

A Performance Analysis of the Aeronautical Telecommunication Network

**Von der Gemeinsamen Fakultät für Maschinenbau und Elektrotechnik
der Technischen Universität Carolo-Wilhelmina
zu Braunschweig**

zur Erlangung der Würde eines
Doktor-Ingenieurs (Dr.-Ing.)

genehmigte

DISSERTATION

von

Jörg Steinleitner

aus Itzehoe



Eingereicht am:	10. Juli 1998
Mündliche Prüfung am:	22. Oktober 1998
Berichterstatter:	Prof. Dr. rer. nat. H. Rohling
Mitberichterstatter:	Prof. Dr. M. Zitterbart

Contents

1	Introduction	1
2	The ATN and the ISO/OSI Reference Model	5
2.1	The ISO/OSI Concept	5
2.1.1	Layering	5
2.1.2	Services and Protocols	7
2.1.3	Connection-Oriented and Connectionless Data Transfer Mode	8
2.2	ICAO's ATN Concept	8
2.2.1	ATN System Architecture	9
2.2.2	Addressing	11
2.2.3	Mobile ATN Subnetworks	12
2.2.3.1	Mode S Subnetwork	12
2.2.3.2	Satcom Subnetwork	12
2.2.3.3	VHF Subnetwork	13
2.3	ATN Protocol Architecture	15
2.3.1	Determination of ATN Communication Protocols	15
2.3.1.1	"Lower Layer" Protocol Stack	15
2.3.1.2	"Upper Layer" Protocol Stack	17
2.3.2	Routing Protocols	18
2.3.3	Network Management Protocols	20
2.4	Why not TCP/IP ?	21
3	The Mode S System	23
3.1	A System Description	24
3.1.1	Scheduling	24
3.1.2	Mode S Interrogations and Reply Formats	25
3.2	The Protocol Layer of the Mode S Subnetwork	25
3.2.1	Physical Layer	25
3.2.1.1	Data Transmission Link	25
3.2.1.2	Sensor	26
3.2.1.3	Transponder	28
3.2.2	Data Link Layer	28
3.2.2.1	The "Comm-A" and "Linked Comm-A" Protocol	30

3.2.2.2	The Air-initiated "Comm-B" and "Linked Comm-B" Protocol.....	30
3.2.2.3	The "Comm-C" Protocol	30
3.2.2.4	The "Comm-D" Protocol	30
3.2.3	Subnetwork Access Sublayer – ADLP and GDLP	31
4	Approaches for ATN Protocol Stack Performance Analysis _____	35
4.1	Considered Performance Analysis Approaches.....	36
4.1.1	Queueing Theory.....	36
4.1.2	Discrete Event Simulation.....	38
4.2	Use of Considered Performance Analysis Approaches	39
5	A Performance Analysis of the Mode S Data Link _____	41
5.1	Assessment of Theoretically Available User Data Rates.....	41
5.1.1	The Impact of Annex-10 Performance Requirements	48
5.1.2	The Impact of Aircraft Distribution – Clustering.....	52
5.1.3	An Analytical Mode S Data Transmission Delay Analysis	55
5.1.4	Summary	64
5.2	Simulation Analysis : Mode S Data Link Layer Model.....	65
5.2.1	Traffic Scenario	65
5.2.2	Interrogator.....	66
5.2.3	Transponder	67
5.2.4	Message Sources	68
5.2.5	Erroneous Transmissions	69
5.2.6	Simulation Output	69
5.3	Simulation Analysis : Mode S Data Link Layer Performance	70
5.3.1	A Baseline: Mean End-To-End Data Transmission Delay	70
5.3.2	Uplink-To-Downlink Data Generation Ratio	71
5.3.3	Air Traffic Scenario	72
5.3.4	Mode S Segment Transmission Failure.....	74
5.3.5	Mode S Specific Services – GICB Data Transmission.....	75
5.3.6	Summary	76
6	Impact of ATN Communications on Mode S Data Link Performance ____	79
6.1	"Lower Layer" Protocol Stack.....	79

6.1.1	Subnetwork Access Sublayer (SNACP).....	79
6.1.1.1	Priority Handling within SNACP	79
6.1.1.2	X.25 Overhead and X.25 Maximum Data Packet Size	81
6.1.1.3	X.25 Data Packet Multiplexing	84
6.1.1.4	Multiplexing, Priority Handling and ISO 8208 Interrupt Packets.....	88
6.1.2	Subnetwork Dependent Convergence Function (SNDCF).....	89
6.1.2.1	Provision of Subnetwork Service in the ATN.....	89
6.1.2.2	SNDCF Data Compression Techniques.....	90
6.1.2.2.1	“Local Reference” (LREF) Compression	91
6.1.2.2.2	V.42bis and ACA Compression Techniques	93
6.1.3	Subnetwork Independent Convergence Protocol (SNICP)	96
6.1.3.1	Provision of Network Service in the ATN	96
6.1.3.2	Routing Decision Support.....	100
6.1.4	Transport Protocol (TP)	101
6.2	“Upper Layer” ATN Protocol Stack.....	108
6.2.1	“Fast Byte” Upper Layer Protocol	108
6.2.2	Presentation Protocol – ASN.1 Data Encoding	108
6.2.3	Application Layer	111
6.2.4	Epilogue: End-to-End Delay Distribution	114
7	ATM Applications and ATN Performance _____	117
7.1	ADS.....	118
7.2	CPDLC	120
7.3	FIS.....	122
7.4	Network Management and Routing Information Exchange.....	123
7.5	Flexible Communication Strategies	124
8	Conclusions _____	127
	Annex _____	131
	List of Figures.....	131
	List of Tables	133
	Bibliography	134
	List of Abbreviations	141