UNIVERSITI PUTRA MALAYSIA

# HANDOVER MANAGEMENT IN MOBILE SATELLITE COMMUNICATIONS

ADUWATI SALI

**HANDOVER MANAGEMENT IN MOBILE SATELLITE COMMUNICATIONS**

**By**

**ADUWATI SALI**

**Thesis Submitted to the School of Graduate Studies, Universiti Putra Malaysia, in Fulfilment of the Requirement for the Degree of Master of Science**

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## DEDICATION

*To my loving parents, for their endless care and comfort,*

*to my friends who are always there for me.*

*Thank you.*

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

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**Chairperson:** **Nor Kamariah Noordin, MSc.**

**Faculty:** **Engineering**

Mobile satellite communication offers vast coverage area with moderate bandwidth demands. However, in mobile satellite communication using Low Earth Orbits (LEO) satellite service, handover frequently occurs due to high velocity and large number of mobile satellites.

With increase demand of multimedia traffic, an optimum utilization of network resources has been investigated. To accommodate and maintain Quality of Service (QoS) of handover calls in mobile satellite communication, priority for handover calls are applied. Traffic parameters of traffic arrival rate, traffic duration and priority among traffic applications are introduced. Traffic applications of type voice, video and data are observed and analysis of traffic behavior on handover has been done.

An optimum set of channels to serve the different traffic types is proposed after considering the handover initiation and handover execution criteria. The algorithm

proposes a more accurate measurement of handover initiation angle, introduced as look-up angle, which further reduces handover rate and successfully conserve the network resources.

Abstrak tesis yang dikemukakan kepada Senat Univeristi Putra Malaysia sebagai memenuhi keperluan untuk ijazah Master Sains

**PENGURUSAN PENGAMBILALIH DALAM KOMUNIKASI SATELIT BERGERAK**

**Oleh**

**ADUWATI SALI**

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Komunikasi satelit bergerak menawarkan liputan kawasan yang luas dengan permintaan jalur lebar sederhana. Walau bagaimanapun, dalam komunikasi satelit bergerak yang menggunakan servis satelit orbit-bumi-rendah (LEO), pengambilalihan kerap terjadi disebabkan oleh kelajuan satelit yang tinggi dan penggunaan banyak satelit bergerak.

Dengan permintaan yang tinggi terhadap trafik multimedia, penggunaan jaringkerja yang optima telah disiasat. Untuk memenuhi dan mengekalkan servis kualiti (QoS) terhadap panggilan pengambilalih dalam komunikasi satelit bergerak, keutamaan telah diberikan kepada panggilan pengambilalih. Parameter trafik seperti kadar tibaan trafik, kelamaan trafik dan prioriti antara aplikasi trafik telah diperkenalkan. Aplikasi trafik seperti suara, video dan data telah dikaji dan analisa terhadap sifat trafik panggilan pengambilalih telah berjaya dilakukan.

Satu set saluran yang optima untuk memenuhi permintaan trafik yang berlainan telah dianjurkan selepas mengambilkira kriteria permulaan pengambilalih dan pengerjaan pengambilalih. Algoritma ini telah mencadangkan satu kiraan yang lebih tepat terhadap sudut permulaan pengambilalih. Di dalam tesis ini, sudut berkenaan dikenal sebagai sudut-pandang, yang akhirnya mengurangkan kadar pengambilalih dan seterusnya berjaya memastikan penggunaan sumber jaringkerja yang saksama.

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Lastly, but never will be the least, the author's parents and family, for their pivotal role in her life, who are always there, praying for her well-being and happiness in life.

I certify that an Examination Committee met on 9th May 2002 to conduct the final examination of Aduwati bt. Sali on her Master of Science thesis entitled "Handover Management in Mobile Satellite Communications" in accordance with Universiti Pertanian Malaysia (Higher Degree) Act 1980 and Universiti Pertanian Malaysia (Higher Degree) Regulations 1981. The Committee recommends that the candidate be awarded the relevant degree. Member of the Examination Committee are as follows:

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The thesis submitted to the Senate of Universiti Putra Malaysia has been accepted as fulfillment of the requirement for the degree of Master of Science.

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## DECLARATION

I hereby declare that the thesis is based on my original work except for quotations and citations which have been duly acknowledged. I also declare that it has not been previously or concurrently submitted for any other degree at UPM or other institutions.

**ADUWATI SALI**

Date: 08/07/02

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## LIST OF ABBREVIATIONS

| | |
|---|---|
| CRC | Cyclic Redundancy Code |
| DC | Departure Controller |
| DCA | Dynamic Channel Allocation |
| FCFS | First-Come-First-Serve |
| FDMA | Frequency Division Multiple Access |
| GEO | Geosynchronous Earth Orbit |
| GoS | Grade of Service |
| GPS | Global Positioning System |
| IPP | Interrupted Poisson Process |
| ISL | Inter-satellite Link |
| ISL | Inter-Satellite Link |
| LEO | Low Earth Orbit |
| MEO | Medium Earth Orbit |
| MMPP | Markov Modulated Poisson Process |
| MT | Mobile Terminal |
| QoS | Quality of Service |
| TCP | Transmission Control Protocol |
| TDMA | Time Division Multiple Access |
| WDFQ | Wireless Differentiated Fair Queuing |

## LIST OF NOTATIONS

| | |
|---|---|
| $\mu_k$ | Call duration |
| $\lambda_k$ | Packet arrival rate |
| $\theta_n$ | Threshold angle |
| $A$ | Coverage of a singe satellite |
| $d$ | Distance between MT location and satellite location projected on Earth |
| $d_{max}$ | Finite buffer time |
| $gbch$ | Guard band channels |
| $K$ | Buffer size |
| $m$ | Number of servers |
| $n$ | Number of spotbeams in one dimension |
| $Nch$ | New call channels |
| $P_k$ | Probability of handover delay / blocking |
| $P_{NC}$ | Probability of blocking for new calls |
| $r$ | Footprint radius |
| $R_g$ | GEO satellite orbit radius |
| $R_l$ | LEO satellite orbit radius |
| $T_{one\text{-}way}$ | One-way propagation delay |
| $V_l$ | LEO satellite velocity |
| $\omega$ | Angular rotation of Earth |

# CHAPTER I

# INTRODUCTION

A satellite constellation can be defined as a number of similar satellites, of similar type and functions, design to be in similar, complementary, orbits for a shared purpose, under shared control. Satellite constellations have been proposed and implemented for use in communications. This chapter introduces background information on satellite constellation confined to the problem statements of this thesis before elaborating detailed handover scenarios in the next chapter.

## Background

The idea of satellite constellations being used to provide wireless communications initially proposes three geostationary satellites providing full equatorial coverage of the earth using geostationary earth orbit (GEO).

Low earth orbit (LEO) and medium earth orbit (MEO) using orbits lower than GEO have been proposed. These give full global or targeted coverage of the earth. Constellations make possible more reuse of limited available communication frequencies, giving higher utilisation of network resources as a result of this frequency reuse.

## Orbit and Altitude Choices

The altitude of satellites in the constellation is a significant factor in determining the number of satellites required to provide global coverage and to determine characteristics of constellation.

A lower altitude decreases free space loss and propagation delay but the service offered to each satellite is limited to a number of users confined in a smaller area on the ground (satellite's footprint). Hence to achieve global coverage, more satellites are needed. This increases frequency reuse and overall system capacity but will also increase overall construction and maintenance. Satellites at lower altitude must move very fast relative to the ground in order to stay in its orbit. As the coverage area moves with respect to the movement of the serving satellite, a lower orbit increase the frequency of handover, which motivates concern of this thesis. Comparisons between satellite orbits are investigated and the next few paragraphs briefly outlines the comparison between GEO, MEO and LEO satellites.

GEO satellites are located at an altitude of 35,786 km. At this altitude, the rotation period of a satellite is approximately equal to 24 hours. Thus, a satellite that is positioned over the Equator is stationary with respect to a fixed point on the Earth surface. GEO systems have large end-to-end delays and high power requirements in the user terminals and the satellites. As a result, it is very difficult to support mobile and interactive communications using GEO satellites. Furthermore, it is difficult to provide small spotbeams inside the satellite coverage area to achieve frequency reuse, since very large antennas in the satellite are needed to realize small spotbeams.

Contrarily, MEO and LEO satellites circulate the Earth in time periods shorter than 24 hours. Hence, these satellites are not stationary with respect to a fixed observer on the Earth surface. LEO and MEO satellites are classified also as non-geostationary satellites. The speed of the satellites increases with decreasing orbit altitude. Thus, LEO satellites move faster than MEOs. Low altitude provides small coverage area for individual satellites. Hence, LEO satellite systems require large number of satellites for global coverage compared to GEO satellites. Small coverage area can be utilized to increase the frequency reuse among the satellites to improve the bandwidth efficiency. Among the non-geostationary systems proposed, LEO satellites are more popular since they can provide lower end-to-end delay and require lower power consumption in the satellites and the user terminals compared to MEOs. However, mobility problems are more challenging because of their higher speed.

## Problem Statements

This thesis takes communication and broadband satellite networks as parallel developments that are increasingly converging and overlapping. It examines, that due to frequent change and uniform velocity of mobile satellites, handover process occurs frequently in LEO satellite network. Taking an approach based on constellation geometry, a queuing scheme is used for handover calls. The scheme leads to a decrease in the probability of forced termination for handover calls. As explained earlier, satellite constellations and its networking experience propagation and access delay. To minimise further delay, buffering is introduced and used to give optimum number of required channels to accommodate the handover calls. By exploiting constellation geometry, handover initiation and execution is demonstrated, to manage the designed constellation network.

By assuming a constant satellite velocity, blocking of handover calls are observed with respect to different traffic types; namely data, video and audio/video. The traffic types are distinguished by respective call duration and introduction of priority, to signify the occupancy of channels for each traffic type. The proposed optimum number of required channels to accommodate the handover calls has a possible two-fold advantage that it could increase the frequency spectrum utilization and reduce dropping of traffic in queuing algorithm.

## Project Objectives

The aim of this thesis is to analyse different types of traffic behaviour with respect to probability of handover failure and probability of handover delay. In order to achieve that, modular objectives are defined as follows:

- To study the integration of satellite communications and mobile communications in Integrated Mobile Telecommunication Systems
- To investigate and evaluate the handover management criteria in satellite communications
- To find the influence factors that affect the probability of delay, namely the arrival rate, the call duration, the buffer size and the number of servers as well as looking at the effects of multi -traffic analysis on the handover management

## Organisation of thesis

**Chapter I**, introduction to thesis, has briefly outline satellite constellations and the motivations for handover management in LEO satellite networks. It has discussed and contrasted various types of constellation, categorizing them by orbital altitude.

**Chapter II** discusses the geometry unique to the satellite constellation, and examines the effect of this geometry on network topology and end-to-end delays experienced by traffic travelling between satellite to ground terminals. Handover and traffic management are investigated to form an algorithm to model the problem scenario.

**Chapter III** examines traffic models suitable to illustrate the traffic type design and performance parameters.

**Chapter IV** presents the project methodology. Analysis parameters are examined and from the parameters, algorithms for handover initiation and execution are proposed. To integrate the real-time and non-real-time traffic, Wireless Adaptive Queuing algorithm is adapted.

**Chapter V** discusses results obtained from the simulations, in the light of the implications of geometrical scenario and algorithms presented in Chapter IV. It shows optimum channels for each traffic type of handover calls, which fully utilise frequency spectrum and prevent network management applications from being bottleneck in the system.

**Chapter VI** concludes this thesis, summarizes contributions and outline of future work.

**References** list down supporting statements that have been referred throughout this thesis.

**Appendices** provide the source codes used for simulating the scenario and algorithms, written in MATLAB©.

# CHAPTER II

# LITERATURE REVIEW

## Introduction

Simulating a satellite network, particularly in handover management, requires an appreciation of how the satellite moves over time, and when a handover should occur. In this thesis, the handover process of interest is spotbeam handover. It is assumed that both a single satellite serves the spotbeams, i.e., no other satellite is involved in the process. A handover call will be blocked if the necessary resources are not available in the new spotbeam. Since the user mobility is negligible compared to satellite speed, the mobility in the system can be approximated by the deterministic and constant movement of the satellites. It is investigated in (Hu, et al., 1998), for IRIDIUM-like mobility case, that the average time between spotbeam handover is 38 s, so if a call last for 3 minutes, it needs at least 4 handovers. The high handover rate draws concern in this thesis to fully utilise the network resources.

## Broadband Satellite Network

The future generation mobile communication has brought in the concept of broadband satellite network. The goal is to provide ubiquitous means of communication for multimedia and high-data rate Internet-based applications. The most important contributor in this generation was the change in service requirements from the simple low bit rate and voice applications toward the Internet and multimedia services.