UAV ASSISTED WIRELESS HOTSPOT

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To my beloved parents, Md.Parvez Alam and Dr. Nilufar Yasmin for always supporting and praying for me in achieving my goals

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ABSTRACT

Fifth Generation (5G) promises to expand mobile networks to serve multiple devices with diversified traffic patterns whenever and wherever needed and connecting new industries with surpassed performance. For traffic offloading, wireless backhauling, swift service recovery after disasters, emergency response, rescue, and search, unmanned aerial vehicle (UAV) can play an essential role in complementing the operation of cellular network. Due to affordable prices, flexible operation, and extensive availability, UAV has recently received much research attention. Nevertheless, most of the existing research focusses on modelling and simulation. There is a lack of work carried on UAV hotspot experimental verification. Therefore, the main objective of this research is to develop a UAV hotspot to validate the theoretical concept. The approach has several notable merits on facilitating demand-based communication like covering sports, rescue management from disasters, and boosting resilience against faults. Primarily, simulation has been carried out for analysing the air-to-ground channel characteristics based on established air-to-ground channel model. The development of wireless hotspot has been carried out using a portable software-defined radio (SDR) and Open-Air Interface software. For real-time measurement of air-to-ground channel characteristics, a prototype of UAV WiFi access point has been created using Raspberry Pi and a USB WiFi adapter integrated with a small quadcopter drone. A comprehensive verification of the study is carried out by using the aerial WiFi hotspot at different altitudes in an open suburban tropical area. The aerial hotspot prototype demonstrates that for UAV altitude up to 40m, real-time communication coverage can be provided to the ground users.

ABSTRAK

Rangkaian (5G) menjanjikan untuk mengembangkan rangkaian mudah alih untuk melayani pelbagai peranti dengan corak lalu lintas yang pelbagai bila-bila masa dan di mana sahaja diperlukan dan menghubungkan industri baru dengan prestasi yang luar biasa. Untuk pemunggahan lalu lintas, backhauling tanpa wayar, pemulihan perkhidmatan yang cepat setelah bencana, tindak balas kecemasan, penyelamatan, dan pencarian, kenderaan udara tanpa pemandu (UAV) dapat memainkan peranan penting dalam melengkapkan operasi rangkaian selular. Oleh kerana harga yang berpatutan, operasi yang fleksibel, dan ketersediaan yang luas, UAV baru-baru ini mendapat banyak perhatian penyelidikan. Walaupun begitu, sebahagian besar penyelidikan yang ada menumpukan pada pemodelan dan simulasi. Terdapat kekurangan kerja yang dilakukan pada pengesahan eksperimen hotspot UAV. Oleh itu, objektif utama penyelidikan ini adalah untuk mengembangkan hotspot UAV untuk mengesahkan konsep teori. Pendekatan ini memiliki beberapa kelebihan penting dalam memfasilitasi komunikasi berdasarkan permintaan seperti meliputi sukan, pengurusan penyelamatan dari bencana, dan meningkatkan daya tahan terhadap kesalahan. Terutama, simulasi telah dilakukan untuk menganalisis ciri saluran udara-ke-darat berdasarkan model saluran udara-ke-darat yang telah ditetapkan. Pengembangan hotspot tanpa wayar telah dilakukan dengan menggunakan radio yang ditentukan perisian mudah alih (SDR) dan perisian Open-Air Interface. Untuk pengukuran masa nyata ciri saluran udara-ke-darat, prototaip titik akses WiFi UAV telah dibuat menggunakan Raspberry Pi dan penyesuai WiFi USB yang disatukan dengan drone quadcopter kecil. Pengesahan kajian secara menyeluruh dilakukan dengan menggunakan hotspot WiFi udara pada ketinggian yang berlainan di kawasan tropika pinggir bandar yang terbuka. Prototaip hotspot udara menunjukkan bahawa untuk ketinggian UAV hingga 40m, liputan komunikasi masa nyata dapat diberikan kepada pengguna darat.

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LIST OF ABBREVIATIONS

UAV	Unmanned Aerial Vehicle
5G	Fifth Generation Network
SDR	Software Defined Radio
LTE	Long Term Evolution
LAP	Low Altitude Platform
LoS	Line of Sight
NLoS	Non-Line of Sight
SNR	Signal to Noise Ratio
FSPL	Free Space Path Loss
OAI	Open-Air Interface
3GPP	3^{rd} Generation Partnership Project
SDR	Software defined Radio
eNB	E-UTRAN Node B
EPC	Evolved Packet Core
UE	User Equipment
HSS	Home Subscriber Server
MME	Mobility Management Entity
SGW	Serving Gateway
PGW	Packet Data Network Gateway
RAN	Radio Access Network
RPI	Raspberry Pi

LIST OF SYMBOLS

η£	-	Symbolizes the mean value of any propagation group
Α	-	The ratio of commercial property and total area
Β	-	The average number of building per unit sector
Γ	-	The overall building ceiling distribution with respect to Rayleigh probability density function
Θ	-	Elevation angle

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CHAPTER 1

INTRODUCTION

1.1 Background of The Study

The prospect of future 5G communication networks is supposed to connect with every little thing, and aid no less than thousand-fold traffic density, hundred billion wirelessly connected devices, and various specifications on the network security, latency, extended battery endurance, etc., as against to the prevailing 4G cellular transmission [28]. In future the communication network is supposed to provide a persistent connection in every possible case without any interruption, which guarantees a diversified traffic pattern [29]. Heterogeneous network, small antenna size, shared cell service, cloud radio access network (CRAN) is another desired feature of the fifth-generation network. These cases are based on the prolonged operation of traffic [30]. While in an unexpected and temporary event, for instance, natural calamities, traffic obstructions, concerts and sports, and communication networks may require additional assistance to sustain pervasive connections. A drone can play a significant role in these cases by actively deploying base stations with various power levels and RAN. The principal interest of drone cells is the radical flexibility they offer [31]. In the recent era, UAV use has increased massively, and it's being used in military applications, remote monitoring, delivery service, photographing, search and rescue, and many more. By deploying UAV base stations and access points, UAV usage can bring a new dimension in wireless technology. However, the operating characteristic of UAV air to ground channel is much different from the traditional terrestrial channel. With the flexibility of operation, optimal altitude adaption, and avoiding obstacles, UAV can supplement the overly engineered terrestrial channels on-demand basis [11].

The Third Generation Partnership Project (3GPP) has recently proposed a research topic to identify the challenges and facilities to deploy UAV user equipment, referred to as aerial UE [32]. Several models on air to the ground channel has been proposed to deploy UAV aerial communication in a different environment. The effectiveness of any propagation model varies from the different geographical area as well as UAV altitude. Despite having a profound amount of research on air to ground propagation channel measurement, the implementation of air to ground channel models has not been studied extensively. With the growing demand for UAVs in commercial and communication aspects, it is vital to implement UAV air to the ground channel to aid on-demand communication.

Therefore, this research focuses on developing a UAV wireless hotspot and measuring and analysing the effectiveness of the proposed air-to-ground channel models.

1.2 Problem Statement

The existing commercial base station equipment is too bulky to be carried by drone for UAV hotspot application. Besides, a built-in measurement setup for the UAV hotspot is not available. The challenges faced in the air to ground communication is unique if compared to the conventional terrestrial channel modelling. Low altitude platform UAV has low LOS probability and susceptible more to shadowing effect, especially in suburban and urban areas [12]. In a tropical environment, vegetation and foliage can favourably affect the radio signal losses at frequencies up to 10GHz [33]. The existing air-to-ground channel models are based on a theoretical model, while empirical models are developed in temperate environments [34]. The applicability of the existing models in a tropical climate like Malaysia with different temperature, humidity, vegetation is a matter of concern. All these motivate the research in this thesis.

1.3 Research Objectives

The objective of the research is stated in the following section:

i. To develop a wireless hotspot prototype to facilitate the study of air to ground channel.

ii. To measure and analyze the air-to-ground channel.

1.4 Scope of Research

In this study, an LTE hotspot was developed using a portable software-defined radio USRP B200 mini-i and open-air interface software as a prototype of self-develop able LTE hotspot for using as an aerial hotspot in a single laptop. Note that for implementing the system with UAV for real-time communication facility of the ground users, advanced SDR USRP B210 is needed. However, due to pandemic, the product is not able to be delivered in the project timeline. Thus, the air to ground channel measurement has been carried out by creating a WiFi access point in Raspberry Pi with TL-WN722N WiFi adapter. This research focuses only on identifying the received signal strength, path loss, SNR and estimated data rate of air to ground channel parameter in the tropical and sub-urban area of Johor Bahru, Malaysia. The experiment was carried out in *Padang Kawad,* UTM. In the proposed study, simulation of the air to ground channel modelling considered LTE, WiFi and 5G frequency while the experimental measurement focused only on WiFi frequency due to limitation of the equipment. A single DJI F450 quadcopter is used for the aerial hotspot measurement powered with 5000mAh, three-cell battery with 5 minutes flight time and can carry around 2.5 kg with flying limit up to 100m.

1.5 Thesis Outline

The outline of this project is as follows:

In chapter one, the background of the development of UAV assisted wireless hotspot is explained and discussed. The problem statements are mentioned and the gap of the thesis is shown, the objectives of this project are defined and set, and the limitations (scope) of the project are described.

In chapter two, the literature review of this project is presented. The overall idea of fifth generation network, UAV, air to ground channel modelling and UAV based hotspot is discussed briefly. Finally, the related research work is stated and gap of the studies has been identified.

In chapter three, the methodology of the project is presented. The flow chart of the project is developed and the steps taken to accomplish the tasks has been described in brief.

In chapter four, the results obtain from the simulation of air to ground channel modelling, implemented hotspot using USRP B200 mini-i and OAI and the measurement results and analysis of aerial hotspot performance has been clarified.

In chapter five, the conclusion of the research has been stated by analysing the results achieved from the study. Besides, the future planning to improve the research work has been presented.

1.6 Summary

In this chapter, the background of the development of UAV assisted wireless hotspot, the problem statements, the objectives to be achieved in this project, the scope of the project, and the outline of this thesis have been defined and elaborated.

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