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AIN SHAMS UNIVERSITY
FACULTY OF ENGINEERING
ELECTRONICS AND COMMUNICATION
ENGINEERING DEPARTMENT

Unmanned Aerial Vehicles in 5G

A Thesis

Submitted in Partial Fulfillment of the Requirements of the
Degree of Doctor of Philosophy

Submitted by:

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Statement

This thesis is submitted as a partial fulfillment of Doctor of Philosophy in Electrical Engineering (Electronics and Communications), Ain Shams University.

The author carried out the work included in this thesis, and no part of it has been submitted for a degree or a qualification at any other scientific entity.

Nour El-Din Safwat Saad Mohamed

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Abstract

Unmanned Aerial Vehicles (UAVs) are considered an important component of fifth-generation (5G). Due to the rapid deployment, mobility, and flexibility of UAVs, they are used in several applications such as public safety, information dissemination, wireless backhaul, and package delivery. Also, they can be used to enhance the coverage and the rate performance of the communication networks.

Despite the several benefits and practical applications of using UAVs as aerial wireless devices, there are still many research challenges that need to be addressed such as channel modeling, coverage estimation, interference mitigation, network architecture, and design. In this thesis, the research scope is focused on air-to-ground, and air-to-air channel modeling, optimal 3D placement, and multi-UAVs deployment considering co-channel Interference.

First, new analytical models for air-to-ground (A2G) and air-to-air (A2A) path loss models are derived. They are proposed for the dense urban environment at frequencies of (1, 2, and 5.8) GHz. The proposed A2G model is compared with the other A2G model and shows better results of standard error and confidence interval validation. The A2A model is proposed to cover the line of sight (LOS) and the non-line of sight (NLOS) conditions. It is validated using standard error and confidence interval validation methods. The proposed A2A model shows better results than the other A2A model by considering the antenna and NLOS excess losses.

Then, 3D placement algorithms of a UAV as a relay station are proposed. They are presented to jointly optimize the transmitting power and relaying distance for coverage maximization. The placement algorithms are proposed for two systems. The first system is the cellular system that uses the UAV as a relay between the base station (BS) and ground user (C2U2G) and the second one is a new proposed system that replaces the cellular base station with Tethered UAV (TU2U2G). A Tethered UAV (TUAV) is a UAV that receives power over a cable from a ground control station. It has advantages of variable height up to (100m) and overcoming the problem of antenna down tilting of Cellular

Abstract

Base station. The TU2U2G system shows better results than the C2U2G system in terms of optimum UAV height, maximum coverage radius, and maximum distance between BS and UAV.

Then, a Multi-UAVs deployment approach to provide wireless communication services for ground users is proposed. The challenge of multi-UAVs coverage maximization considering the co-channel interference is addressed in the proposed approach. To this end, analytical expressions for the downlink probability of coverage (P_c) using stochastic geometry are derived. Based on the probability of coverage-derived expressions, The deployment algorithms are proposed to achieve the target probability of coverage by reducing the co-channel interference using two methods: frequency reuse and adjustment of the separation distance between UAVs. The numerical results show a comparison between the Algorithms that illustrates the effect of using frequency reuse and adjusting the separation distance between UAVs on the probability of coverage and coverage area.

Finally, using the proposed models and placement algorithms, a UAV Network Planning (UNP) Tool is proposed. UNP is developed by MATLAB. It offers A2G path loss calculations, 3D placement of UAV as a relay station, and multi-UAV deployment.

Keywords: UAV, Path loss, Tethered UAV, Co-channel Interference, Multi-UAV deployments.

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