



UNIVERSITI PUTRA MALAYSIA

**INTER-SATELLITE LINK CHANNEL MANAGEMENT
FOR MOBILE SATELLITE SYSTEMS**

ANGELINE ANTHONY DASS

FK 2003 6

**INTER-SATELLITE LINK CHANNEL MANAGEMENT FOR MOBILE
SATELLITE SYSTEMS**

By

ANGELINE ANTHONY DASS

**Thesis Submitted to the School of Graduate Studies, Universiti Putra Malaysia,
In Fulfillment of the Requirements for the degree of Master of Science**

April 2003



To God and my family.....



Abstract of thesis presented to the Senate of Universiti Putra Malaysia in fulfillment of the requirements for the degree of Master of Science

**INTER-SATELLITE LINK CHANNEL MANAGEMENT FOR MOBILE
SATELLITE SYSTEMS**

By

ANGELINE ANTHONY DASS

May 2003

Chairman : Professor Dr. Borhanuddin Mohd. Ali

Faculty: Engineering

Low Earth Orbit (LEO) satellite constellations are foreseen as appropriate alternatives to the geostationary satellite systems for providing global personal communications services (PCS). Compared to geostationary satellites, these constellations offer a significantly smaller round trip delay between earth and space segments. Furthermore, the use of inter-satellite links (ISLs) has been identified as a means to provide global connectivity in space, thereby enhancing system autonomy and flexibility, and has been retained in the design of systems like Teledesic and SkyBridge. From a network point of view, a major benefit of a ISL subnetwork in space lies in the possibility to transport long distance traffic over reliable and high capacity connections, thus forming a good base for ATM (asynchronous transfer mode) operation. With the development of the third generation (3G) and fourth generation (4G) wireless networks, ATM is regarded as one of the potential promising candidates for providing QoS guaranteed broadband telecommunication services. It is possible to integrate the mobile satellite and ATM by applying the inter/intra satellite links (ISLs) as the physical layer of WATM and



considering a connection between two satellites as a virtual path connection (VPC) in ATM.

A handoff event will cause re-allocation on the affected ISL channel resources. As the increasing of the arrival rate of handoff calls, channel management becomes a very important issue in providing QoS. Methods to keep the frequency of handoff as low as possible, and how to alleviate the side-effects of handoff events on the whole network are very important in providing QoS promised service. A good routing scheme is always highly related to the happening of handoff events.

In order to best utilize the network resource and provide better network QoS, a dynamic channel allocation scheme (DCAS) is considered, giving higher priority to handoff calls compared to new calls and real time traffic over non real time traffic. The higher priority traffic will have a larger probability to access a channel, while the lower priority traffic will have a smaller probability to obtain a channel. In this way, we give highest priority to the real time handoff calls, followed by the non real time handoff calls, then the real time new calls and lastly the non real time new calls. The channel access probability also depends on the mobility of call (handover call arrival rate over the new call arrival rate) and the channel resources. A suitable routing method was used based on the Modified Dijkstra Shortest Path algorithm. For an efficient channel management scheme, the dynamic channel allocation and shortest path routing methods are combined. The new channel management scheme allows the higher priority call to obtain a larger call acceptance probability and utilize the shortest path, while the lower priority call will have a smaller call acceptance probability and utilize the longer routes.

The network performance is measured from its end-to-end delay, new call blocking probability, and handoff call blocking probability. The new channel management scheme improves the utilization of the network resources by reducing the handover call blocking probability while guaranteeing a certain quality of service for the new call blocking probability.

Abstrak tesis yang dikemukakan kepada Senat Universiti Putra Malaysia sebagai memenuhi sebahagian daripada keperluan ijazah Master Sains

**PENGURUSAN SALURAN ANTARA SATELLITE UNTUK SISTEM
SATELLITE BERGERAK**

Oleh

ANGELINE ANTHONY DASS

Mei 2002

Pengerusi : Profesor Dr. Borhanuddin Mohd. Ali

Fakulti : Kejuruteraan

Buruj satelit orbit-bumi-rendah telah dikenalpasti sebagai gantian sesuai kepada sistem satelit geopegun untuk membekalkan perkhidmatan komunikasi peribadi global (PCS). Berbanding dengan satelit geopegun, buruj-buruj ini menawarkan kelengahan pusingan perjalanan yang lebih kecil di antara segmen bumi dan angkasa. Tambahan pula, penggunaan hubungan antara satelit (ISL) telah dikenalpasti sebagai cara mengadakan sambungan global di angkasa, dan meningkatkan autonomi dan kefleksibelan sistem, dan telah digunakan dalam rekabentuk system seperti Teledesic dan SkyBridge. Dari kaca mata rangkaian, satu kebaikan subrangkaian hubungan antara satelit (ISL) adalah kemudahan mengangkut trafik jarak jauh di atas sambungan yang dipercayai dan berkapasiti tinggi, sekaligus membentuk satu asas yang baik untuk operasi cara pindahan tak segerak (ATM). Dengan pembangunan rangkaian wayarles generasi ketiga (3G) dan generasi keempat (4G), ATM telah dikenali sebagai calon yang baik untuk membekalkan perkhidmatan telekomunikasi jalur lebar dengan perkhidmatan kualitinya (QoS)



terjamin. Adalah mungkin untuk menggabungkan satelit bergerak dan ATM dengan menggunakan hubungan inter/intra sebagai lapisan fizikal ATM wayarles (WATM) dan menganggap sambungan antara dua satelit sebagai litar laluan maya (VPC) dalam ATM.

Kejadian pengambilalih akan menyebabkan peruntukan semula sumber saluran ISL yang terlibat. Ketinggian kadar ketibaan panggilan pengambilalih, membuatkan pengurusan saluran menjadi isu yang sangat penting untuk mengekalkan QoS. Cara-cara untuk mengurangkan kejadian pengambilalih dan kesannya terhadap seluruh rangkaian adalah sangat penting dalam mengekalkan perkhidmatan kualiti yang terjamin. Skim penghalaan yang baik sentiasa dikaitkan dengan kejadian pengambilalihan.

Demi menggunakan sumber rangkaian dengan baik dan membekalkan perkhidmatan kualiti yang lebih baik, satu skim peruntukan saluran dinamik (DCAS) telah dipertimbangkan, dengan memberi keutamaan yang lebih tinggi kepada panggilan pengambilalih berbanding kepada panggilan baru, dan trafik masa nyata berbanding kepada trafik bukan masa nyata. Trafik yang berkeutamaan lebih tinggi akan mempunyai kebarangkalian yang lebih tinggi untuk mendapat saluran, manakala trafik yang berkeutamaan lebih rendah akan mempunyai kebarangkalian yang lebih kecil. Dengan cara ini, kita memberi keutamaan tertinggi kepada panggilan pengambilalih masa nyata, panggilan pengambilalih bukan masa nyata, panggilan baru masa nyata dan akhirnya panggilan baru bukan masa nyata. Kebarangkalian perolehan saluran juga bergantung kepada mobiliti panggilan (kadar ketibaan panggilan pengambilalih kepada kadar ketibaan panggilan baru) dan keadaan sumber saluran. Suatu cara laluan yang sesuai

digunakan berasaskan algoritma Modified Dijkstra Shortest Path. Untuk skim pengurusan saluran yang efisien, skim peruntukan saluran dinamik dan laluan jalan terpendek telah digabungkan. Skim pengurusan saluran yang baru membenarkan panggilan berkeutamaan tinggi untuk mendapat kebarangkalian panggilan diterima yang lebih besar dan menggunakan laluan terpendek, manakala panggilan berkeutamaan lebih rendah mempunyai kebarangkalian panggilan diterima yang lebih kecil dan menggunakan laluan yang lebih jauh.

Kebolehan rangkaian diukur dari kelewatan hujung ke hujung, kebarangkalian halangan panggilan baru dan kebarangkalian halangan panggilan pengambilalih. Skim baru pengurusan saluran memperbaiki penggunaan sumber rangkaian dengan mengurangkan kebarangkalian halangan panggilan pengambilalih dan mengekalkan servis kualiti tertentu bagi kebarangkalian halangan panggilan baru.

ACKNOWLEDGEMENTS

I would like to express my greatest appreciation and gratitude to God the almighty and merciful for giving me the strength and ability to complete my research.

I would like to express my sincere appreciation to Prof. Borhanuddin Mohd. Ali, chairman of my supervisory committee for his time and guidance. I would like to express my deepest gratitude to Dr. Hadi Mohd. Habaebi for being in my supervisory committee and for his time, guidance and motivation. I would like to thank Dr. V. Prakash for his ideas and support as a committee member throughout my research.

I would also like to thank Puan Nor Kamariah Nordin, for her helpful suggestions, guidance and time. Special thanks goes to Mr. Ashraf Gasim Elsid Abdalla for his encouragement and support. I wish to thank Dr. Sabira Khatun for her help with the mathematical models.

I am very grateful to Sahar Talib who has been a great help in the simulation part of this research, and fellow students Shamini, Khalid, Zubeir, Coulibaly, Prihandoko, Michael, Aduwati and Saravanan, from the wireless group who were always willing to spend time and provide any help they could.

Finally, I would like to thank my family members and friends for their unlimited love, encouragement and support.



TABLE OF CONTENTS

	Page
DEDICATION	ii
ABSTRACT	iii
ABSTRAK	vi
ACKNOWLEDGEMENTS	ix
APPROVAL SHEET	x
DECLARATION FORM	xii
LIST OF TABLES	xv
LIST OF FIGURES	xvi
LIST OF ABBREVIATIONS	xx
LIST OF NOTATIONS	xxiii
CHAPTER	
1. INTRODUCTION	1.1
1.1 Background and Motivation	1.1
1.2 Problem Definition	1.2
1.3 Research Objectives	1.4
1.4 Contribution of the Thesis	1.4
1.5 Thesis Organization	1.5
2. LITERATURE REVIEW	2.1
2.1 Concept of Asynchronous Transfer Mode	2.1
2.2 ATM Based LEO Satellite System	2.3
2.2.1 Broadband Satellite Systems	2.3
2.2.2 Mobile Satellite Systems	2.6
2.2.3 Teledesic System	2.12
2.2.4 ATM Based Routing with ISL	2.19
2.3 Channel Assignment Schemes	2.23
2.3.1 Fully Shared Scheme	2.23
2.3.2 Guard Channel Scheme	2.24
2.3.3 Dynamic Channel Reservation Scheme	2.24
2.4 Path Selection and Optimization	2.29
2.4.1 Path Definition based on ISLs	2.29
2.4.2 Path Selecting and Reserving Schemes	2.33
2.4.2.1 Traffic Detecting Scheme (TDS)	2.33
2.4.2.2 Moving Estimation Scheme (MES)	2.35
2.4.2.3 Path Reservation Scheme	2.37
2.6 Handoff Schemes	2.37
2.6.1 Modified Dijkstra Shortest Path (MDSP)	2.38
2.6.2 Rerouting Nodes Handoff (RNH)	2.39
2.7 Summary	2.41
3. METHODOLOGY	3.1
3.1 Simulation Model	3.1
3.2 Traffic Modeling	3.11



3.2.1	Defining types of traffic	3.11
3.2.2	Determining traffic through a node	3.14
3.3	Proposed Dynamic Channel Allocation Scheme	3.16
3.4	Channel Management Scheme	3.23
3.5	Summary	3.26
4.	RESULTS AND DISCUSSIONS	4.1
4.1	Design Parameters	4.1
4.2	Performance Parameters	4.2
4.3	Performance Evaluation of the Dynamic Channel Allocation Scheme	4.2
4.4	Channel Allocation Based on Traffic Priority	4.8
4.5	Call Dropping and Blocking Probability	4.15
4.6	Total System Delay	4.27
4.7	Summary	4.33
5.	CONCLUSION AND FUTURE WORKS	5.1
5.1	Conclusion	5.1
5.2	Recommendations and Future Work	5.3
	REFERENCES	R.1
	APPENDICES	A.1
	BIODATA OF AUTHOR	B.1



LIST OF TABLES

Table		Page
2.1	General Comparisons for LEO-MEO-GEO Constellations	2.6
2.2	Comparison Parameters for the LEO Satellite Constellations	2.13
3.1	Link Labels for the nine-node model	3.4
3.2	Coordinates for the nine-node model	3.8
3.3	Shortest Paths for pair A1 - C3	3.10
3.4	Parameters for Teledesic satellite service	3.20
3.5	Traffic Types	3.20
4.1	Initial random traffic load on each link when $C = 12500$	4.10
4.2	(a) Processing delay when 2 hops apart	4.32
	(b) Processing delay when 3 hops apart	4.32



LIST OF FIGURES

Figure		Page
1.1	Thesis Organization	1.6
2.1	Satellite Orbits	2.3
2.2	Bent-pipe connectivity in satellite systems	2.8
2.3	Connectivity in satellite systems using on-board processing and ISLs	2.9
2.4	LEO satellite network with seam	2.11
2.5	Teledesic inter-satellite connections a) 3D view b) 2D view	2.13
2.6	Teledesic Beam Steering	2.15
2.7	Space division between supercells and cell scan pattern (cell 9 illuminated in all supercells)	2.15
2.8	Uplink FDM and downlink ATDM used for transmission multiplexing in Teledesic	2.16
2.9	Fixed TDMA among nine cells in supercell	2.17
2.10	VPC's between start satellite S1 and S2	2.21
2.11	VP/VC routing concept for LEO systems with ISLs	2.22
2.12	A wireless channel model of the DCRS	2.25
2.13	A call processing flow diagram for DCRS	2.26
2.14	Request probability for the channel allocation	2.27
2.15	Satellite nodes in Teledesic System (2D view)	2.30
2.16	ISL path setup between Satellite A and B	2.31
2.17	Potential paths for a given pair of nodes	2.33
2.18	Traffic detecting path selecting scheme	2.33
2.19	Moving estimation based path selecting scheme	2.36
2.20	Rerouting node handoff scheme	2.40



3.1	Nine nodes from Teledesic satellite system with 8 ISLs	3.2
3.2	Nine nodes and ISLs labeled	3.3
3.3	(a) 4ISLs	3.5
	(b) 8ISLs	3.5
3.4	Comparison of 8 ISL and 4 ISL paths for selected pair of nodes	3.6
3.5	Long and short links comparison for the 288 Teledesic model	3.7
3.6	Shortest Path for node A1 and C3	3.9
3.7	Minimum paths through a node	3.15
3.8	Procedure of DCAS for real time and non real time traffic (without separate regions)	3.18
3.9	DCAS considering threshold range (with regions) for number of occupied channels	3.22
3.10	Overview of channel management scheme	3.23
3.11	Procedure of Channel Management Scheme	3.24
4.1	a) Probability of accepting a new call vs Mobility of calls	4.3
	b) Probability of accepting new call vs Number of occupied channels	4.3
4.2	Call acceptance probability vs Occupied Channels	4.4
4.3	Performance of P_{accept} when M is varied	4.5
4.4	Performance of P_{accept} when M=0.1	4.6
4.5	Performance of P_{accept} when M=1	4.7
4.6	Performance of P_{accept} when M=10	4.8
4.7	Nine nodes and ISLs labeled	4.9
4.8	Channel Allocation for Pair A1-B2 (2 hops)	4.11
4.9	Channel Allocation for Pair B1-B2 (1 hop)	4.13
4.10	Channel Allocation for Pair B1-B2 (1 hop), Call Arrival = 45, 000 calls	4.14

4.11	Channel Allocation for Pair A3-C1 (4 hops), Call Arrival = 10,000 calls of each traffic type	4.15
4.12	HO_RT Call Dropping Probability for B1-B2	4.17
4.13	HO_NRT Call Dropping Probability for B1-B2	4.17
4.14	NC_RT Call Blocking Probability for B1-B2	4.18
4.15	Non Real-time NC Call Blocking Probability for B1-B2	4.18
4.16	HO_RT Call Dropping Probability for A1-C1	4.19
4.17	HO_NRT Call Dropping Probability for A1-C1	4.19
4.18	NC_RT Call Blocking Probability for A1-C1	4.19
4.19	NC_NRT Call Blocking Probability for A1-C1	4.19
4.20	HO_RT Call Dropping Probability for A3-C2	4.20
4.21	HO_NRT Call Dropping Probability for A3-C2	4.20
4.22	NC_RT Call Blocking Probability for A3-C2	4.20
4.23	NC_NRT Call Blocking Probability for A3-C2	4.20
4.24	HO_RT Call Dropping Probability for A3-C1	4.21
4.25	HO_NRT Call Dropping Probability for A3-C1	4.21
4.26	NC_RT Call Blocking Probability for A3-C1	4.21
4.27	NC_NRT Call Blocking Probability for A3-C1	4.21
4.28	Call Blocking and Dropping for B3-C3	4.22
4.29	Call Blocking and Dropping Probability for B3-C3	4.23
4.30	Call Blocking and Dropping Probability for A1-C1	4.24
4.31	Call Blocking vs Call Arrival (Mix Traffic, 25% of HO_RT)	4.26
4.32	Call Blocking vs Call Arrival (Mix Traffic, 75% of HO_RT)	4.26
4.33	Total Propagation Delay vs Distance of the Source and Destination Pair	4.29



4.34	System Delay for Different Traffic Types	4.30
4.35	Average delay vs Distance for all Traffic Types	4.31
4.36	Average System Delay (Pair A1-A3)	4.33



LIST OF ABBREVIATIONS

GII	-	Global Information Infrastructure
PCS	-	Personal Communications Services
3G	-	Third generation
4G	-	Fourth generation
LEO	-	Low Earth Orbit
MEO	-	Medium Earth Orbit
GEO	-	Geosynchronous Earth Orbit
HEO	-	Highly Elliptical Orbit
ATM	-	Asynchronous Transfer Mode
WATM	-	Wireless Asynchronous Transfer Mode
SATATM	-	Satellite Asynchronous Transfer Mode
NCBP	-	New Call Blocking Probability
HCBP	-	Handoff Call Blocking Probability
MDSP	-	Modified Dijkstra Shortest Path
RNH	-	Rerouting Nodes Handoff
DCAS	-	Dynamic Channel Allocation Scheme
CDS	-	Channel Detection Scheme
IMT-2000	-	International Mobile Telecommunications, after 2000
B-ISDN	-	Broadband Integrated Service Digital Network
TDMA	-	Time Division Multiple Access
MF-TDMA	-	Multi-Frequency Time Division Multiple Access
ATDM	-	Asynchronous Time Division Multiplexing



FDMA	-	Frequency Division Multiple Access
SDMA	-	Space Division Multiple Access
EIRP	-	Effective Isotropic Radiated Power
COCC	-	Constellation Operations Control Centers
NOCC	-	Network Operations Control Centers
QoS	-	Quality of Service
UNI	-	Usernetwork Interface
NNI	-	Network–Network Interface
VP	-	Virtual Path
MT	-	Mobile Terminal
MU	-	Mobile User
MES	-	Moving Estimation Scheme
MHz	-	Mega Hertz
GHz	-	Giga Hertz
ITU	-	International Telecommunication Union
VPI	-	Virtual Path Identifier
VCI	-	Virtual Channel Identifier
VCC	-	Virtual Channel Connection
CAC	-	Connection Admission Control
UPC	-	Usage Parameter Control
SVC	-	Signaling Virtual Channel
MSVC	-	Meta Signaling Virtual Channel
LAN	-	Local Area Network



PCN	-	Personal Communication Network
RSSP	-	Responsible Satellite Selection Procedure
DVTR	-	Dynamic Virtual Topology Routing
AAL	-	ATM Adaptive Layer
MAC	-	Medium Access Control
DLC	-	Data Link Control
FSS	-	Fully Shared Scheme
BS	-	Base Station
GCS	-	Guard Channel Scheme
DCRS	-	Dynamic Channel Reservation Scheme
TDS	-	Traffic Detecting Scheme
PRS	-	Path Reservation Scheme
QPSK	-	Quadrature Phase Shift Keying
PSK	-	Phase Shift Keying
CRC	-	Cyclic Redundancy Check
FSS	-	Fixed Satellite Service
ISL	-	Inter Satellite Link
FHRP	-	Footprint Handover Rerouting Protocol
GCAC	-	Geographical Connection Admission Control
LW	-	Link Weight
TLW	-	Total Link Weight



LIST OF NOTATIONS

λ_h	-	Arrival Rate of Handoff Calls
λ_n	-	Arrival rate of New Calls
C	-	Total Number of Channels
T	-	Treshold
i	-	Number of Occupied Channels
L_s	-	Location of Satellite
Δx	-	Horizontal Difference
Δy	-	Vertical Difference
D_0	-	Length of the shortest path
N_o	-	Number of Shortest Paths Between Two Satellites
$E[N_o]$	-	Expected Number of Shortest Paths
TW	-	Traffic Weight
Ave_AC	-	Average Number of Available Channels
Min_AC	-	Minimum Number of Available Channels
LW	-	Link Weight
TLW	-	Total Link Weight
T_{del}	-	Average Satellite Switching Delay Factor
μ	-	Average Call Duration Time
P_C	-	Probability of C Users in the System
P_{Accept}	-	Access Probability



CHAPTER 1

INTRODUCTION

1.1 Background and Motivation

Satellite will continue to be an essential element in the establishment of long-distance telecommunications for many years, and it will have a major role in the implementation of the so-called global information infrastructure in the future. This is because of the particular feature of the satellite that can provide wide coverage independent of the actual land distance between any pair of communicating entities. The demand for global broadband telecommunication services is increasing rapidly. Several plans for next generation satellite communications are being proposed to satisfy the global broadband requirements. Pervasive and ubiquitous exchange of information is the idea behind most proposals for creating an integrated global information infrastructure (GII) [(Chitre, et. al.,1999), (Toh, et. al., 1998)] in which users can freely move around, and still access public and private databases and communicate with each other in an efficient and cost effective way.

Low Earth and Medium Earth Orbit (LEO/MEO) satellite constellations are foreseen as appropriate alternatives to the geostationary satellite systems for providing global personal communications services (PCS). Compared to geostationary satellites, these constellations offer a significantly smaller round trip delay between earth and space segments. Furthermore, the use of inter-satellite links (ISLs) has been identified as a