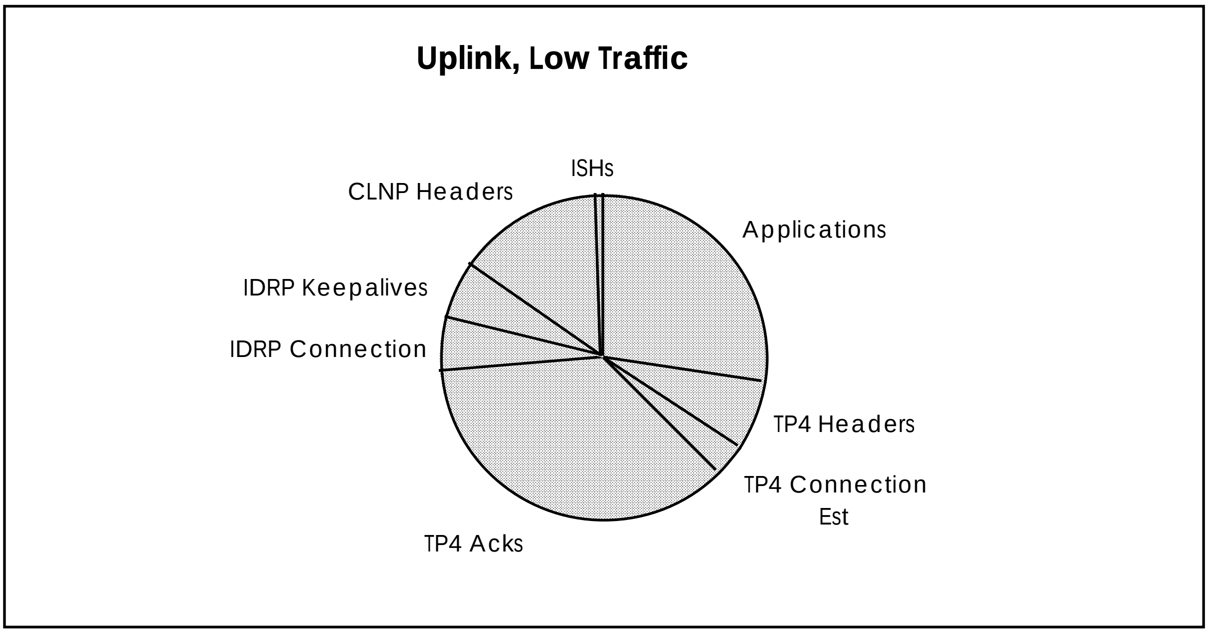
The percent overhead in the last row of each table is the ratio of the total number of octets of protocol overhead to the total number of octets of application messages. For the uplink in the low traffic case, 2.6 octets of overhead were sent for every byte of application data. For the downlink, 25 octets of overhead were sent for every byte of application data.

Table 5. Distribution of Protocol Overhead - Low Traffic

	Uplink		Downlink	
	Octets	Percent of Total Uplink Traffic	Octets	Percent of Total Downlink Traffic
Applications	614,294	28%	63,306	4%
TP4 Headers	152,260	7%	152,250	9%
TP4 Connection Est	68,299	3%	69,806	4%
TP4 Acks	798,366	36%	752,201	45%
IDRP Connection	119,436	5%	119,064	7%
IDRP Keepalives	132,360	6%	133,050	8%
CLNP Headers	321,504	14%	361,506	22%
ISHs	17,100	1%	17,100	1%
Total	2,223,619		1,668,283	
Percent Overhead (OH octets/App octets)	262%		2535%	

Table 6. Distribution of Protocol Overhead - High Traffic

	Uplink		Downlink	
	Octets	Percent of Total Uplink Traffic	Octets	Percent of Total Downlink Traffic
Applications	3,566,835	42%	350,524	7%
TP4 Headers	838,050	10%	840,850	16%
TP4 Connection Est	69,039	1%	70,248	1%
TP4 Acks	2,631,481	31%	2,564,414	50%
IDRP Connection	119,436	1%	119,064	2%
IDRP Keepalives	132,390	2%	133,050	3%
CLNP Headers	1,038,849	12%	1,080,201	21%
ISHs	17,100	0%	17,100	0%
Total	8,413,180		5,175,451	
Percent Overhead (OH octets/App octets)	136%		1376%	



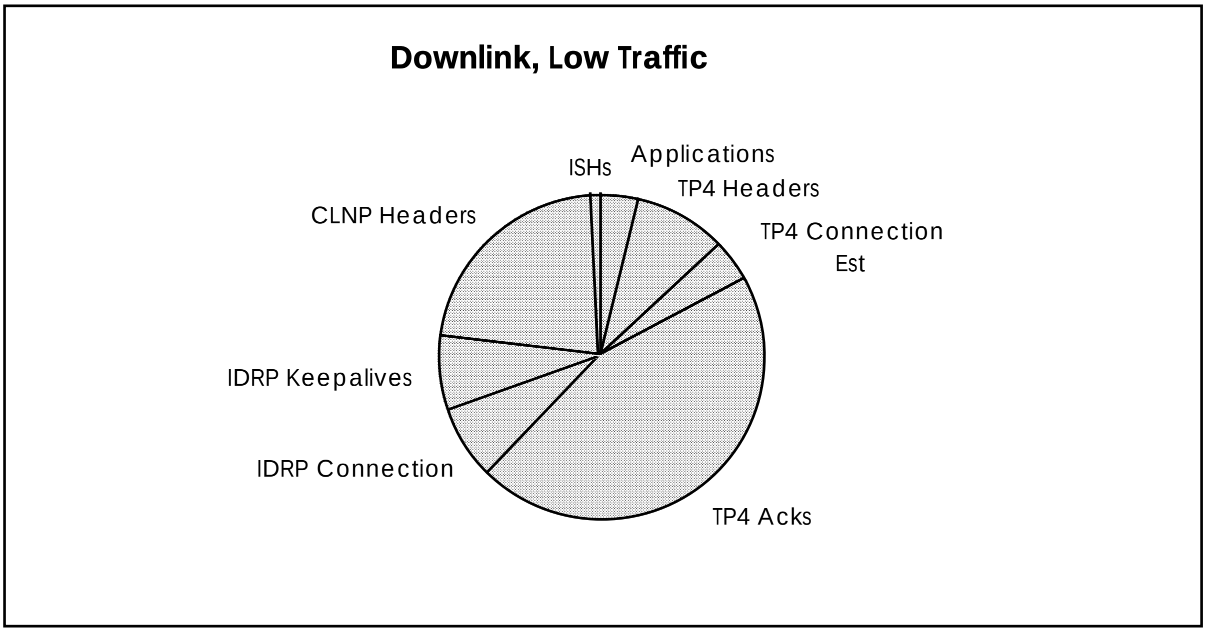
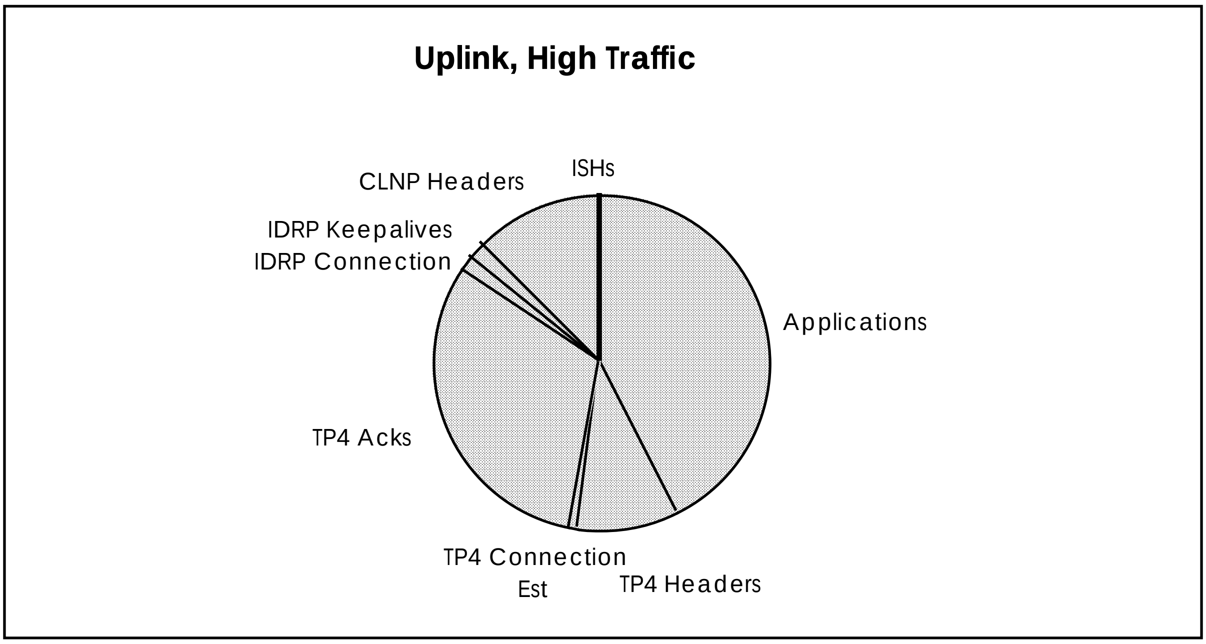


Figure 1. Distribution of Overhead with Low Traffic



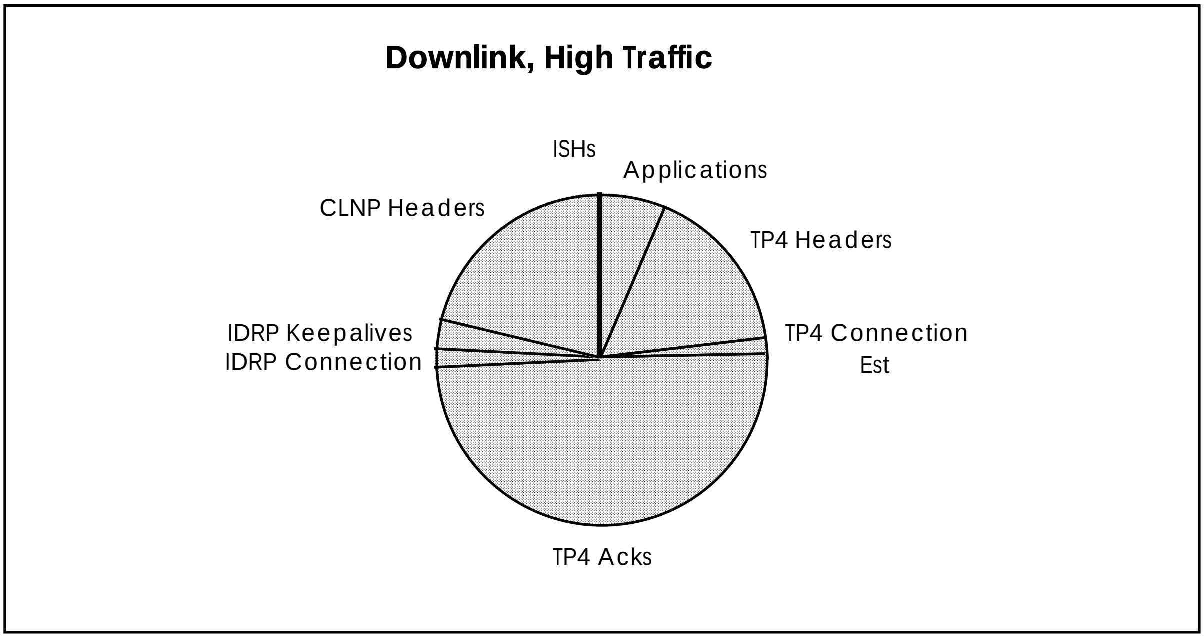


Figure 2. Distribution of Overhead with High Traffic

4.0 CONCLUSIONS

There is a high percentage of protocol overhead on the air/ground subnets. Given the limited bandwidth on the air/ground subnetworks, this is a cause for concern. Two changes to the ATN should be considered to reduce the overhead.

Transport acknowledgments make up 31% to 50% of the total traffic, including application messages, in these simulations. This raises the question whether it is appropriate to run a connection oriented transport protocol over the ATN's limited air/ground subnetworks, and especially whether that protocol should be ISO 8073. ISO 8073 uses separate transport protocol data units for acknowledgments, rather than piggybacking an acknowledgment sequence number in data packets as in Transmission Control Protocol (TCP, RFC 793). It has been argued that connection oriented transport is needed for the end-to-end integrity necessary for FAA certification. However, data link applications that do not require reliable delivery, or those that have their own application level mechanisms to ensure reliable delivery, should consider using a connectionless transport protocol. Doing so would eliminate transport connection overhead and transport acknowledgments and would shorten transport headers. As a result, approximately half the total traffic on the air/ground subnetwork might be eliminated.

For example, the CPDLC message set was designed so that when the human needs assurance of message delivery, the remote user is forced to respond at an application level (for example, with a WILCO). Whatever benefits accrue from the transport protocol are outweighed by the bandwidth it uses.

IDRP packets make up as much as 15% of total traffic. IDRP can cause long delays for application traffic because each IDRP packet is relatively long, several IDRP packets are sent in sequence, and IDRP packets are sent with a higher priority than any application messages. With ATN as currently planned, IDRP will be necessary on the air/ground link in order to tell the aircraft what ground systems can be reached through a given air/ground connection. IDRP may also be necessary on the air/ground link to provide an authentication mechanism for mobiles using the ATN. CAASD has proposed an alternative [4] to using IDRP on the air/ground link which will provide the necessary routing information with none of the overhead imposed by IDRP. This alternative should be reconsidered in light of its bandwidth efficiency.

5.0 REFERENCES

1. W. Robert Rice, "Data Link Traffic Estimates," WN94W0000012, The MITRE Corporation, July 1994.

2. FAA, Operational Requirements for the Aeronautical Data Link System, 3 January 1995.

3. "Information Processing Systems - Telecommunications and Information Exchange between Systems - Protocol for Exchange of Inter-domain Routeing Information among Intermediate Systems to Support Forwarding of ISO 8473 PDUs," ISO/IEC 10747, 18 October 1993.

4. T. Signore, "CNS/ATM-1 Package Policy Implementation Definition," WG2/WP-72, January 1995.

6.0 ACKNOWLEDGEMENTS

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