ENERGY-EFFICIENT DEPLOYMENT OF UNMANNED AERIAL VEHICLES IN WIRELESS COMMUNICATION SYSTEMS

by
Hasini Viranga Abeywickrama

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Prof. Eryk Dutkiewicz
Dr. Ying He
Dr. Beeshanga Abewardana Jayawickrama

School Electrical and Data Engineering
University of Technology Sydney
Sydney, Australia

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ABSTRACT

Unmanned Aerial Vehicles (UAVs) are fast gaining popularity in a wide spectrum of areas in wireless communications. Their many desirable features - ability to hover, ability to fly in otherwise inaccessible areas and ease of deployment make UAVs promising aerial mobile base stations. Base stations mounted on UAVs (UAV-BSs) can provide wireless coverage to areas of urgent need, without having to deploy additional infrastructure. However, UAVs have limitations that hinder their full potential. Limited available energy is identified as a key constraint of UAVs, therefore energy efficiency is important in UAV applications. Our work focuses on energy-efficient deployment of UAV-BSs in wireless communication networks.

Collision avoidance is identified as a key mission requirement in many UAV applications. Most of the collision avoidance methods for UAVs do not consider energy efficiency. However, minimising the energy spent on avoiding collisions is important to preserve the energy available for the assigned task. We propose energy efficient inter-UAV collision avoidance algorithms for multi-UAV systems. We propose selecting a subset of UAVs involved to act on avoiding collisions, while the rest of the UAVs are not impacted from potential collisions. We reduce the total distance travelled by the UAVs which results in improved energy efficiency.

To improve the energy efficiency in a multi-UAV system, it is important to understand the factors that contribute to high energy consumption. Thus, having a complete and accurate energy model for UAVs is fundamental. We propose an energy model for UAVs, based on empirical studies

of battery performance. The experiments were conducted on a commercial UAV with commercial and custom designed power loggers. The studies focused on determining the impact of payload, speed, wind, movement and communication on UAV energy consumption. We tested the reliability of the proposed energy model by using it to estimate the energy requirement of a planned UAV mission. The comparison of the predicted and measured energy requirements indicates negligible error of prediction.

Deploying UAV-BSs to provide wireless connectivity can be highly advantageous and challenging. The limited available energy, possible collisions, managing interference, maintaining system fairness and other related factors make the problem of UAV-BS deployment and path planning too difficult to be solved by traditional methods. We propose Reinforcement Learning (RL) based solutions for UAV-BS path planning and deployment problem. Extensive simulations show that the proposed methods outperform the baseline methods with increased user throughput, increased number of users covered and increased system fairness.

CERTIFICATE OF ORIGINAL AUTHORSHIP

I, Hasini Viranga Abeywickrama declare that this thesis, is submitted in fulfilment of the requirements for the award of Doctor of Philosophy, in the School of Electrical and Data Engineering, Faculty of Engineering and Information Technology at the University of Technology Sydney.

This thesis is wholly my own work unless otherwise referenced or acknowledged. In addition, I certify that all information sources and literature used are indicated in the thesis.

This document has not been submitted for qualifications at any other academic institution

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To Thaththa, Amma

and

Chitral

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List of Publications

Journal publications

- **Hasini Viranga Abeywickrama**, Ying He, Eryk Dutkiewicz, Beeshanga Abewardana Jayawickrama and Markus Mueck, "A Reinforcement Learning Approach for Fair User Coverage Using UAV Mounted Base Stations Under Energy Constraints", in *IEEE Open Journal of Vehicular Technology*, vol. 1, pp.67-81, Feb. 2020. (Corresponding to Chapter 5)

- **Hasini Viranga Abeywickrama**, Beeshanga Abewardana Jayawickrama, Ying He and Eryk Dutkiewicz, "Comprehensive Energy Consumption Model for Unmanned Aerial Vehicles, Based on Empirical Studies of Battery Performance", in *IEEE Access*, vol. 6, pp. 58383-58394, Oct. 2018. (Corresponding to Chapter 4)

Under Review

- **Hasini Viranga Abeywickrama**, Ying He, Eryk Dutkiewicz and Beeshanga Abewardana Jayawickrama, "Reinforcement Learning Based Path Planning for UAV Mounted Base Stations for Improved Throughput with Selective CoMP", submitted to *IEEE Transactions on Mobile Computing*, 2021. (Corresponding to Chapter 6)

Conference publications

- **Hasini Viranga Abeywickrama**, Ying He, Eryk Dutkiewicz and Beeshanga Abewardana Jayawickrama, "An Adaptive UAV Network for Increased User Coverage and Spectral Efficiency", in *Proc. IEEE Wireless Communications and Networking Conference (WCNC)*, pp. 1-6, 2019. (Corresponding to Chapter 5)

- **Hasini Viranga Abeywickrama**, Beeshanga Abewardana Jayawickrama, Ying He and Eryk Dutkiewicz, "Empirical Power Consumption Model for UAVs", in *Proc. IEEE Vehicular Technology Conference (VTC-Fall)*, pp. 1-5, 2018. (Corresponding to Chapter 4)

- **Hasini Viranga Abeywickrama**, Beeshanga Abewardana Jayawickrama, Ying He and Eryk Dutkiewicz, "Potential Field Based Inter-UAV Collision Avoidance Using Virtual Target Relocation", in *Proc. IEEE Vehicular Technology Conference (VTC-Spring)*, pp. 1-5, 2018. (Corresponding to Chapter 3)

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