

# **User Random Access Delay Optimization in Low-Earth-Orbit Satellite Communication System based on Synchronization Signal Block Periodicity**

A Thesis  
Presented to  
The Academic Faculty

by

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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.

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# 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 since it provides global coverage, low latency, and high throughput.

However, to achieve LEO satellite network service, there are some key challenges that need to be resolved. One of the challenges is the unavoidable frequent handover. The high speed of LEO satellite forces user equipments (UEs) on the ground to switch the serving satellites frequently [1]. 3GPP has discussed some solutions to deal with this issue. By using quasi-earth-fixed cell and satellite switch with re-synchronization, the frequent handovers are avoided and the signalling overhead is reduced [2]. Also, with the help of the ephemeris data of satellites and the position information of UEs, the matching between satellites and UEs has been largely improved [3]. Nonetheless, 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**

The quasi-Earth-fixed cell is a new non-geostationary satellite orbit (NGSO) satellite beam technique compared to earth-moving cell. Unlike the earth-moving cell that the coverage area of the satellite beam changes when the LEO satellite is moving, the quasi-earth-fixed cell adjusts the beam direction so that the coverage area remains the same in a certain period.

##### **2.1.2 Random Access Procedure**

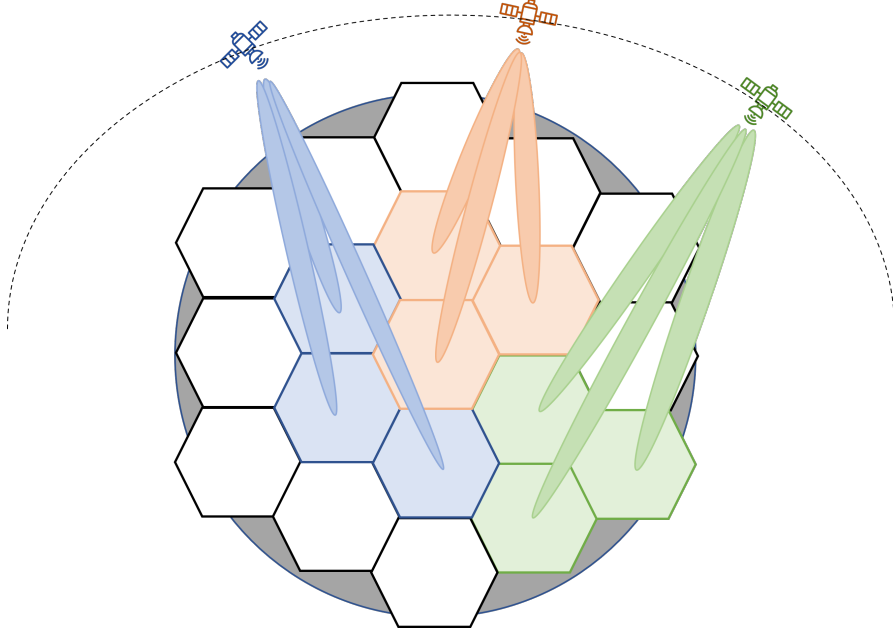
#### ***2.2 Related Work***

# CHAPTER 3

## SYSTEM MODEL

### 3.1 System Model

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



**Figure 1:** Illustration of satellite beams and cells

#### 3.1.1 Free Space Path Loss

In the LEO satellite system, the free space path loss model can be express as follows [4]:

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

where  $\lambda$  is the wavelength, and  $d$  is the distance between the  $n$ th satellite and the  $u$ th user.



### 3.1.2 Channel Model

The shadowed-Rician fading channel model is considered [5]. Let  $h_{n,k}$  denote the channel gain between the  $n$ th satellite and the  $k$ th cell. The cumulative distribution function (CDF) of the channel gain:

$$F_{h_{n,k}}(x) = K \sum_{n=0}^{\infty} \frac{(m)_n \delta^n (2b)^{1+n}}{(n!)^2} \gamma \left( 1 + n, \frac{x}{2b} \right) \quad (3.2)$$

where  $K = (2bm/(2bm+\Omega))^m/2b$ ,  $\delta = \Omega/(2bm+\Omega)/2b$ .  $\Omega$  is the average power of LOS component, and  $2b$  is the average power of the multi-path component except the LOS component.  $m$  is the Nakagami parameter.

### 3.1.3 Antenna Radiation Pattern

We introduce the antenna radiation pattern in [6]:

$$G(\theta) = G_{max} \left[ \frac{J_1(\mu(\theta))}{2\mu(\theta)} + 36 \frac{J_3(\mu(\theta))}{\mu(\theta)^3} \right]^2, \quad (3.3)$$

where  $\theta$  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  $\theta_{3dB}$  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.

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

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

## 3.2 Problem Formulation

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

$$T_k^{SSB} \in \{20, 40, 80, 160\}, \forall k \quad (3.5)$$

We define the time duration of each slot as 160ms.

## 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

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