Wireless Networks

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Resource Allocation for OFDMA Systems

Springer

Wireless Networks

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ISSN 2366-1186 ISSN 2366-1445 (electronic)
Wireless Networks
ISBN 978-3-030-19391-1 ISBN 978-3-030-19392-8 (eBook)
https://doi.org/10.1007/978-3-030-19392-8

This Springer imprint is published by the registered company Springer Nature Switzerland AG
The registered company address is: Gewerbestrasse 11, 6330 Cham, Switzerland

Preface

This book investigates and surveys resource allocation techniques for MIMO-OFDMA systems. The radio resources of traditional communication systems are defined and distributed in a hierarchical structure. However, due to the space, time, and frequency variations and randomness of next-generation wireless communication systems, the traditional hierarchical allocation methods cannot optimize them. Therefore, people pay more attention to cross-layer wireless resource allocation technologies today, so as to achieve joint scheduling and optimization of system space, time, and frequency resources. As several important wireless resources, the rational use and distribution of users, power, and spectrum resources play an extremely crucial role in ensuring communication quality and improving communication performance.

This book first introduces the sources and historic collection campaigns of resource allocation in wireless communication systems. Secondly, the unique characteristics of MIMO-OFDMA systems will be thoroughly studied and summarized. Thirdly, remarks on resource allocation and spectrum sharing will be presented, which demonstrate the great value of resource allocation techniques but also introduce distinct challenges of resource allocation in MIMO-OFDMA systems. Fourthly, novel resource allocation techniques for OFDMA Systems will be surveyed from various applications (e.g., for unicast, or multicast with Guaranteed BER and Rate, subcarrier and power allocation with various detectors, low-complexity energy-efficient resource allocation, etc.). Due to the high mobility and low latency requirements of 5G wireless communications, this book will discuss how to deal with the imperfect CSI, e.g., throughput maximization, outage probabilities maximization and guarantee, energy efficiency, physical-layer security issues with feedback channel capacity constraints, in order to characterize and understand the applications of practical scenes. Finally, the challenges and open opportunities of resource allocation in MIMO-OFDMA will be broadly investigated and concluded in terms of communications, networking, and energy efficiency, as well as the security issues of private-sensitive scenes.

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Acknowledgements

This work was supported in part by the Ministry National Key Research and Development Project under Grant 2017YFE0121400, the National Science and Technology Major Project under Grant 2018ZX03001031, and the Major Project from Beijing Municipal Science and Technology Commission under Grant Z181100003218007.

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Chapter 1
Introduction

Resource allocation for orthogonal frequency division multiple access (OFDMA) systems which can effectively solve the signal distortion caused by the frequency-selective fading of the wireless channel and provide a high data transmission rate is a challenging issue for next-generation wireless communications. OFDMA is a multiuser OFDM system. It can adaptively allocate subcarriers based on different users' channel conditions on different subcarriers and adjust power and number of bits on different subcarriers. In an OFDMA system, a proper resource allocation strategy can be used to optimize system performance within a limited spectrum while ensuring service QoS requirements. Therefore, designing an efficient resource allocation strategy for OFDMA systems is an important issue that is attracting attention in current mobile communications.

1.1 OFDM/OFDMA Technology

Looking at the development of wireless communication technology, supporting high-speed broadband data transmission is the main goal of mobile communication development. OFDM technology is considered to be an important technology for 4G wireless communication because of its highly scalable structure, good anti-multipath interference capability, and efficient spectrum utilization. However, OFDM-based OFDMA technology can effectively use multiuser diversity. The gain further increases the utilization of spectrum resources. Therefore, OFDM/OFDMA technology has received extensive attention in recent years. At present, OFDM/OFDMA technology has spread throughout the various fields of wireless communications, leading the future development of mobile communications. OFDM/OFDMA technology has the following advantages [1]:

1. Strong resistance to frequency-selective fading. OFDM divides a frequency-selective fading channel into N parallel-independent flat-fading channels and

C. Chen, X. Cheng, *Resource Allocation for OFDMA Systems*, Wireless Networks,
https://doi.org/10.1007/978-3-030-19392-8_1

transmits data independently on each subcarrier at the original rate of 1/N. Therefore, the symbol time on each subcarrier is N times that of a single carrier system. This makes OFDM more resistant to impulse noise and fast channel fading. In addition, OFDM also introduces protection time slots and CPs and makes the guard interval length greater than the maximum delay spread in the wireless channel, which can effectively eliminate ISI during transmission [2–4].

2. High spectrum utilization. OFDM allows overlapping orthogonal subcarriers to be used as sub-channels instead of using traditional FDM to separate the subcarriers using guard bands so that the bandwidth can be used to transmit data. Since there are no spectral components of other subcarriers at the center frequency point of each subcarrier, it is possible to ensure that the subcarriers are orthogonal in the spectrum overlap and eliminate the inter-subcarrier ICI.
3. OFDM systems have strong bandwidth scalability. OFDM can easily implement data transmission under various bandwidths by using FFT. Because of the development of large-scale integrated circuits, it has become easier to implement FFT [5], which has made OFDM more robust in supporting broadband communications.
4. More flexible resource allocation strategies can be used. In an OFDM system, each subcarrier can independently select an appropriate modulation method, transmission rate, and transmission power. In an OFDMA system, different users can be further assigned different subcarriers. In this way, the base station can dynamically adjust the resource allocation strategy on each subcarrier according to the objective of system optimization, so that the characteristics of frequency diversity and user diversity gain can be utilized to improve the performance of the system [6, 7].

OFDM/OFDMA technology also has disadvantages such as sensitivity to frequency offset and phase noise [8–10], the existence of peak-to-average ratios [11–13], and synchronization [14, 15] and other issues. However, with the in-depth development of wireless communication technology and the solution of many key technical problems, OFDM/OFDMA will play an increasingly important role in the future of wireless communications.

1.2 Radio Resource Allocation Technology

With the popularization of mobile communication technologies, mobile communication technologies are faced with a dramatic increase in the number of users and the continuous improvement of the quality of service (QoS) requirements of users. Wireless resource management has become a key technology to improve the performance of mobile communication. Technology. Wireless resource allocation is responsible for the utilization of air interface resources. Its goal is to provide QoS guarantees for users within the network under limited resources and improve resource utilization, network capacity, and coverage [16].

Wireless system resources are the resources that are used when information is transmitted and processed wirelessly. Generally, they can be divided into two categories:

1. Transmission resources: The resources of the channel occupied by signals in the transmission process include:
   - Frequency resources: The bandwidth and frequency band occupied by the channel.
   - Time resource: The time slot occupied by the transmission signal.
   - Code resources: Generally used in CDMA systems, including channelization codes (differentiated channels) and scrambling codes (differing users in uplink and distinguishing cells in downlink).
   - Space resources: Occupancy of the transmitted signal to the antenna.
   - Geographical resources: The coverage and access of the coverage area and the community.
2. Node resources: In the process of signal transmission, the occupation of transmission node resources includes:
   - Power resource: The power consumed by a node when sending a signal.
   - Time resource: The time consumed by the processor when the node processes signals and allocates resources.
   - Space resources: Occupation of memory when nodes handle signals and allocate resources.

Therefore, from the perspective of transmission resources, the allocation of wireless resources is to use limited resources such as spectrum, time slots, codes, and antennas, so as to effectively increase the capacity of the system and ensure the QoS performance of the service. From the perspective of node resources, the algorithm for wireless resource allocation should make reasonable use of the limited transmit power of the nodes and design suitable algorithms with low time and space complexity to achieve a balance between the complexity of the algorithm and the performance of the system.

Resources allocation is to complete the allocation of wireless resources to the service, including:

1. Power control: Different nodes adjust the transmit power on the allocated channel according to the current link status. On the one hand, the power control reduces the interference of the same system and adjacent channels of the entire system by ensuring the QoS requirements of the service. On the other hand, it is also necessary to increase the capacity of the system through power adjustment and improve the utilization of spectrum resources. In addition, for the user, it is also necessary to extend the standby time of the wireless terminal through appropriate power control. In Chap. 2, we give an overview of OMA system.
2. Adaptive rate control/modulation: Rate control is to adjust the channel/source coding rate of information transmission according to the quality of the link under the constraint of the node power limitation. On the one hand, it is necessary to