

Preface

The wireless industry has already been preparing for the emerging fifth-generation (5G) standards in recent years. A 5G system is featured by (1) addressing the demands and business contexts of 2020 and beyond, (2) creating an access network to enable a fully mobile and interconnected society, (3) providing massive amount of miscellaneous devices with the connections to packet data network, and (4) bearing huge volume of data services in the manner of a deeply heterogeneous system. 5G achieves higher speed, increased capacity, decreased latency, and better quality of service (QoS). One of the promising technologies to meet the above requirement is the small cell network (SCN), which allows short-range, low-power, and low-cost base stations operating in conjunction with the main macrocellular network infrastructure. SCN introduces additional heterogeneity to wireless communication system, and thus, the so-called self-organizing network (SON) technology has been extensively studied to overcome the challenges.

5G network architecture tends to involve more low power nodes (LPNs), which make the system design more complicated. For example, the deployment of small cells in coverage holes can effectively reduce the penetration loss with a large amount of users. However, the small cell may produce interference to the users served by other power nodes. To solve this problem, we advocate a novel concept of smart LPN as the SON solution for 5G heterogeneous networks (HetNets). As illustrated in this book, the smart LPN integrates a number of hardcore technologies, such as cognitive radio and three-dimensional (3D) multiple-input and multiple-output (MIMO), to realize the function of automatic configuration and optimization. To provide physical layer insight into SON, 3D MIMO channel model has widely prevailed in recent years. 3D array deploys antenna elements in both horizontal and vertical dimensions. By taking into account the vertical dimension channel information, 3D beamforming not only provides more accurate channel estimation, but also mitigates intercell interference more effectively even without inter-eNB coordination.

The future 5G SON will integrate with a variety of cutting-edge technologies, for example, adopting the intelligent software-defined networking (SDN) and network function virtualization (NFV) to automatically take care of traffic control, resource allocation, density management, and security. SDN was formally defined by open networking forum (ONF), a user-driven organization dedicated to the promotion and adoption of SDN through open standards. SDN separates the control of network devices from the data they transport and the switching software from the actual network hardware. The OpenFlow standard integrates the network control plane into software running on an attached server or network controller, which enables the network control to become directly programmable and the underlying infrastructure to be abstracted for applications and network services. The NFV, on the other hand, is a network architecture that virtualizes entire classes of network node functions into building blocks. The goal of NFV is to decouple network functions from dedicated hardware devices and allow network services that are now being carried out by routers, firewalls, load balancers, and other dedicated hardware devices to be hosted on virtual machines (VMs). In this way, the operators can architect their networks by deploying network services on the top of standard devices. In the era of 5G, the network must be capable of meeting a huge amount of user diversified service demands at different data rates. Therefore, it should involve all the automatic technologies available, including SON, SDN, and NFV, to orchestrate all the available frequency resources, infrastructures, and hardware devices.

In 2010, Thomas L. Marzetta investigated multi-user MIMO (MU-MIMO) systems with multi-cellular time-division duplex (TDD) scenario, where each base station is supposed to deploy very large number of antennas, later known as massive MIMO. Massive MIMO has become one of the most important candidate technologies for 5G mobile networks. In massive MIMO system, the base stations (BSs) are equipped with hundreds of service antennas, in order to form diversified 3D MIMO channel between the BSs and users. With more antenna elements, it becomes realistic to steer the transmission toward the intended receiver and significantly reduce the interference. Massive MIMO can be deployed in heterogeneous networks, which are composed of a variety of cells, for example, a macrocell and several small cells. The cell association for users and the resource allocation for base stations become a problem due to complex network design and implementation. This raises the importance of huge spatial domain information management and complicated MIMO coordination.

The rest of this book is summarized as follows.

1. In Chap. 1, we highlight the important role of SON in 5G heterogeneous networks. First, several pivotal functions of SON are introduced and explained in the context of 5G scenarios. Then, cognitive radio, compressed sensing, and smart LPN are investigated as promising technologies for the implementation. Finally, numerical results are presented for the performance evaluation using 3D MIMO channel model.

2. In Chap. 2, we focus on the SDN and NFV technology for 5G heterogeneous networks. A variety of SDN standards are introduced and studied in details. An intelligent SDN architecture is then proposed based on the key technologies of 5G. To provide SDN with infrastructure support, NFV is also investigated as a flexible and affordable solution to service providers.
3. In Chap. 3, we investigate the 5G massive MIMO coordination under SDN platform. Massive MIMO technology is introduced as an essential part of future mobile networks. Then, an SDN-controlled MIMO coordination is proposed for the heterogeneous network environment. A null space-based hybrid precoding scheme is also developed for SDN implementation and evaluated with numerical results.

5G Heterogeneous Networks

Self-organizing and Optimization

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2016, XII, 52 p. 21 illus., Softcover

ISBN: 978-3-319-39371-1