CHAPTER I: INTRODUCTION

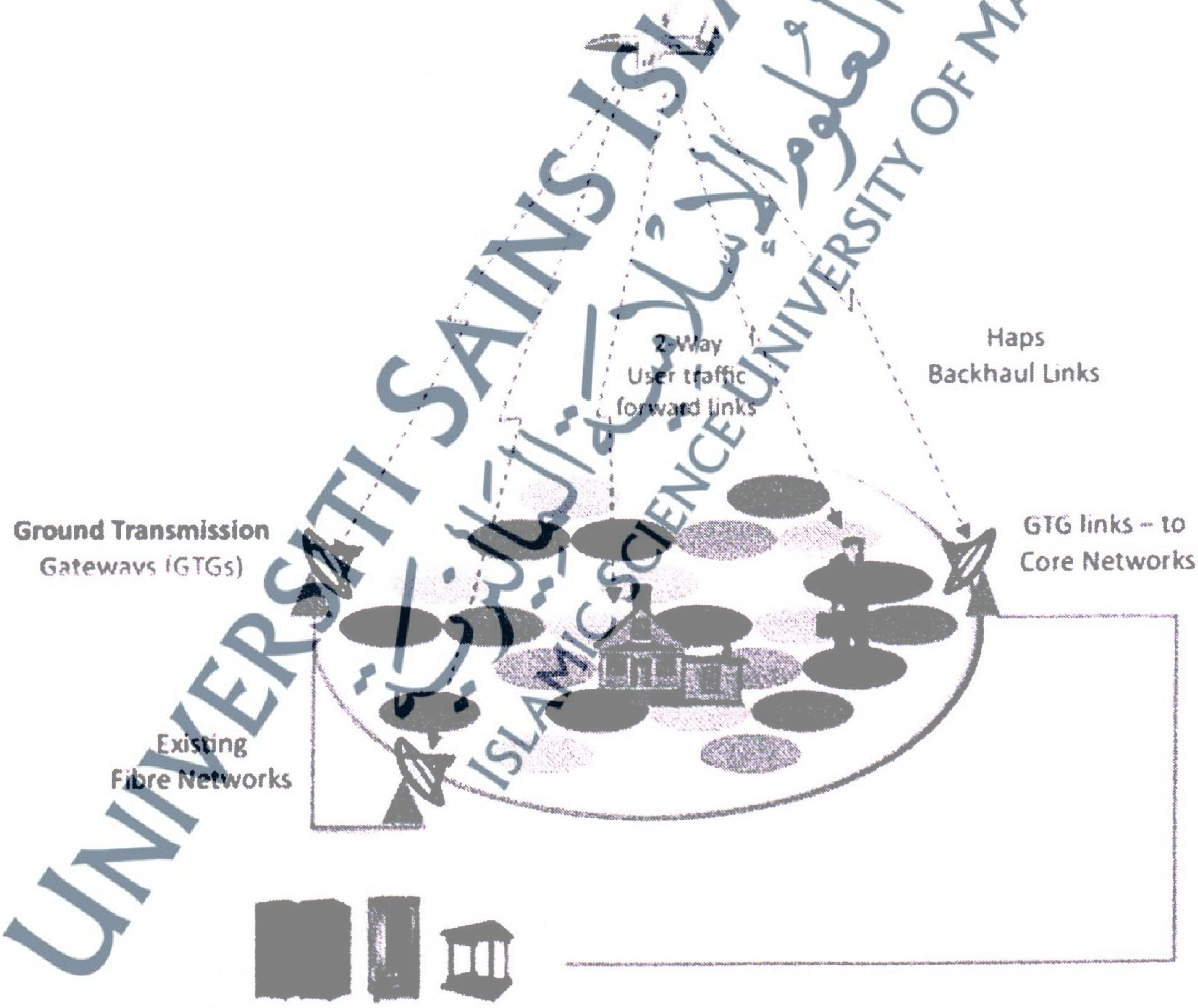
1.1 Introduction

The demand for achieving higher data rates for wireless communications has accelerated the development of more innovative communication infrastructures. Terrestrial and satellite systems are used to providing mobile communications services. Both technologies have many benefits but they also have few limitations. Recently, an innovative way of overcoming the limitations of both the terrestrial tower-based and satellite systems is to provide wireless communications via High Altitude Platform Station (HAPS). It is based on quasi-stationary aerial platforms operating in the stratosphere. The technology is known by different names such as, High Altitude Platform Stations (HAPS), High Altitude Long Endurance (HALE), Stratospheric Platforms (SPFs), or Stratosphere Platform Radios (SPR). These are manned or unmanned aerial platforms located at 17 to 22 km above the Earth's surface (Struzak, 2003). HAPS is a new generation system combining the advantages of both terrestrial and satellite while avoiding their disadvantages. As shown in Figure 1.1, HAPS technology will be used for delivering wireless communication services from the stratosphere layer to customers on the ground. It can be quickly deployed in the sky, and can form multi-shape coverage areas. It acts as base-stations or relay nodes, where subscribers can send information and exchange data directly to the platform to be then switched to other subscribers within the same coverage area, or through heterogeneous networks to reach any other specific destinations.

Various nationwide applications and wireless communication services are planned to be provided by HAPS at costs lower than anything commercially available. It has many advantages over other conventional wireless communication infrastructures such as terrestrial and satellite communications systems.

HAPS technology can be best described as a middle technology layer, that lies between the terrestrial and satellite layers, and is deployed at intermediate altitudes between them to provide multiple satisfactory services to clientele (Zavala et al., 2008).

Figure 1.1: Communication services provided by HAPS Technology [www.qucomhaps.com, 11 Dec 2014]



In the design of earth-space links for communication systems, several factors must be taken into consideration. These factors include absorption of atmospheric gases, scattering and depolarization by hydrometeors such as clouds and precipitation (Freeman, 2007). All these effects must be considered since they are the causes of signal impairment for earth-satellite systems.

One of the main key issues in the exploitation of HAPS is the rain where the rain attenuation is most dominant at the frequencies above 10 GHz. The effect of rainfall is more severe in tropical regions, which are characterized by heavy rainfall intensity for long periods of the day (Ojo et al., 2008 and Moupfouma et al., 1995). The rain attenuation analysis is very important to study the rain fade characteristics. The rain attenuation is a part of the information used to estimate the link budget for predicting the expected outage as a result of rain attenuation impact on the microwave links (Ajayi, 1990; Islam et al., 2009). There are two different types of rain attenuation predictions on any microwave link, the analytical models which are based on physical laws governing electromagnetic wave propagation and which attempt to reproduce the actual physical behavior in the attenuation process; and the empirical models which are based on measurement databases from stations in different climatic zones within a given region (Crane, 2003; Ramachandran, 2005).

ITU-R and many other authors have suggested the need for determination of the rainfall rate parameter ($R_{0.01}$) to achieve accurate calculations involving attenuation studies. $R_{0.01}$ (mm/h) is defined as the rainfall rate exceeded for 0.01% of time in average year, this percentage of the time is recommended to help radio system engineers to predict the expected worst case of attenuation due to rain in certain areas. The amounts of $R_{0.01}$ for different regions can be obtained from the available rainfall rate data in the ITU-R data bank or from long-term local measurements.

1.2 Problem Statement

HAPS frequency bands (28 to 31 GHz, 48 to 51 GHz) are suffer due to the rain attenuation. The HAPS signal will experience large attenuation which increases as the rainfall rate per time unit increases. Because of the higher frequency band used in HAPS technology, it requires higher fade margin than other technologies operating at lower frequency bands.

One of the most efficient models dedicated to predict the rain attenuation is the ITU-R model where it is globally accepted because it is able to predict the rain attenuation for different areas regardless of the characteristics of the area of interest. The ITU-R model has been tested against available data and has been shown to yield an accuracy that is both compatible with the natural variability of propagation phenomena and adequate for most present applications in system planning (ITU-R, 2012). However, the deficiency of the ITU-R model that it is not efficient when the signal path is partially affected by rain. Therefore, the circumventing in such manner is needed to cope on this issue if happened.

The signal quality will be highly affected by the rain, because the higher the frequency the higher the signal susceptible to the rain, especially in tropical regions, where the rainfall continues for long periods of time and the rain intensity is very heavy, reaching up to 150 mm/hr (Fabien, 2001; Ippolito, 1999). Therefore, the uplink and the downlink signal degradation will be clearly noticeable. Thus, in order to maintain lower transmitted power, one of the challenges is to investigate the efficient location for the HAPS stratospheric segment among the ground segments.

HAPS technology is conceived to combine the advantages of both terrestrial and satellite communication systems to deliver multi-service broad or wideband communications to users at a low cost. Thus, it is important to integrate the satellite with the HAPS to overcome the outages that may take place to the HAPS services, so the satellite will be responsible for data transceiving. However, a new rain attenuation model dedicated to the non-stationary satellites is needed to predict rain attenuation. Wind occurs at all levels of the atmosphere from the ground up to higher than 50 km. Because the wind carries the clouds along, the clouds movement depends on the speed of wind per kilometer. Thus, it very important to calculate the effective rain cell size based on the relative clouds movement.

1.3 Thesis Objectives

The purposes of this thesis are:

1. Identification the best location for placing the HAPS stratospheric segment based on estimating the rain attenuation for the peninsular Malaysian region.
2. Developing a rain attenuation model that is able to predict the rain attenuation for Geostationary systems (Geo-stationary satellites and/or HAPS) when the signal path is either completely or partially affected by the rain.
3. Proposing a new prediction model that is able to predict the rain attenuation model for non-stationary satellites such as LEO and MEO.

1.4 Scope Of The Thesis

This work is to develop a technical solution for the radio attenuation problems. The main challenge facing the establishment of the HAPS technology in Malaysia is the rain attenuation. Rain attenuation issue has been taken into consideration to estimate and analyze the HAPS channel in this region. The estimation has been done based on thirteen years (1991 to 2004) statistical rainfall data with an integration time of one minute. The evaluation of predicting the rain attenuation has been conducted for the peninsular Malaysian region to identify the best location for placing the HAPS stratospheric segment. The peninsular has divided into two parts, where one HAPS segment dedicated to each part. The study was done based on ten ground stations that suffer the highest rainfall intensities on the ground.

1.5 Thesis Structure

The atmospheric effects of high altitude platform propagation above the region of Malaysian peninsular, problem statements, objectives, scope of the thesis are documented in the first chapter.

Chapter 2 focuses on the literature review related to the rain attenuation, HAPS, and satellite. The theoretical background of the high altitude platforms technology and its applications, system architecture, and the HAPS project in Malaysia are also discussed. The chapter also discusses the HAPS network as well as the integrated HAPS-to-satellite scenario.

This chapter is also covers the calculation of rain attenuation prediction based on different models.

Chapter 3 describes the research methodology of the thesis. The HAPS link budget design based on the local data are also covered. This chapter also demonstrates the mathematical equations of the new rain attenuation prediction models developed in this work. Additionally, the evaluation of signal attenuation has been conducted to identify the best location for placing the HAPS stratospheric segment.

Chapter 4 presents all of the results obtained in the thesis. Analysis and discussion of the simulation program, attenuation prediction, fade margin, link budget, site diversity gain calculations are also. The results of rain attenuation predicted in the sites of interest are illustrated in this chapter.

Chapter 5 concludes the work. The conclusion is given based on the analysis of results from the previous chapters. Future work, and the recommendations for others to upgrade this work are also included.