Title of the Thesis

A Thesis
Presented to
The Academic Faculty

by

Po-Yu Yen

In Partial Fulfillment
of the Requirements for the Degree
Master of Science in the
Graduate Institute of Communication Engineering

National Taiwan University

July 2012

ABSTRACT

Low Earth Orbit (LEO) satellite network has been a promising technology due to the wide spread coverage area and high data throughput. However, with the high speed of satellites, frequent handover is unavoidable for user equipments (UEs) on the ground, causing significant interruption time and signaling overhead. Thus, we introduce a quasi-earth-fixed satellite beam scheme to solve the continually handover from the UEs at the cell edge. In this scheme, we allocate the satellite beams to the ground cells in order to maximize overall throughput. After that, we also propose a UE cell selection algorithm, which base on both position information and UE measurement.

TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

CHAPTER 1

INTRODUCTION

Non terrestrial network (NTN) has become a promising technique in 6G network. It provides network connectivity to area that traditional network platform cannot reach. For instance, forests, oceans, and deserts. Various platforms are used to provide network services in NTN, such as GEO, MEO, LEO satellites, UAVs, and drones. Among these platforms, LEO is the most actively discussed because of the lowest transmission delay.

However, to acheive LEO satellite network service, there are some key challanges that need to be resolved. One of the challanges is the unavoidable frequent handover. The high speed of LEO satellite forces user equipments (UEs) on the ground to switch the serving satellites frequently. 3GPP has discussed some solutions to deal with this issue. By using quasi-earth-fixed cell, the frequent handovers are avoided and the signalling overhead is reduced. Also, with the help of the ephemeris data of satellies and the position information of UEs, the handover decision has been largely improved. Nontheless, it still has some problems during the random access procedure.

CHAPTER 2

BACKGROUND AND RELATED WORK

The goal of this chapter is for laying the technical background (such as distributed source coding) for understanding the contribution of your thesis; non-technical background (such as the background of M2M communications) can go to Chapter 1.

Related work should be be classified into proper sub-sections depending on the topics related to your thesis research.

2.1 LEO satellite network

2.1.1 Quasi-Earth-Fixed cell

2.2 Related Work

CHAPTER 3

SYSTEM MODEL

3.1 System Model

In this paper, we consider a LEO satellite communication system. There are N satellites denoted as $\mathcal{N} = \{n \mid n = 1, 2, \ldots, N\}$, and each satellite has M beams denoted as $\mathcal{M} = \{m \mid m = 1, 2, \ldots, M\}$. The coverage area covers K cells on the ground denoted as $\mathcal{K} = \{k \mid k = 1, 2, \ldots, K\}$. There are U user equipments (UEs) in the coverage area denoted as $\mathcal{U} = \{u \mid u = 1, 2, \ldots, U\}$. A hexagonal grid of cells is considered. A quasi-earth-fixed cell scheme is considered.

3.1.1 Channel Model

In the LEO satellite system, the free space path loss model can be express as follows [1]:

$$L_{n,u} = \left(\frac{\lambda}{4\pi d_{n,u}}\right)^2 \tag{3.1}$$

where λ is the wavelength,and d is the distance between the satellite n and the user u. Also, we introduce the antenna radiation pattern in [2]:

$$G(\theta) = G_{max}\left[\frac{J_1(\mu(\theta))}{2\mu(\theta)} + 36\frac{J_3(\mu(\theta))}{\mu(\theta)^3}\right]^2, \tag{3.2}$$

where θ represents the angle between the user and the beam center with respect to the satellite, G_{max} is the maximum antenna gain, $\mu(\theta) = 2.07123 \cdot \sin(\theta)/\sin(\theta_{3dB})$, where θ_{3dB} is the 3 dB half-power beamwidth angle of the antenna, and $J_1(\cdot)$ and $J_3(\cdot)$ represent the Bessel functions of the first kind of orders 1 and 3.

And considering the rain fading effect, we introduce a raining fading factor follows the Gaussian distribution $r \sim \mathcal{N}(\mu, \sigma)$, where μ and σ depends on the location, polarization, and elevation angle between UE and satellite [3]. Also, considering the payload (PL) oscillator phase noise n_{theta} at the n-th satellite that follows a Gaussian distribution with zero mean and standard deviation 0.24:

$$\hat{\theta}_{n,u} = \theta_{n,u} + n_{theta} \tag{3.3}$$

Thus, The received power from the beam m of satellite n to the user u is:

$$\hat{P}_{n,m,u} = P_{n,m} \cdot L_{n,u} \cdot G(\hat{\theta}_{n,u}) \cdot r_{n,u} \tag{3.4}$$

3.2 Problem Formulation

Followed by 3GPP protocol [4], the supported SSB periodicity values are {20, 40, 80, 160} miliseconds. Here we define the SSB periodicity of each cell:

$$T_{SSB,k} \in \{20, 40, 80, 160\}, \forall k \tag{3.5}$$

We define the time duration of each slot as 160ms. In Figure 1, we illustrate how SSB periodicity affects the system: as the SSB periodicity increases, the amount of served cells from a single beam increases but the random access time duration will also increases. On the other hand, if the SSB periodicity decreases, the amount of served cells from a single beam decreases but the random access time duration will decreases.

We define the random access time duration $T_{RA,u}$ as the time from when UE start initial access to when it successfully detects the SSB signal. The initial access time of UE u $T_{i,u}$follows the uniform distribution $T_{i,u} \sim U[0, 160]$ in a time slot. The successful detection of SSB signal is defined as the received signal power from the UE u is above the threshold power P_{thres}.

In this thesis, we optimize the SSB periodicity for each cell to minimize the random access time duration, while maintaining a fixed power and beam count for each satellite.

$$\begin{aligned} \min_{\mathcal{P}, \mathcal{T}_{SSB}} \quad & \sum_{\mathcal{U}} T_{RA,u} \\ \text{s.t.} \quad & \sum_{m} P_{n,m} \leq P_{total}, \forall n \in \mathcal{N}. \\ & T_{SSB,k} \in \{20, 40, 80, 160\}, \forall k \end{aligned}$$

20ms	1	1	1	1	1	1	1	1
40ms	1	2	1	2	1	2	1	2
80ms	1	2	3	4	1	2	3	4
160ms	1	2	3	4	5	6	7	8

Figure 1: SSB in one time slot

CHAPTER 4

PROPOSED ALGORITHM

CHAPTER 5

PERFORMANCE EVALUATION

All figures should be of the same width whenever possible for consistency.

5.1 Simulation Setup

We use BONMON [?] to solve the optimization problem. The simulation setup follows that in [?].

5.2 Simulation Results

CHAPTER 6

CONCLUSION AND FUTURE WORK

REFERENCES

[1] J. Wang, C. Jiang, L. Kuang, and R. Han, "Satellite multi-beam collaborative scheduling in satellite aviation communications," *IEEE Transactions on Wireless Communications*, vol. 23, no. 3, pp. 2097–2111, 2024.

[2] S.-H. Chen, L.-H. Shen, K.-T. Feng, L.-L. Yang, and J.-M. Wu, "Energy-efficient joint handover and beam switching scheme for multi-leo networks," in *2024 IEEE 99th Vehicular Technology Conference (VTC2024-Spring)*, 2024, pp. 1–7.

[3] T. Van Chien, E. Lagunas, T. H. Ta, S. Chatzinotas, and B. Ottersten, "User scheduling and power allocation for precoded multi-beam high throughput satellite systems with individual quality of service constraints," *IEEE Transactions on Vehicular Technology*, vol. 72, no. 1, pp. 907–923, 2023.

[4] 3GPP, "Radio Resource Control (RRC) protocol specification," 3rd Generation Partnership Project (3GPP), Technical Report TR 38.331, March 2024, version 18.1.0. Online Available at: https://www.3gpp.org/ftp/Specs/archive/38_series/38.331/