Millimeter Wave Mimo Precoding Combining Challenges And

mmWave Massive MIMO: A Paradigm for 5G is the first book of its kind to hinge together related discussions on mmWave and Massive MIMO under the umbrella of 5G networks. New networking scenarios are identified, along with fundamental design requirements for mmWave Massive MIMO networks from an architectural and practical perspective. Working towards final deployment, this book updates the research community on the current mmWave Massive MIMO roadmap, taking into account the future emerging technologies emanating from 3GPP/IEEE. The book's editors draw on their vast experience in international research on the forefront of the mmWave Massive MIMO research arena and standardization. This book aims to talk openly about the topic, and will serve as a useful reference not only for postgraduates students to learn more on this evolving field, but also as inspiration for mobile communication researchers who want to make further innovative strides in the field to mark their legacy in the 5G arena. Contains tutorials on the basics of mmWave and Massive MIMO Identifies new 5G networking scenarios, along with design requirements from an architectural and practical perspective Details the latest updates on the evolution of the mmWave Massive MIMO roadmap, considering future emerging technologies emanating from 3GPP/IEEE Includes contributions from leading experts in the field in modeling and prototype design for mmWave Massive MIMO design Presents an ideal reference that not only helps postgraduate students learn more in this evolving field, but also inspires mobile communication researchers towards further innovation

This book presents state-of-the-art millimetre wave antennas for next generation 5G communications. The propagation losses associated with the millimetre waves and the signal blockage due to the objects present between transmitter and receiver require novel antenna topologies to address these issues. Various aspects of antenna design related to millimetre wave 5G communication including 28-GHz channel characteristics, mmWave antenna requirements, antenna design strategies for 28 GHz, MIMO/multibeam antennas, and mmWave lens antennas are highlighted. Apart from the general antenna requirements and study related to the 28 GHz frequency band, various new metamaterial-based antennas employing uniaxial or biaxial anisotropic media that enhance the antenna radiation performance are covered in detail. In addition, various new antenna systems such as wide-scan antenna arrays, dual-polarized antennas, and dual-beam/multibeam antennas are covered in this book. The book concludes with the glimpses of the millimetre wave lens antennas and the design of very thin planar metamaterial lens for 5G massive MIMO applications.

Many problems in the sciences and engineering can be rephrased as optimization problems on matrix search spaces endowed with a so-called manifold structure. This book shows how to exploit the special structure of such problems to develop efficient numerical algorithms. It places careful emphasis on both the numerical formulation of the algorithm and its differential geometric abstraction--illustrating how good algorithms draw equally from the insights of differential geometry, optimization, and numerical analysis. Two more theoretical chapters provide readers with the background in differential geometry necessary to algorithmic development. In the other chapters, several well-known optimization methods such as steepest descent and conjugate gradients are generalized to abstract manifolds. The book provides a generic development of each of these methods, building upon the material of the geometric chapters. It then guides readers through the calculations that turn these geometrically formulated methods into concrete numerical algorithms. The state-of-the-art algorithms given as examples are competitive with the best existing algorithms for a selection of eigenspace problems in numerical linear algebra. Optimization Algorithms on Matrix Manifolds offers techniques with broad applications in linear algebra, signal processing, data mining, computer vision, and statistical analysis. It can serve as a graduate-level textbook and will be of interest to applied mathematicians, engineers, and computer scientists.

Advanced Antenna Systems for 5G Network Deployments: Bridging the Gap between Theory and Practice provides a comprehensive understanding of the field of advanced antenna systems (AAS) and how they can be deployed in 5G networks. The book gives a thorough understanding of the basic technology components, the state-of-the-art multi-antenna solutions, what support 3GPP has standardized together with the reasoning, AAS performance in real networks, and how AAS can be used to enhance network deployments. Explains how AAS features impact network performance and how AAS can be effectively used in a 5G network, based on either NR and/or LTE Shows what AAS configurations and features to use in different network deployment scenarios, focusing on mobile broadband, but also including fixed wireless access Presents the latest developments in multi-antenna technologies, including Beamforming, MIMO and cell shaping, along with the potential of different technologies in a commercial network context Provides a deep understanding of the differences between mid-band and mm-Wave solutions

Key Technologies for 5G Wireless Systems
Novel Millimetre Wave Antennas for MIMO and 5G Applications
5th International Conference, HCC 2019, Čačak, Serbia, August 5–7, 2019, Revised Selected Papers
Hybrid Precoding and Combining Algorithms for Wideband Millimeter Wave MIMO Systems

16th EAI International Conference, ChinaCom 2021, Virtual Event, November 21–22, 2021, Proceedings
Massive MIMO Systems

This book constitutes the refereed post-conference proceedings of the 12th International Conference on Wireless and Satellite Services, WiSATS 2021, held in Nanjing, China, in September 2020. Due to COVID-19 pandemic the conference was held virtually. The 79 full papers were carefully reviewed and selected from 140 submissions. The conference's central theme is the means of using the wireless and satellite services directly to the user for personal communications, multimedia and location identification. The services enabled by WiSATS not only cover the requirements of an ordinary citizen but also provide personal and public services for global coverage communications as the applications of internet of things. .

A comprehensive overview of the 5G landscape covering technology options, most likely use cases and potential system architectures.

Multiple-input, multiple-output (MIMO), which transmits multiple data streams via multiple antenna elements, is one of the most attractive technologies in the wireless communication field. Its extension, called 'massive MIMO' or 'large-scale MIMO', in which base station has over one hundred of the antenna elements, is now seen as a promising candidate to realize 5G and beyond, as well as 6G mobile communications. It has been the first decade since its fundamental concept emerged. This Special Issue consists of 19 papers and each of them focuses on a popular topic related to massive MIMO systems, e.g. analog/digital hybrid signal processing, antenna fabrication, and machine learning incorporation. These achievements could boost its realization and deepen the academic and industrial knowledge of this field.

Covers the fundamental principles of space-time coding for wireless communications over MIMO channels.

Optimization Algorithms on Matrix Manifolds

Advanced Antenna Systems for 5G Network Deployments

Millimeter Wave and Massive MIMO Communications for Next-generation Wireless Systems

Proceedings of the 2018 CSPS Volume III: Systems

From Mobile to 5G

Millimeter-Wave (mmWave) Communications

This book presents the fundamental concepts, recent advancements, and opportunities for future research in various key enabling technologies in next-generation wireless communications. The book serves as a comprehensive source of information in all areas of wireless communications with a particular emphasis on physical (PHY) layer techniques related to 5G wireless systems and beyond. In particular, this book focuses on different emerging techniques that can be adopted in 5G wireless networks. Some of those techniques include massive-MIMO, mm-Wave communications, spectrum sharing, device-to-device (D2D) and vehicular to anything (V2X) communications, radio-frequency (RF) based energy harvesting, and NOMA. Subsequent chapters cover the fundamentals and PHY layer design aspects of different techniques that can be useful for the readers to get familiar with the emerging technologies and their applications.

A comprehensive and invaluable guide to 5G technology, implementation and practice in one single volume. For all things 5G, this book is a must-read.

Signal processing techniques have played the most important role in wireless communications since the second generation of cellular systems. It is anticipated that new techniques employed in 5G wireless networks will not only improve peak service rates significantly, but also enhance capacity, coverage, reliability , low-latency, efficiency, flexibility, compatibility and convergence to meet the increasing demands imposed by applications such as big data, cloud service, machine-to-machine (M2M) and mission-critical communications. This book is a comprehensive and detailed guide to all signal processing techniques employed in 5G wireless networks. Uniquely organized into four categories, New Modulation and Coding, New Spatial Processing, New Spectrum Opportunities and New System-level Enabling Technologies, it covers everything from network architecture, physical-layer (down-link and up-link), protocols and air interface, to cell acquisition, scheduling and rate adaption, access procedures and relaying to spectrum allocations. All technology aspects and major roadmaps of global 5G standard development and deployments are included in the book. Key Features: Offers step-by-step guidance on bringing 5G technology into practice, by applying algorithms and design methodology to real-time circuit implementation, taking into account rapidly growing applications that have multi-standards and multi-systems. Addresses spatial signal processing for 5G, in particular massive multiple-input multiple-output (massive-MIMO), FD-MIMO and 3D-MIMO along with orbital angular momentum multiplexing, 3D beamforming and diversity. Provides detailed algorithms and implementations, and compares all multicarrier modulation and multiple access schemes that offer superior data transmission performance including FBMC, GFDM, F-OFDM, UFMC, SEFDM, FTN, MUSA, SCMA and NOMA. Demonstrates the translation of signal processing theories into practical solutions for new spectrum opportunities in terms of millimeter wave, full-duplex transmission and license assisted access. Presents well-designed implementation examples, from individual function block to system level for effective and accurate learning. Covers signal processing aspects of emerging system and network architectures, including ultra-dense networks (UDN), software-defined networks (SDN), device-to-device (D2D) communications and cloud radio access network (C-RAN).

Get up to speed with the protocols, network architectures and techniques for 5G wireless networks with this comprehensive guide.

This book brings together papers from the 2018 International Conference on Communications, Signal Processing, and Systems, which was held in Dalian, China on July 14–16, 2018. Presenting the latest developments and discussing the interactions and links between these multidisciplinary fields, the book spans topics ranging from communications, signal processing and systems. It is aimed at undergraduate and graduate electrical engineering, computer science and mathematics students, researchers and engineers from academia and industry as well as government employees.

mmWave Massive MIMO

Fundamentals and System Designs

First International Conference, TIOTC 2021, Erbil, Iraq, June 6–8, 2021, Revised Selected Papers

Theory and Practice

Artificial Intelligence in China

Millimeter-Wave Networks

Author has written several excellent Springer books.; This book is a sequel to Introduction to Topological Manifolds; Careful and illuminating explanations, excellent diagrams and exemplary motivation; Includes short preliminary sections before each section explaining what is ahead and why

This book covers the design and optimization of hybrid RF-baseband precoding for massive multiple-input multiple-output (MIMO)-enabled cloud radio access networks (RANs), where use cases such as millimeter-wave wireless backhauling, fully-loaded cellular networks are of interest. The suitability and practical implementation of the proposed precoding

solutions for the Cloud RAN architecture are also discussed. Novel techniques are examined for RF precoding optimization in combination with nonlinear precoding at baseband, and the superiority of joint RF-baseband design is verified. Moreover, the efficacy of hybrid RF-baseband precoding to combat intercell interference in a multi-cell environment with universal frequency reuse is investigated, which is concluded to be a promising enabler for the dense deployment of base stations. This book mainly targets researchers and engineers interested in the challenges, optimization, and implementation of massive MIMO precoding in 5G Cloud RAN. Graduate students in electrical engineering and computer science interested in the application of mathematical optimization to model and solve precoding problems in massive MIMO cellular systems will also be interested in this book.

Hybrid Precoding and Combining Algorithms for Wideband Millimeter Wave MIMO SystemsMassive MIMO SystemsMDPI

Multiple-input multiple-output (MIMO) technology constitutes a breakthrough in the design of wireless communications systems, and is already at the core of several wireless standards. Exploiting multipath scattering, MIMO techniques deliver significant performance enhancements in terms of data transmission rate and interference reduction. This 2007 book is a detailed introduction to the analysis and design of MIMO wireless systems. Beginning with an overview of MIMO technology, the authors then examine the fundamental capacity limits of MIMO systems. Transmitter design, including precoding and space-time coding, is then treated in depth, and the book closes with two chapters devoted to receiver design. Written by a team of leading experts, the book blends theoretical analysis with physical insights, and highlights a range of key design challenges. It can be used as a textbook for advanced courses on wireless communications, and will also appeal to researchers and practitioners working on MIMO wireless systems.

Proceedings of the 3rd International Conference on Communications and Cyber Physical Engineering

MIMO Wireless Communications

Artificial Intelligence for Communications and Networks

Foundations of User-Centric Cell-Free Massive MIMO

12th EAI International Conference, WiSATS 2021, Virtual Event, China, July 31 - August 2, 2021 : Proceedings

5G Mobile and Wireless Communications Technology

This book constitutes thoroughly reviewed, revised and selected papers from the 5th International Conference on Human Centered Computing, HCC 2019, held in Čačak, Serbia, in August 2019. The 48 full and 23 short papers presented in this volume were carefully reviewed and selected from a total of 133 submissions. The papers focus on deep learning and its applications on a variety of real-life problems, ranging from image/video analysis, to human-computer interaction, and to logistics and supply chain management.

Multiple-input multiple-output (MIMO) communication is expected to play a central role in future wireless systems through the deployment of a large number of antennas at the transmitters and receivers. In low-frequency systems, massive MIMO offers high multiplexing gains that boost system spectral efficiency. In millimeter wave (mmWave) systems, the deployment of large antenna arrays at both the base station and mobile users is necessary to guarantee sufficient received signal power. Realizing these systems in practice, however, requires addressing several key challenges: (i) fully-digital solutions are costly and power hungry, (ii) channel training and estimation process has high overhead, and (iii) precoders design optimization problems are non-trivial. In this dissertation, precoding and channel estimation strategies that address these challenges are proposed for both mmWave and massive MIMO systems. The proposed solutions adopt hybrid analog/digital architectures that divide precoding/combining processing between RF and baseband domains and lead to savings in cost and power consumption. Further, the developed techniques leverage the structure and characteristics of mmWave and massive MIMO channels to reduce the training overhead and precoders design complexity. The main contributions of this dissertation are (i) developing a channel estimation solution for hybrid architecture based mmWave systems, exploiting the sparse nature of the mmWave channels, (ii) designing hybrid precoding algorithm for multi-user mmWave and massive MIMO systems, (iii) proposing a multi-layer precoding framework for massive MIMO cellular systems, and (iv) developing hybrid precoding and codebook solutions for frequency selective mmWave systems. Mathematical analysis as well as numerical simulations illustrate the promising performance of the proposed solutions, marking them as enabling technologies for mmWave and massive MIMO systems.

This book is a collection of research papers and articles presented at the 3rd International Conference on Communications and Cyber-Physical Engineering (ICCCE 2020), held on 1-2 February 2020 at CMR Engineering College, Hyderabad, Telangana, India. Discussing the latest developments in voice and data communication engineering, cyber-physical systems, network science, communication software, image and multimedia processing research and applications, as well as communication technologies and other related technologies, it includes contributions from both academia and industry. This book is a valuable resource for scientists, research scholars and PG students working to formulate their research ideas and find the future directions in these areas. Further, it may serve as a reference work to understand the latest engineering and technologies used by practicing engineers in the field of communication engineering.

A comprehensive and approachable introduction to 5G Written by a noted expert on the subject, An Introduction to 5G: The New Radio, 5G Network and Beyond offers an introductory system-level guide to 5G. The material covered includes: The use cases and requirements of the 5G system The architecture of the next generation radio access network and the 5G core The principles of radio

transmission, millimetre waves and MIMO antennas The architecture and detailed design of the 5G new radio The implementation of HTTP/2 on the service-based interfaces of the 5G core The signalling procedures that govern the end-to-end-operation of the system The new features that are introduced in Releases 16 and 17 An Introduction to 5G is written for engineering professionals in mobile telecommunications, for those in non-technical roles such as management, marketing and intellectual property, and for students. It requires no more than a basic understanding of mobile communications, and includes detailed references to the underlying 3GPP specifications for 5G. The book's approach provides a comprehensive, end-to-end overview of the 5G standard, which enables readers to move on with confidence to the more specialized texts and to the specifications themselves.

UAV Communications for 5G and Beyond
Human Centered Computing
Proceedings of the International Conference on Artificial Intelligence in China
802.11n and 802.11ac
ICCCE 2020
Introduction to Smooth Manifolds

This textbook takes a unified view of the fundamentals of wireless communication and explains cutting-edge concepts in a simple and intuitive way. An abundant supply of exercises make it ideal for graduate courses in electrical and computer engineering and it will also be of great interest to practising engineers.

This volume constitutes selected papers presented at the First International Conference on Emerging Technology Trends in IoT and Computing, TIOTC 2021, held in Erbil, Iraq, in June 2021. The 26 full papers were thoroughly reviewed and selected from 182 submissions. The papers are organized in the following topical sections: Internet of Things (IOT): services and applications; Internet of Things (IOT) in healthcare industry; IOT in networks, communications and distributed computing; real world application fields in information science and technology.

The aim of this book is to present the modern design and analysis principles of millimeter-wave communication system for wireless devices and to give postgraduates and system professionals the design insights and challenges when integrating millimeter wave personal communication system. Millimeter wave communication system are going to play key roles in modern gigabit wireless communication area as millimeter-wave industrial standards from IEEE, European Computer Manufacturing Association (ECMA) and Wireless High Definition (Wireless HD) Group, are on their way to the market. The book will review up-to-date research results and utilize numerous design and analysis for the whole system covering from Millimeter wave frontend to digital signal processing in order to address major topics in a high speed wireless system. This book emphasizes the importance and the requirements of high-gain antennas, low power transceiver, adaptive equalizer/modulation, channeling coding and adaptive multi-user detection for gigabit wireless communications. In addition, the book will include the updated research literature and patents in the topics of transceivers, antennas, MIMO, channel capacity, coding, equalizer, Modem and multi-user detection. Finally the application of these antennas will be discussed in light of different forthcoming wireless standards at V-band and E-band.

A comprehensive textbook for advanced undergraduate or graduate students.
Beamforming Design and Performance Analysis
First EAI International Conference, AICON 2019, Harbin, China, May 25–26, 2019, Proceedings, Part I
An Introduction to 5G

Signal Processing for 5G: Algorithms and Implementations
Communications, Signal Processing, and Systems

Offers concise, practical knowledge on modern communication systems to help students transition smoothly into the workplace and beyond This book presents the most relevant concepts and technologies of today's communication systems and presents them in a concise and intuitive manner. It covers advanced topics such as Orthogonal Frequency-Division Multiplexing (OFDM) and Multiple-Input Multiple-Output (MIMO) Technology, which are enabling technologies for modern communication systems such as WiFi (including the latest enhancements) and LTE-Advanced. Following a brief introduction to the field, Digital Communication for Practicing Engineers immerses readers in the theories and technologies that engineers deal with. It starts off with Shannon Theorem and Information Theory, before moving on to basic modules of a communication system, including modulation, statistical detection, channel coding, synchronization, and equalization. The next part of the book discusses advanced topics such as OFDM and MIMO, and introduces several emerging technologies in the context of 5G cellular system radio interface. The book closes by outlining several current research areas in digital communications. In addition, this text: Breaks down the subject into self-contained lectures, which can be read individually or as a whole Focuses on the pros and cons of widely used techniques, while providing references for detailed mathematical analysis Follows the current technology trends, including advanced topics such as OFDM and MIMO Touches on content this is not usually contained in textbooks such as cyclo-stationary symbol timing recovery, adaptive self-interference canceler, and Tomlinson-Harashima precoder Includes many illustrations, homework problems, and examples Digital Communication for Practicing Engineers is an ideal guide for graduate students and professionals in digital communication looking to understand, work with, and adapt to the current and future technology.

Written by pioneers of the concept, this is the first complete guide to the physical and engineering principles of Massive MIMO. Assuming only a basic background in communications and statistical signal processing, it will guide readers through key topics in multi-cell systems such as propagation modeling, multiplexing and de-multiplexing, channel estimation, power control, and performance evaluation. The authors' unique capacity-bounding approach will enable readers to carry out effective system performance analyses and develop advanced Massive MIMO techniques and algorithms. Numerous case studies, as well as problem sets and solutions accompanying the book online, will help readers put knowledge into practice and acquire the skill set needed to design and analyze complex wireless communication systems. Whether you are a graduate student, researcher, or industry professional working in the field of wireless communications, this will be an indispensable

guide for years to come.

The fifth generation of mobile communication systems (5G) is nowadays a reality. 5G networks are been deployed all over the world, and the first 5G-capable devices (e.g., smartphones, tablets, wearable, etc.) are already commercially available. 5G systems provide unprecedented levels of connectivity and quality of service (QoS) to cope with the incessant growth in the number of connected devices and the huge increase in data-rate demand. Massive MIMO (multiple-input multiple-output) technology plays a key role in 5G systems. The underlying principle of this technology is the use of a large number of co-located antennas at the base station, which coherently transmit/receive signals to/from multiple users. This signal co-processing at multiple antennas leads to manifold benefits: array gain, spatial diversity and spatial user multiplexing. These elements enable to meet the QoS requirements established for the 5G systems. The major bottleneck of massive MIMO systems as well as of any cellular network is the inter-cell interference, which affects significantly the cell-edge users, whose performance is already degraded by the path attenuation. To overcome these limitations and provide uniformly excellent service to all the users we need a more radical approach: we need to challenge the cellular paradigm. In this regard, cell-free massive MIMO constitutes the paradigm shift. In the cell-free paradigm, it is not the base station surrounded by the users, but rather it is each user being surrounded by smaller, simpler, serving base stations referred to as access points (APs). In such a system, each user experiences being in the cell-center, and it does not experience any cell boundaries. Hence, the terminology cell-free. As a result, users are not affected by inter-cell interference, and the path attenuation is significantly reduced due to the presence of many APs in their proximity. This leads to impressive performance. Although appealing from the performance viewpoint, the designing and implementation of such a distributed massive MIMO system is a challenging task, and it is the object of this thesis. More specifically, in this thesis we study: Paper A) The large potential of this promising technology in realistic indoor/outdoor scenarios while also addressing practical deployment issues, such as clock synchronization among APs, and cost-efficient implementations. We provide an extensive description of a cell-free massive MIMO system, emphasizing strengths and weaknesses, and pointing out differences and similarities with existing distributed multiple antenna systems, such as Coordinated MultiPoint (CoMP). Paper B) How to preserve the scalability of the system, by proposing a solution related to data processing, network topology and power control. We consider a realistic scenario where multiple central processing units serve disjoint subsets of APs, and compare the spectral efficiency provided by the proposed scalable framework with the canonical cell-free massive MIMO and CoMP. Paper C) How to improve the spectral efficiency (SE) in the downlink (DL), by devising two distributed precoding schemes, referred to as local partial zero-forcing (ZF) and local protective partial ZF, that provide an adaptable trade-off between interference cancelation and boosting of the desired signal, with no additional front-haul overhead, and that are implementable by APs with very few antennas. We derive closed-form expressions for the achievable SE under the assumption of independent Rayleigh fading channel, channel estimation error and pilot contamination. These closed-form expressions are then used to devise optimal max-min fairness power control. Paper D) How to further improve the SE by letting the user estimate the DL channel from DL pilots, instead of relying solely on the knowledge of the channel statistics. We derive an approximate closed-form expression of the DL SE for conjugate beamforming (CB), and assuming independent Rayleigh fading. This expression accounts for beamformed DL pilots, estimation errors and pilot contamination at both the AP and the user side. We devise a sequential convex approximation algorithm to globally solve the max-min fairness power control optimization problem, and a greedy algorithm for uplink (UL) and DL pilot assignment. The latter consists in jointly selecting the UL and DL pilot pair, for each user, that maximizes the smallest SE in the network. Paper E) A precoding scheme that is more suitable when only the channel statistics are available at the users, referred to as enhanced normalized CB. It consists in normalizing the precoding vector by its squared norm in order to reduce the fluctuations of the effective channel seen at the user, and thereby to boost the channel hardening. The performance achieved by this scheme is compared with the CB scheme with DL training (described in Paper D). Paper F) A maximum-likelihood-based method to estimate the channel statistics in the UL, along with an accompanying pilot transmission scheme, that is particularly useful in line-of-sight operation and in scenarios with resource constraints. Pilots are structurally phase-rotated over different coherence blocks to create an effective statistical distribution of the received pilot signal that can be efficiently exploited by the AP when performing the proposed estimation method. The overall conclusion is that cell-free massive MIMO is not a utopia, and a practical, distributed, scalable, high-performance system can be implemented. Today it represents a hot research topic, but tomorrow it might represent a key enabler for beyond-5G technology, as massive MIMO has been for 5G. La quinta generazione dei sistemi radiomobili cellulari (5G) è oggi una realtà. Le reti 5G si stanno diffondendo in tutto il mondo e i dispositivi 5G (ad esempio smartphones, tablets, indossabili, ecc.) sono già disponibili sul mercato. I sistemi 5G garantiscono livelli di connettività e di qualità di servizio senza precedenti, per fronteggiare l'incessante crescita del numero di dispositivi connessi alla rete e della domanda di dati ad alta velocità. La tecnologia Massive MIMO (multiple-input multiple-output) riveste un ruolo fondamentale nei sistemi 5G. Il principio alla base di questa tecnologia è l'impiego di un elevato numero di antenne collocate nella base station (stazione radio base) le quali trasmettono/ricevono segnali, in maniere coerente, a/da più terminali utente. Questo co-processamento del segnale da parte di più antenne apporta molteplici benefici: guadagno di array,

diversità spaziale e multiplazione degli utenti nel dominio spaziale. Questi elementi consentono di raggiungere i requisiti di servizio stabiliti per i sistemi 5G. Tuttavia, il limite principale dei sistemi massive MIMO, così come di ogni rete cellulare, è rappresentato dalla interferenza inter-cella (ovvero l'interferenza tra aree di copertura gestite da diverse base stations), la quale riduce in modo significativo le performance degli utenti a bordo cella, già degradate dalle attenuazioni del segnale dovute alla considerevole distanza dalla base station. Per superare queste limitazioni e fornire una qualità del servizio uniformemente eccellente a tutti gli utenti, è necessario un approccio più radicale e guardare oltre il classico paradigma cellulare che caratterizza le attuali architetture di rete. A tal proposito, cell-free massive MIMO (massive MIMO senza celle) costituisce un cambio di paradigma: ogni utente è circondato e servito contemporaneamente da numerose, semplici e di dimensioni ridotte base stations, denominate access points (punti di accesso alla rete). Gli access points cooperano per servire tutti gli utenti nella loro area di copertura congiunta, eliminando l'interferenza inter-cella e il concetto stesso di cella. Non risentendo più dell'effetto "bordo-cella", gli utenti possono usufruire di qualità di servizio e velocità dati eccellenti. Sebbene attraente dal punto di vista delle performance, l'implementazione di un tale sistema distribuito è una operazione impegnativa ed è oggetto di questa tesi. Piu specificatamente, questa tesi di dottorato tratta: Articolo A) L'enorme potenziale di questa promettente tecnologia in scenari realistici sia indoor che outdoor, proponendo anche delle soluzioni di implementazione flessibili ed a basso costo. Articolo B) Come preservare la scalabilità del sistema, proponendo soluzioni distribuite riguardanti il processamento e la condivisione dei dati, l'architettura di rete e l'allocazione di potenza, ovvero come ottimizzare i livelli di potenza trasmessa dagli access points per ridurre l'interferenza tra utenti e migliorare le performance. Articolo C) Come migliorare l'efficienza spettrale in downlink (da access point verso utente) proponendo due schemi di pre-codifica dei dati di trasmissione, denominati local partial zero-forcing (ZF) e local protective partial ZF, che forniscono un perfetto compromesso tra cancellazione dell'interferenza tra utenti ed amplificazione del segnale desiderato. Articolo D) Come migliorare l'efficienza spettrale in downlink permettendo al terminale utente di stimare le informazioni sulle condizioni istantanee del canale da sequenze pilota, piuttosto che basarsi su informazioni statistiche ed a lungo termine, come convenzionalmente previsto. Articolo E) In alternativa alla soluzione precedente, uno schema di pre-codifica che è più adatto al caso in cui gli utenti hanno a disposizione esclusivamente informazioni statistiche sul canale per poter effettuare la decodifica dei dati. Articolo F) Un metodo per permettere agli access points di stimare, in maniera rapida, le condizioni di canale su base statistica, favorito da uno schema di trasmissione delle sequenze pilota basato su rotazione di fase. Realizzare un sistema cell-free massive MIMO pratico, distribuito, scalabile e performante non è una utopia. Oggi questo concept rappresenta un argomento di ricerca interessante, attraente e stimolante ma in futuro potrebbe costituire un fattore chiave per le tecnologie post-5G, proprio come massive MIMO lo è stato per il 5G. Den femte generationens mobilkommunikationssystem (5G) är numera en verklighet. 5G-nätverk är utplacerade på ett flertal platser världen över och de första 5G-kapabla terminalerna (såsom smarta telefoner, surfplattor, kroppsburna apparater, etc.) är redan kommersiellt tillgängliga. 5G-systemen kan tillhandahålla tidigare oöverträffade nivåer av uppkoppling och servicekvalitet och är designade för en fortsatt oavbruten tillväxt i antalet uppkopplade apparater och ökande datataktskrav. Massiv MIMO-teknologi (eng: multiple-input multiple-output) spelar en nyckelroll i dagens 5G-system. Principen bakom denna teknik är användningen av ett stort antal samlokaliserade antenner vid basstationen, där alla antennerna sänder och tar emot signaler faskoherent till och från flera användare. Gemensam signalbehandling av många antennsignaler ger ett flertal fördelar, såsom hög riktverkan via lobformning, vilket leder till högre datatakter samt möjliggör att flera användare utnyttjar samma radioresurser via rumslig användarmultiplexering. Eftersom en signal kan gå genom flera olika, möjligen oberoende kanaler, så utsätts den för flera olika förändringar samtidigt. Denna mångfald ökar kvaliteten på signalen vid mottagaren och förbättrar radiolänkens robusthet och tillförlitlighet. Detta gör det möjligt att uppfylla de höga kraven på servicekvalitet som fastställts för 5G-systemen. Den största begränsningen för massiva MIMO-system såväl som för alla cellulära mobilnätverk, är störningar från andra celler som påverkar användare på cellkanten väsentligt, vars prestanda redan begränsas av sträckdämpningen på radiokanalen. För att övervinna dessa begränsningar och för att kunna tillhandahålla samma utmärkta servicekvalitet till alla användare behöver vi ett mer radikalt angreppssätt: vi måste utmana cellparadigmet. I detta avseende utgör cellfri massiv-MIMO teknik ett paradigmskifte. I cellfri massive-MIMO är utgångspunkten inte att basstationen är omgiven av användare som den betjänar, utan snarare att varje användare omges av basstationer som de betjänas av. Dessa basstationer, ofta mindre och enklare, kallas accesspunkter (AP). I ett sådant system upplever varje användare att den befinner sig i centrum av systemet och ingen användare upplever några cellgränser. Därav terminologin cellfri. Som ett resultat av detta påverkas inte användarna av inter-cellstörningar och sträckdämpningen reduceras kraftigt på grund av närvaron av många accesspunkter i varje användares närhet. Detta leder till imponerande prestanda. Även om det är tilltalande ur ett prestandaperspektiv så är utformningen och implementeringen av ett sådant distribuerat massivt MIMO-system en utmanande uppgift, och det är syftet med denna avhandling att studera detta. Mer specifikt studerar vi i denna avhandling: A) den mycket stora potentialen med denna teknik i realistiska inomhus- såväl som utomhusscenarier, samt hur man hanterar praktiska implementeringsproblem, såsom klocksynkronisering bland accesspunkter och kostnadseffektiva implementeringar; B) hur man ska uppnå skalbarhet i systemet genom att föreslå lösningar

relaterade till databehandling, nätverkstopologi och effektkontroll; C) hur man ökar datahastigheten i nedlänken med hjälp av två nyutvecklade distribuerade överföringsmetoder som tillhandahåller en avvägning mellan störningsundertryckning och förstärkning av önskade signaler, utan att öka mängden intern signalering till de distribuerade accesspunkterna, och som kan implementeras i accesspunkter med mycket få antenner; D) hur man kan förbättra prestandan ytterligare genom att låta användaren estimera nedlänkskanalen med hjälp av nedlänkspiloter, istället för att bara förlita sig på kunskap om kanalstatistik; E) en överföringsmetod för nedlänk som är mer lämpligt när endast kanalstatistiken är tillgänglig för användarna. Prestandan som uppnås genom detta schema jämförs med en utökad variant av den nedlänk-pilotbaserade metoden (beskrivet i föregående punkt); F) en metod för att uppskatta kanalstatistiken i upplänken, samt en åtföljande pilotsändningsmetod, som är särskilt användbart vid direktvägsutbredning (line-of-sight) och i scenarier med resursbegränsningar. Den övergripande slutsatsen är att cellfri massiv MIMO inte är en utopi, och att ett distribuerat, skalbart, samt högpresterande system kan implementeras praktiskt. Idag representerar detta ett hett forskningsämne, men snart kan det visa sig vara en viktig möjliggörare för teknik bortom dagens system, på samma sätt som centraliserad massiv MIMO har varit för de nya 5G-systemen.

This book brings together papers presented at the International Conference on Artificial Intelligence in China (ChinaAI) 2019, which provided a venue for disseminating the latest advances and discussing the interactions and links between the various subfields of AI. Addressing topics that cover virtually all aspects of AI and the latest developments in China, the book is chiefly intended for undergraduate and graduate students in Electrical Engineering, Computer Science, and Mathematics, for researchers and engineers from academia and industry, and for government employees (e.g. at the NSF, DOD, and DOE).

5G and Beyond

Next Generation Wireless LANs

The Future of IoT

Massive MIMO

PHY Layer Perspective

Hybrid Massive MIMO Precoding in Cloud-RAN

The Definitive, Comprehensive Guide to Cutting-Edge Millimeter Wave Wireless Design "This is a great book on mmWave systems that covers many aspects of the technology targeted for beginners all the way to the advanced users. The authors are some of the most credible scholars I know of who are well respected by the industry. I highly recommend studying this book in detail." —Ali Sadri, Ph.D., Sr. Director, Intel Corporation, MCG mmWave Standards and Advanced Technologies Millimeter wave (mmWave) is today's breakthrough frontier for emerging wireless mobile cellular networks, wireless local area networks, personal area networks, and vehicular communications. In the near future, mmWave products, systems, theories, and devices will come together to deliver mobile data rates thousands of times faster than today's existing cellular and WiFi networks. In Millimeter Wave Wireless Communications, four of the field's pioneers draw on their immense experience as researchers, entrepreneurs, inventors, and consultants, empowering engineers at all levels to succeed with mmWave. They deliver exceptionally clear and useful guidance for newcomers, as well as the first complete desk reference for design experts. The authors explain mmWave signal propagation, mmWave circuit design, antenna designs, communication theory, and current standards (including IEEE 802.15.3c, Wireless HD, and ECMA/WiMedia). They cover comprehensive mmWave wireless design issues, for 60 GHz and other mmWave bands, from channel to antenna to receiver, introducing emerging design techniques that will be invaluable for research engineers in both industry and academia. Topics include Fundamentals: communication theory, channel propagation, circuits, antennas, architectures, capabilities, and applications Digital communication: baseband signal/channel models, modulation, equalization, error control coding, multiple input multiple output (MIMO) principles, and hardware architectures Radio wave propagation characteristics: indoor and outdoor applications Antennas/antenna arrays, including on-chip and in-package antennas, fabrication, and packaging Analog circuit design: mmWave transistors, fabrication, and transceiver design approaches Baseband circuit design: multi–gigabit-per-second, high-fidelity DAC and ADC converters Physical layer: algorithmic choices, design considerations, and impairment solutions; and how to overcome clipping, quantization, and nonlinearity Higher-layer design: beam adaptation protocols, relaying, multimedia transmission, and multiband considerations 60 GHz standardization: IEEE 802.15.3c for WPAN, Wireless HD, ECMA-387, IEEE 802.11ad, Wireless Gigabit Alliance (WiGig)

The millimeter-wave frequency band (30–300 GHz) is considered a potential candidate to host very high data rate communications. First used for high capacity radio links and then for broadband indoor wireless networks, the interest in this frequency band has increased as it is proposed to accommodate future 5G mobile communication systems. The large bandwidth available will enable a number of new uses for 5G. In addition, due to the large propagation

attenuation, this frequency band may provide some additional advantages regarding frequency reuse and communication security. However, a number of issues have to be addressed to make mm-wave communications viable. This book collects a number of contributions that present solutions to these challenges.

Modern day cellular mobile networks use Massive MIMO technology to extend range and service multiple devices within a cell. This has brought tremendous improvements in the high peak data rates that can be handled. Nevertheless, one of the characteristics of this technology is large variations in the quality of service dependent on where the end user is located in any given cell. This becomes increasingly problematic when we are creating a society where wireless access is supposed to be ubiquitous. When payments, navigation, entertainment, and control of autonomous vehicles are all relying on wireless connectivity the primary goal for future mobile networks should not be to increase the peak rates, but the rates that can be guaranteed to the vast majority of the locations in the geographical coverage area. The cellular network architecture was not designed for high-rate data services but for low-rate voice services, thus it is time to look beyond the cellular paradigm and make a clean-slate network design that can reach the performance requirements of the future. This monograph considers the cell-free network architecture that is designed to reach the aforementioned goal of uniformly high data rates everywhere. The authors introduce the concept of a cell-free network before laying out the foundations of what is required to design and build such a network. They cover the foundations of channel estimation, signal processing, pilot assignment, dynamic cooperation cluster formation, power optimization, fronthaul signaling, and spectral efficiency evaluation in uplink and downlink under different degrees of cooperation among the access points and arbitrary linear combining and precoding. This monograph provides the reader with all the fundamental information required to design and build the next generation mobile networks without being hindered by the inherent restrictions of modern cellular-based technology.

Beyond 2020, wireless communication systems will have to support more than 1,000 times the traffic volume of today's systems. This extremely high traffic load is a major issue faced by 5G designers and researchers. This challenge will be met by a combination of parallel techniques that will use more spectrum more flexibly, realize higher spectral efficiency, and densify cells. Novel techniques and paradigms must be developed to meet these goals. The book addresses diverse key-point issues of next-generation wireless communications systems and identifies promising solutions. The book's core is concentrated to techniques and methods belonging to what is generally called radio access network.

A Paradigm for 5G
Bridging the Gap Between Theory and Practice
Cell-Free Massive MIMO
Fundamentals of Wireless Communication
Alternating Projection Methods
Wireless and Satellite Systems

If you've been searching for a way to get up to speed on IEEE 802.11n and 802.11ac WLAN standards without having to wade through the entire specification, then look no further. This comprehensive overview describes the underlying principles, implementation details and key enhancing features of 802.11n and 802.11ac. For many of these features the authors outline the motivation and history behind their adoption into the standard. A detailed discussion of key throughput, robustness, and reliability enhancing features (such as MIMO, multi-user MIMO, 40/80/160 MHz channels, transmit beamforming and packet aggregation) is given, plus clear summaries of issues surrounding legacy interoperability and coexistence. Now updated and significantly revised, this 2nd edition contains new material on 802.11ac throughput, including revised chapters on MAC and interoperability, plus new chapters on 802.11ac PHY and multi-user MIMO. An ideal reference for designers of WLAN equipment, network managers, and researchers in the field of wireless communications.

The last ten years have seen a massive growth in the number of connected wireless devices. Billions of devices are connected and managed by wireless networks. At the same time, each device needs a high throughput to support applications such as voice, real-time video, movies, and games. Demands for wireless throughput and the number of wireless devices will always increase. In addition, there is a growing concern about energy consumption of wireless communication systems. Thus, future wireless systems have to satisfy three main requirements: i) having a high throughput; ii) simultaneously serving many users; and iii) having less energy consumption. Massive multiple-input multiple-output (MIMO) technology, where a base station (BS) equipped with very large number of antennas (collocated or distributed) serves many users in the same time-frequency resource, can meet the above requirements, and hence, it is a promising candidate technology for next generations of wireless systems. With massive antenna arrays at the BS, for most propagation environments, the channels become favorable, i.e., the channel vectors between the users and the BS are (nearly) pairwisely orthogonal, and hence, linear processing is nearly optimal. A huge throughput and energy efficiency can be achieved due to the multiplexing gain and the array gain. In particular, with a simple power control scheme, Massive MIMO can offer uniformly good service for all users. In this dissertation, we focus on the performance of Massive MIMO. The dissertation consists of two main parts: fundamentals and system designs of Massive MIMO. In the first part, we focus on fundamental limits of the system performance under practical constraints such as low complexity processing, limited length of each coherence interval, intercell interference, and finite-dimensional channels. We first study the potential for power savings of the Massive MIMO uplink with maximum-ratio combining (MRC), zero-forcing, and minimum mean-square error receivers, under perfect and imperfect channels. The energy and spectral efficiency tradeoff is investigated. Secondly, we consider a physical channel model where the angular domain is divided into a finite number of distinct directions. A lower bound on the capacity is derived, and the effect of pilot contamination in this finite-dimensional channel model is analyzed. Finally, some aspects of favorable propagation in Massive MIMO under Rayleigh fading and line-of-sight (LoS) channels are investigated. We show that both

Rayleigh fading and LoS environments offer favorable propagation. In the second part, based on the fundamental analysis in the first part, we propose some system designs for Massive MIMO. The acquisition of channel state information (CSI) is very importantin Massive MIMO. Typically, the channels are estimated at the BS through uplink training. Owing to the limited length of the coherence interval, the system performance is limited by pilot contamination. To reduce the pilot contamination effect, we propose an eigenvalue-decomposition-based scheme to estimate the channel directly from the received data. The proposed scheme results in better performance compared with the conventional training schemes due to the reduced pilot contamination. Another important issue of CSI acquisition in Massive MIMO is how to acquire CSI at the users. To address this issue, we propose two channel estimation schemes at the users: i) a downlink "beamforming training" scheme, and ii) a method for blind estimation of the effective downlink channel gains. In both schemes, the channel estimation overhead is independent of the number of BS antennas. We also derive the optimal pilot and data powers as well as the training duration allocation to maximize the sum spectral efficiency of the Massive MIMO uplink with MRC receivers, for a given total energy budget spent in a coherence interval. Finally, applications of Massive MIMO in relay channels are proposed and analyzed. Specifically, we consider multipair relaying systems where many sources simultaneously communicate with many destinations in the same time-frequency resource with the help of a massive MIMO relay. A massive MIMO relay is equipped with many collocated or distributed antennas. We consider different duplexing modes (full-duplex and half-duplex) and different relaying protocols (amplify-and-forward, decode-and-forward, two-way relaying, and one-way relaying) at the relay. The potential benefits of massive MIMO technology in these relaying systems are explored in terms of spectral efficiency and power efficiency.

Explore foundational and advanced issues in UAV cellular communications with this cutting-edge and timely new resource UAV Communications for 5G and Beyond delivers a comprehensive overview of the potential applications, networking architectures, research findings, enabling technologies, experimental measurement results, and industry standardizations for UAV communications in cellular systems. The book covers both existing LTE infrastructure, as well as future 5G-and-beyond systems. UAV Communications covers a range of topics that will be of interest to students and professionals alike. Issues of UAV detection and identification are discussed, as is the positioning of autonomous aerial vehicles. More fundamental subjects, like the necessary tradeoffs involved in UAV communication are examined in detail. The distinguished editors offer readers an opportunity to improve their ability to plan and design for the near-future, explosive growth in the number of UAVs, as well as the correspondingly demanding systems that come with them. Readers will learn about a wide variety of timely and practical UAV topics, like: Performance measurement for aerial vehicles over cellular networks, particularly with respect to existing LTE performance Inter-cell interference coordination with drones Massive multiple-input and multiple-output (MIMO) for Cellular UAV communications, including beamforming, null-steering, and the performance of forward-link C&C channels 3GPP standardization for cellular-supported UAVs, including UAV traffic requirements, channel modeling, and interference challenges Trajectory optimization for UAV communications Perfect for professional engineers and researchers working in the field of unmanned aerial vehicles, UAV Communications for 5G and Beyond also belongs on the bookshelves of students in masters and PhD programs studying the integration of UAVs into cellular communication systems.

The Internet of Things (IoT) has seen the eventual shift to the "Internet of Everything" in the recent years, unveiling its ubiquitous presence spanning from smart transports to smart healthcare, from smart education to smart shopping. With the 5G rollouts across the different countries of the world, it raises newer perspectives toward the integration of 5G in IoT. For IoT-based smart devices, 5G not only means speed, but also better stability, efficiency, and more secure connectivity. The reach of 5G in IoT is extending in multifarious areas like self-driving vehicles, smart grids for renewable energy, AI-enabled robots on factory floors, intelligent healthcare services . . . The endless list is the real future of 5G in IoT. Features: Fundamental and applied perspectives to 5G integration in IoT Transdisciplinary vision with aspects of Artificial Intelligence, Industry 4.0, and hands-on practice tools Discussion of trending research issues in 5G and IoT As 5G technologies catalyze a paradigm shift in the domain of IoT, this book serves as a reference for the researchers in the field of IoT and 5G, proffering the landscape to the trending aspects as well as the key topics of discussion in the years to come.

Communications and Networking

5G and Beyond Wireless Systems

Millimeter Wave Communication Systems

Scalability, Signal Processing and Power Control

2019 22nd International Symposium on Wireless Personal Multimedia Communications (WPMC)

Millimeter Wave Wireless Communications

This two-volume set LNICST 286-287 constitutes the post-conference proceedings of the First EAI International Conference on Artificial Intelligence for Communications and Networks, AICON 2019, held in Harbin, China, in May 2019. The 93 full papers were carefully reviewed and selected from 152 submissions. The papers are organized in topical sections on artificial intelligence, mobile network, deep learning, machine learning, wireless communication, cognitive radio, internet of things, big data, communication system, pattern recognition, channel model, beamforming, signal processing, 5G, mobile management, resource management, wireless position.

Space-Time Coding

Emerging Technology Trends in Internet of Things and Computing

Fundamentals of Massive MIMO

The New Radio, 5G Network and Beyond

Digital Communication for Practicing Engineers

New Directions in Wireless Communications Systems