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Flying Ad Hoc Networks

Cooperative Networking and Resource Allocation

Springer

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ISSN 2366-1186 ISSN 2366-1445 (electronic)
Wireless Networks
ISBN 978-981-16-8849-2 ISBN 978-981-16-8850-8 (eBook)
https://doi.org/10.1007/978-981-16-8850-8

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The registered company address is: 152 Beach Road, #21-01/04 Gateway East, Singapore 189721, Singapore

Preface

Reliable unmanned autonomous flight control programs and unmanned aerial vehicles (UAVs) equipped with radio communication devices have been actively developed around the world. Given their low cost, flexible maneuvering, and unmanned operation, UAVs have been widely used in both civilian operations and military missions, including environmental monitoring, emergency communications, express distribution, and even military surveillance and attacks, for example. Although UAV technologies have to some degree matured, given that a range of standards and protocols used in terrestrial wireless networks are not applicable to UAV networks, and that some practical constraints such as battery power and no-fly zone hinder the maneuverability capability of a single UAV, we need to explore advanced communication and networking theories and methods for the sake of supporting future ultra-reliable and low-latency applications. Typically, the full potential of UAV network's functionalities can be tapped with the aid of the cooperation of multiple drones relying on their ad hoc networking, in-network communications, and coordinated control. Furthermore, some swarm intelligence models and algorithms conceived for dynamic negotiation, path programming, formation flight, and task assignment of multiple cooperative drones are also beneficial in terms of extending UAV's functionalities and coverage, as well as of increasing their efficiency. Here, we call the networking and cooperation of multiple drones as the terminology 'flying ad hoc network (FANET)', and there indeed are numerous new challenges to be overcome before the widespread of so-called heterogeneous FANETs.

In this book, we examine a range of technical issues about FANETs from physical-layer channel modeling to MAC-layer resource allocation, and also introducing novel UAV aided mobile edge-computing techniques. With regard to communication channels in FANET, we commence with an introduction about UAV communication channel characteristics including its link budget, major channel fading, and channel impulse response and metrics, followed by three typical kinds of channel model. Moreover, with regard to multi-UAV-assisted seamless information coverage, we present three dynamic seamless coverage strategies for dense urban areas, quality of service (QoS)-guaranteed Internet of things (IoT) networks, as well as for minimum delay constraint. Next, we discuss cooperative resource allocation in FANETs, where we provide two near-optimal joint UAV's position/trajectory and resource allocation algorithms, while also presenting a resource allocation scheme for IoT nonorthogonal multiple access (NOMA) uplink transmission. Finally, we address the mobile edge computing for FANETs, where load balance-oriented, latency- and reliability-guaranteed, and energy-efficient secure UAV-assisted edge-computing schemes are investigated.

The aim of this book is to educate information technology engineers, computer and information scientists, applied mathematicians and statisticians, as well as systems engineers to carve out the critical role that analytical and experimental engineering play in the research and development of FANETs. This book emphasizes on multi-UAV networking technologies and applications in next-generation wireless networks.

To summarize, the key advantages of this book are listed as follows:

1. It provides an introduction to the FANET paradigm, from both physical-layer and upper-layer perspectives, which currently has attracted substantial attention from both academic and industrial areas.
2. It discusses the state of the art for the FANET and its characteristics against other mobile ad hoc networks. It also surveys the basic UAV/FANET communication channels.
3. It highlights three hot topics in FANET, i.e., seamless information coverage, cooperative resource allocation, and mobile edge computing. A range of examples are illustrated in detail so as to provide a wide scope for general readers relying on introducing their problem formulation, solution algorithms, and simulation results in a comprehensive way. These successful cases can guide us to efficiently construct a multi-UAV heterogenous network.

This book is organized as follows: Chap. 1 provides an overview of the FANET concept and discusses it against traditional mobile ad hoc networks. In Chap. 2, we introduce the UAV communication channels. In Chaps. 3–5, we provide study cases to show how to solve the key challenges in multi-UAN-aided seamless information coverage, cooperative resource allocation, and mobile edge computing in FANET, respectively.

Acknowledgments Dr. Jingjing Wang and Dr. Chunxiao Jiang would like to thank those who helped to get this book published, especially our graduate students Zhengru Fang and Zonglin Li who helped to proofread the entire book. Moreover, we would like to acknowledge the support of the National Natural Science Foundation of China and the Young Elite Scientist Sponsorship Program by CAST.

Beijing, China — Jingjing Wang
Beijing, China — Chunxiao Jiang
November 2021

Contents

Acronyms

A2A	Air-to-Air
A2G	Air-to-Ground
ABS	Aerial Base Stations
AI	Artificial Intelligence
AP	Access Point
AWGN	Additive White Gaussian Noise
B5G	Beyond 5G
BCD	Block Coordinate Decent
BLOS	Beyond Line-of-sight
C/N	Carrier-to-noise ratio
CAA	Civil Aviation Administration
CABR	Civil Aviation Administration
CIR	Channel Impulse Response
CNPC	Control and Nonpayload Communication
CSI	Channel State Information
D2D	Device-to-device
eMBB	Enhanced Mobile Broadband
FAA	Federal Aviation Administration
FANET	Flying Ad Hoc Networks
G2G	Ground-to-Ground
GA	Genetic Algorithm
GEO	Geosynchronous Earth Orbit
GR	Greedy Algorithm
GS	Ground Station
ICAO	International Civil Aviation Organization
IoT	Internet of Things
ITU	International Telecommunication Union
LEO	Low Earth Orbit
LMS	Least Mean Square
LOS	Line-of-sight
MANET	Mobile Ad Hoc Networks

MANETs	Mobile Ad Hoc Networks
MEC	Mobile Edge Computing
MIMO	Multiple Input and Multiple Output
mMTC	Massive Machine-type Communication
NOMA	Non-orthogonal Multiple Access
OFDM	Orthogonal Frequency Division Multiplexing
OFDMA	Orthogonal Frequency Division Multiple Access
PLS	Physical-Layer Security
QoS	Quality-of-Service
SCA	Successive Convex Optimization
SIC	Successive Interference Cancellation
SIMO	Single Input and Multiple Output
SISO	Single Input and Single Output
SWIPT	Simultaneous Wireless Information and Power Transfer
TDD	Time Division Duplexing
UAV	Unmanned Aerial Vehicles
UMENs	UAV-enabled Mobile Edge Computing Nodes
uRLLC	Ultra Reliable Low Latency Communication
VANET	Vehicular Ad Hoc Networks
VLOS	Visual Line-of-sight