Graduate School of Fundamental Science and Engineering
Waseda University

博　士　論　文　概　要
Doctoral Dissertation Synopsis

論　文　題　目
Dissertation Title

Resource Allocation Scheme employing NOMA
for UAV-assisted Cellular Networks

UAVを用いたセルラー網におけるNOMAを用いた
リソース割り当て方式

申　請　者
(Applicant Name)
Dhruba Raj DHAKAL
ダッカル　ダルバ ラジュ

Department of Computer Science and Communications Engineering, Research on Wireless Access

December, 2021

Cellular communications is now in the implementation phase of its fifth-generation (5G) networks. The first-generation (1G) cellular communications system was put into operation around 1980 and is now one of the rapidly developing areas leading the world into the current information age. The field of wireless communication is becoming wider and wider with the new generation networks. The goal of 5G communication mainly focuses on three network capabilities: ultra reliability and low latency communications (URLLC), massive machine type communication (mMTC), and enhanced mobile broadband (eMBB). New technologies such as millimeter wave (mmWave), massive multiple input multiple output (mMIMO), heterogeneous networks (Het-Net), and ultra-dense networks (UDN) are proposed as possible technologies to achieve these goals. The researchers present the roadmap for next-generation (beyond 5G and 6G) network requirements and possible technologies that cannot be met by the 5G network. The next-generation network (NGN) should provide global connectivity with an integrated space-air-ground-sea network, full spectrum utilization from sub-6GHz to THz including the optical band, an AI-based ultra-dense network, and a highly secure network. With the development of wireless network, one of the most important and researched areas is multiple access scheme, as it can play an important role in improving key performance indicators (KPIs).

Orthogonal resource allocation multiple access systems such as frequency division multiple access (FDMA), time division multiple access (TDMA), code division multiple access (CDMA), and orthogonal frequency division multiple access (OFDMA) are used in 1G, 2G, 3G, and 4G networks, respectively, while recently non-orthogonal multiple access (NOMA) has received more attention from researchers. NOMA is first considered for LTE and then for 5G networks, but is not yet ready to be deployed in today's networks, so it is still an open problem in wireless communications. This work is a study based on resource allocation in the power domain (PD) NOMA network where UAVs serve as base stations (BS). In particular, weighted max-min fairness (MMF) optimization-based user clustering and power allocation are investigated using two application scenarios of emerging UAV technology in cellular downlink (DL) communications, one being a single-cell UAV network and the other being a UAV-supported heterogeneous network.

Chapter 1 deals with the introduction to this thesis. First, the background of the research is described, including some historical and current developments of cellular networks. The next part of this chapter describes the research gap that motivates the research direction. After the motivation section, the main contributions of this work are highlighted. Finally, the last section summarizes the structure of the thesis and presents the flow of the thesis.

Chapter 2 explains the fundamentals of UAV and NOMA for future networks. The first section explains why UAVs are an indispensable part of the next-generation network, with its advantages and challenges when implemented with other technologies. The second section explains the basic theory of NOMA with power domain multiplexing, superposition coding (SC), and successive interference cancelation (SIC). It explains how NOMA can be beneficial for future wireless communications compared to existing techniques. It also describes the basic concept of weighted max-min fairness, which is implemented in this work.

Chapter 3 examines in detail a simple model of a single-cell system. The performance of NOMA is highly dependent on resource allocation, e.g., power allocation and channel allocation. In this study, we investigate the power allocation (PA) scheme,to optimize the weighted MMF for 2-user and 3-user clusters. We use the PSO-based power allocation algorithm due to its promising behavior. As the application scope of NOMA becomes wider, we considered a cellular network supported by a UAV as a base station integrated with the NOMA system. The PA for the weighted MMF problem in NOMA is non-convex, it is difficult to find the optimal solution directly. The simulation results show the performance of the PSO-based algorithms at different adaptive weights and their convergence properties. We also showed the tradeoff between data rate and fairness with weighted max-min fairness. Numerical results compare the performance of NOMA and orthogonal multiple access (OMA) and demonstrate the importance of the proposed algorithm. A meta-heuristic algorithm based on the PSO is implemented as a power allocation algorithm, which is easy to implement and has versatile application properties, but in the scenario of optimization for a large number of users, it shows limited convergence performance. Moreover, the cellular users are assigned to multiple channels

and a suboptimal fractional power allocation (FPA) is implemented to allocate the power for each channel. In this study, it is assumed that each user can perfectly execute SIC.

In Chapter 4, power allocation is studied in a two-tier heterogeneous network (Het-Net) supported by unmanned aerial vehicles (UAVs). UAVs are considered as an indispensable part of the future wireless network, so we studied the weighted max-min fairness-based power allocation optimization for UAV-assisted networks in a heterogeneous cellular system. Details of the system model, problem formulation, user assignment, power allocation, and simulation results are provided in this chapter. In this system model, multiple UAV small cells employing the NOMA scheme are supported on the territory of a terrestrial macro cellular network employing the OMA scheme. Due to imperfect channel estimation among UAV users, they could not perform a perfect SIC and also suffer from interference from the macrocell BS. To respond to the non-convex power allocation problem for weighted max-min fairness (MMF) based optimization, a modified novel algorithm based on Perron-Frobenius (PF) theory based optimization algorithm was developed. The performance of this algorithm shows better convergence characteristics compared to the previous algorithm. The theoretical basis and simulation results with imperfect SIC conditions and different weight conditions for user data rates are presented.
Finally, the conclusions, limitations, and possible future improvements of this research are highlighted in Chapter 5.

Thus, the two studies explained in Chapters 3 and 4 deal with weighted MMF -based resource allocation in the NOMA scheme in cellular wireless networks. One is a single-cell scenario with a simple metaheuristic power allocation algorithm, and the other is a more complex system model considering imperfect SIC and Het-Net with an optimal power allocation algorithm. The Weighted MMF -based optimization can allocate data rates to users with the given priority of users.

List of research achievements for application of Doctor of Engineering, Waseda University

Full Name : Dhruba Raj Dhakal seal or signature

Date Submitted(yyyy/mm/dd): 2021/12/02

種類別 (By Type)	題名、 発表・発行掲載誌名、 発表・発行年月、 連名者（申請者含む） (theme, journal name, date & year of publication, name of authors inc. yourself)
Journal	○ **Dhakal, D. R,** Pan, Z., Saito, M., & Shimamoto, S., Dynamic Resource Allocation in Non-orthogonal Multiple Access Using Weighted Maximin Fairness Strategy for a UAV Network, Journal of Signal Processing Systems 92, no. 12 (2020): 1397-1406
International Conference	○ **Dhakal, D. R**, Pan, Z., & Shimamoto, S. , Resource Allocation for Weighted Max-min Fairness in NOMA with Imperfect SIC, IEEE SII Conference, January 2022. **Dhakal, Dhruba Raj**, Phonfred J. Okoth, Takuro Sato, and Shigeru Shimamoto, Multiuser Transmit Heuristic Beamforming using Constrained Binary PSO based Antenna Selection, 37th JSST International Conference, Muroran, Hokkaido, September 2018. Okoth, P. J., Nguyen, Q. N., **Dhakal, D. R**., Nozaki, D., Yamada, Y., & Sato, T., An Efficient Codebook Based Beam Training Technique for Millimeter-Wave Communication Systems, IEEE Asia-Pacific Microwave Conference (APMC), November 2018.
Workshops	**Dhruba Raj Dhakal**, “Dynamic Resource Allocation for Weighted Max-Min Fairness in NOMA with Imperfect CSI”, 2020 Hanyang-Waseda (WUHU) IT workshop, Online, 25 Nov 2020. **Dhruba Raj Dhakal**, “Adaptive beamforming for 5G communication system”, 2017 Hanyang-Waseda (WUHU) IT workshop, Seoul, South Korea, 1-2 Dec 2017.