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Multi-hop Routing in Wireless Sensor Networks

An Overview,
Taxonomy, and
Research Challenges



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Wei Deng, Reza Mahmoudi, Arthur van Roermund



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Beamforming Antennas in Multi-Hop Wireless Networks Osama Bazan, Muhammad Jaseemuddin, 2015-11-05 In this book the authors first present an overview of the challenges and issues facing MAC and routing in multi hop wireless networks with beamforming antennas Subsequently we discuss various MAC and routing protocols that are specifically designed to address those issues and hence exploit the benefits of beamforming antennas We also present a framework to provide Quality of Service QoS in contention based wireless networks with beamforming antennas Finally we conclude the book with a discussion on open research topics

Beamforming Antennas in Wireless Networks Osama Bazan, Baha Uddin Kazi, Muhammad Jaseemuddin, 2021-07-09 Wireless networks are facing growing demand for high capacity better coverage support of new applications and broad range of services In this book the authors first present an overview of beamforming antennas and millimeter wave communications followed by a discussion on the challenges and issues facing MAC and multi hop routing in the wireless networks with beamforming antennas Then they discuss various MAC and routing protocols that are specifically designed to address those issues and exploit the benefits of millimeter wave and beamforming antennas Authors also present a framework to provide Quality of Service QoS in contention based wireless networks with beamforming antennas Finally the book is concluded with a discussion on open research topics for future generation WLAN systems

Wireless Multi-hop Networks with Beamforming Antennas and Multi-user Detection Robert Vilzmann, 2009

Fundamentals of Differential Beamforming Jacob Benesty, Jingdong Chen, Chao Pan, 2016-04-27 This book provides a systematic study of the fundamental theory and methods of beamforming with differential microphone arrays DMAs or differential beamforming in short It begins with a brief overview of differential beamforming and some popularly used DMA beampatterns such as the dipole cardioid hypercardioid and supercardioid before providing essential background knowledge on orthogonal functions and orthogonal polynomials which form the basis of differential beamforming From a physical perspective a DMA of a given order is defined as an array that measures the differential acoustic pressure field of that order such an array has a beampattern in the form of a polynomial whose degree is equal to the DMA order Therefore the fundamental and core problem of differential beamforming boils down to the design of beampatterns with orthogonal polynomials But certain constraints also have to be considered so that the resulting beamformer does not seriously amplify the sensors self noise and the mismatches among sensors Accordingly the book subsequently revisits several performance criteria which can be used to evaluate the performance of the derived differential beamformers Next differential beamforming is placed in a framework of optimization and linear system solving and it is shown how different beampatterns can be designed with the help of this optimization framework The book then presents several approaches to the design of differential beamformers with the maximum DMA order with the control of the white noise gain and with the control of both the frequency invariance of the beampattern and the white noise gain Lastly it elucidates a joint optimization method that

can be used to derive differential beamformers that not only deliver nearly frequency invariant beam patterns but are also robust to sensors self noise *Time Multiplexed Beam-Forming with Space-Frequency Transformation* Wei Deng, Reza Mahmoudi, Arthur H.M. van Roermund, 2012-08-23 This book describes a unique approach to smart receiver system design It starts with the analysis of a very basic single path receiver structure then using similar methods extends the analysis to a more complicated multi path receiver Within the multi path structure two different types of phased array architectures are discussed Analog beam forming and digital beam forming The pros and cons are studied and the gaps are identified Whereas previous books in this area focus mainly on phased array circuit implementations this book fills a gap by providing a system level approach and introduces new methods for developing smart systems **RF Antenna Beam Forming** Shun-Ping Chen, Heinz Schmiedel, 2023-03-24 This book is designed for both the scientific audience research and development engineers and the university students The fundamentals of radio frequency antenna beam forming is explained in this book The principles of beam focusing and beam steering in near field and far field are visualized with 2D and 3D simulations and compared with measurement results Besides linear and planar antenna arrays also conformal arrays i.e. concave and convex antenna arrays suitable for certain applications are investigated and presented Also related applications of radio frequency beam forming like open loop and closed loop large scale antenna arrays or massive MIMO which is one of the break through technologies for 5G and future 6G and involves an extremely large number of antenna elements for the multi user beam forming as well as thinned antenna arrays with electrically large distances between the antenna elements are discussed

Array Beamforming Enabled Wireless Communications Zhenyu Xiao, Lipeng Zhu, Lin Bai, Xiang-Gen Xia, 2023-04-25 This book investigates the most advanced theories and methodologies of array beamforming with a focus on antenna array enabled wireless communication technology Combining with the current development needs and trends of wireless communication technology around the world the authors explore the potentials and challenges of large scale antenna array beamforming technology in next generation mobile communication and some important emerging application scenarios The book first introduces the basic structure of antenna array hierarchical codebook and channel estimation with high dimensionality with which the time cost of searching the channel information can be effectively reduced It then explicates high efficiency beamforming transmission methods for point to point transmission full duplex point to point transmission and point to multipoint transmission where array beamforming enabled non orthogonal multiple access NOMA technologies for typical two user systems and general multi user systems are emphasized The book also discusses array beamforming enabled unmanned aerial vehicle UAV communications and array beamforming enabled space air ground communications with the uniqueness and relative solutions for single UAV systems and multi UAV networks being analyzed This will be a vital reference for researchers students and professionals interested in wireless communications array beamforming and millimeter wave communications *Time Multiplexed Beam-Forming with Space-Frequency Transformation* Wei Deng, Reza

Mahmoudi, Arthur van Roermund, 2012-08-23 This book describes a unique approach to smart receiver system design It starts with the analysis of a very basic single path receiver structure then using similar methods extends the analysis to a more complicated multi path receiver Within the multi path structure two different types of phased array architectures are discussed Analog beam forming and digital beam forming The pros and cons are studied and the gaps are identified Whereas previous books in this area focus mainly on phased array circuit implementations this book fills a gap by providing a system level approach and introduces new methods for developing smart systems Array Processing Jacob Benesty, Israel Cohen (Professor of electrical engineering), Jingdong Chen, 2019-06-04 The focus of this book is on array processing and beamforming with Kronecker products It considers a large family of sensor arrays that allow the steering vector to be decomposed as a Kronecker product of two steering vectors of smaller virtual arrays Instead of directly designing a global beamformer for the original array once the steering vector has been decomposed smaller virtual beamformers are designed and separately optimized for each virtual array This means the matrices that need to be inverted are smaller which increases the robustness of the beamformers and reduces the size of the observations The book explains how to perform beamforming with Kronecker product filters using an unconventional approach It shows how the Kronecker product formulation can be used to derive fixed adaptive and differential beamformers with remarkable flexibility Furthermore it demonstrates how fixed and adaptive beamformers can be intelligently combined optimally exploiting the advantages of both The problem of spatiotemporal signal enhancement is also addressed and readers will learn how to perform Kronecker product filtering in this context *Statistical Robust Beamforming for Broadcast Channels and Applications in Satellite Communication* Andreas Gründinger, 2019-11-27 This book investigates adaptive physical layer beamforming and resource allocation that ensure reliable data transmission in the multi antenna broadcast channel The book provides an overview of robust optimization techniques and modelling approximations to deal with stochastic performance metrics One key contribution of the book is a closed form description of the achievable rates with unlimited transmit power for a rank one channel error model Additionally the book provides a concise duality framework to transform mean square error MSE based beamformer designs e g quality of service and balancing optimizations into equivalent uplink filter designs For the algorithmic solution the book analyses the following paradigm transmission to receivers with large MSE targets low demands is switched off if the transmit power is low The book also studies chance constrained optimizations for limiting the outage probability In this context the book provides two novel conservative outage probability approximations that result in convex beamformer optimizations To compensate for the remaining inaccuracy the book introduces a post processing power allocation Finally the book applies the introduced beamformer designs for SatCom where interference from neighboring spotbeams and channel fading are the main limitations *Wideband Beamforming* Wei Liu, Stephan Weiss, 2010-05-03 This book provides an excellent reference for all professionals working in the area of array signal processing and its applications in wireless communications Wideband

beamforming has advanced with the increasing bandwidth in wireless communications and the development of ultra wideband UWB technology In this book the authors address the fundamentals and most recent developments in the field of wideband beamforming The book provides a thorough coverage of the subject including major sub areas such as sub band adaptive beamforming frequency invariant beamforming blind wideband beamforming beamforming without temporal processing and beamforming for multi path signals Key Features Unique book focusing on wideband beamforming Discusses a hot topic coinciding with the increasing bandwidth in wireless communications and the development of UWB technology Addresses the general concept of beamforming including fixed beamformers and adaptive beamformers Covers advanced topics including sub band adaptive beamforming frequency invariant beamforming blind wideband beamforming beamforming without temporal processing and beamforming for multi path signals Includes various design examples and corresponding complexity analyses This book provides a reference for engineers and researchers in wireless communications and signal processing fields Postgraduate students studying signal processing will also find this book of interest

Spectrum Sharing for Wireless Communications ChunSheng Xin,Min Song,2015-02-26 This SpringerBrief presents intelligent spectrum sharing technologies for future wireless communication systems It explains the widely used opportunistic spectrum access and TV white space sharing which has been approved by the FCC Four new technologies to significantly increase the efficiency of spectrum sharing are also introduced The four technologies presented are Dynamic Spectrum Co Access Incentivized Cooperative Spectrum Sharing On Demand Spectrum Sharing and Licensed Shared Spectrum Access These technologies shed light on future wireless communication systems and pave the way for innovative spectrum sharing with increased spectrum utilization Increased utilization will allow networks to meet the demand for radio spectrum and promote the growth of wireless industry and national economy Spectrum Sharing is a valuable resource for researchers and professionals working in wireless communications Advanced level students in electrical engineering and computer science will also find this content helpful as a study guide *Array Beamforming with Linear Difference Equations* Jacob Benesty,Israel Cohen,Jingdong Chen,2021-03-01 This book studies the link between differential beamforming and differential equations which in turn enables the study of fundamental theory and methods of beamforming from a different perspective leading to new insights into the problem and new methods to solve the problem The book first presents a brief overview of the problems and methods for beamforming and some performance measures popularly used either to evaluate beamformers or to derive optimal beamformers Then first order second order and general high order linear difference equations are discussed based on which the authors show how to formulate the beamforming problem and derive different beamforming methods including fixed and adaptive ones Furthermore the authors show how to apply the theory of difference equations to the general problem of speech enhancement and deduce a number of noise reduction filters including the maximum SNR filter the Wiener filter the MVDR filter etc Also covered in the book are the difference equations and

differential beamforming from the spectral graph perspective Presents basic concepts fundamental principles and methods for beamforming from the perspective of linear difference equations Provides formulation and methods of conventional beamforming and first order second order and general high order linear difference equations for beamforming Includes the applications of linear difference equations to the problem of noise reduction Explains beamforming based on difference equations with graphs **Beamforming Coordination Techniques in OFDM Multi-hop Cellular Networks** Marc Torrellas Socastro, 2011 English Design and evaluate multi hop cellular networks assuming coordination among multiantenna base stations and relay stations using linear precoders

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