OLIVER HOLLAND, HANNA BOGUCKA,
AND ARTURAS MEDEISIS

OPPORTUNISTIC SPECTRUM SHARING and WHITE SPACE ACCESS

THE PRACTICAL REALITY

WILEY

Opportunistic Spectrum Sharing And White Space Access The Practical Reality

Farzad Hessar

Opportunistic Spectrum Sharing And White Space Access The Practical Reality:

Opportunistic Spectrum Sharing and White Space Access Oliver Holland,Hanna Bogucka,Arturas Medeisis,2015-04-22 Details the paradigms of opportunistic spectrum sharing and white space access as effective means to satisfy increasing demand for high speed wireless communication and for novel wireless communication applications This book addresses opportunistic spectrum sharing and white space access being particularly mindful of practical considerations and solutions In Part I spectrum sharing implementation issues are considered in terms of hardware platforms and software architectures for realization of flexible and spectrally agile transceivers Part II addresses practical mechanisms supporting spectrum sharing including spectrum sensing for opportunistic spectrum access machine learning and decision making capabilities aggregation of spectrum opportunities and spectrally agile radio waveforms Part III presents the ongoing work on policy and regulation for efficient and reliable spectrum sharing including major recent steps forward in TV White Space TVWS regulation and associated geolocation database approaches policy management aspects and novel licensing schemes supporting spectrum sharing In Part IV business and economic aspects of spectrum sharing are considered including spectrum value modeling discussion of issues around disruptive innovation that are pertinent to opportunistic spectrum sharing and white space access and business benefits assessment of the novel spectrum sharing regulatory proposal Licensed Shared Access Part V discusses deployments of opportunistic spectrum sharing and white space access solutions in practice including work on TVWS system implementations standardization activities and development and testing of systems according to the standards Discusses aspects of pioneering standards such as the IEEE 802 22 Wi Far standard the IEEE 802 11af White Fi standard the IEEE Dynamic Spectrum Access Networks Standards Committee standards and the ETSI Reconfiguration Radio Systems standards Investigates regulatory and regulatory linked solutions assisting opportunistic spectrum sharing and white space access including geo location database approaches and licensing enhancements Covers the pricing and value of spectrum the economic effects and potentials of such technologies and provides detailed business assessments of some particularly innovative regulatory proposals The flexible and efficient use of radio frequencies is necessary to cater for the increasing data traffic demand worldwide This book addresses this necessity through its extensive coverage of opportunistic spectrum sharing and white space access solutions Opportunistic Spectrum Sharing and White Space Access The Practical Reality is a great resource for telecommunication engineers researchers and students

Internet of Things, Smart Spaces, and Next Generation Networks and Systems Yevgeni Koucheryavy,Sergey Balandin,Sergey Andreev,2022-03-15 This book constitutes the joint refereed proceedings of the 21st International Conference on Next Generation Teletraffic and Wired Wireless Advanced Networks and Systems NEW2AN 2021 and the 14th Conference on Internet of Things and Smart Spaces ruSMART 2021 The conference was held virtually due to the COVID 19 pandemic The 41 revised full papers presented were carefully reviewed and selected from 118 submissions *Sensing*

Techniques for Next Generation Cognitive Radio Networks Bagwari, Ashish,Bagwari, Jyotshana,Tomar, Geetam Singh,2018-08-30 The inadequate use of wireless spectrum resources has recently motivated researchers and practitioners to look for new ways to improve resource efficiency As a result new cognitive radio technologies have been proposed as an effective solution Sensing Techniques for Next Generation Cognitive Radio Networks is a pivotal reference source that provides vital research on the application of spectrum sensing techniques While highlighting topics such as radio identification compressive sensing and wavelet transform this publication explores the standards and the methods of cognitive radio network architecture This book is ideally designed for IT and network engineers practitioners and researchers seeking current research on radio scene analysis for cognitive radios and networks **e-Infrastructure and e-Services for Developing Countries** Gervais Mendy,Samuel Ouya,Ibra Dioum,Ousmane Thiaré,2019-03-21 This book constitutes the thoroughly refereed proceedings of the 10th EAI International Conference on e Infrastructure and e Services for Developing Countries AFRICOMM 2018 held in Dakar Senegal in November 2018 The 28 full papers were carefully selected from 49 submissions The accepted papers provide a wide range of research topics including e health environment cloud VPN and overlays networks services e Learning agriculture IoT social media mobile communication and security

Internet of Things in Smart Sewer and Drainage Systems Abdul Salam,2023-12-14 This multidisciplinary book provides insights into the applications of the Internet of Things IoT to combined sewer overflows CSO and stormwater management SWM systems It explores technical challenges and presents recent results to improve sewer and drainage system management using wireless underground communications and sensing in IoT The book addresses both existing sensing network technologies and those currently in development in three major areas of CSO combined sewer overflow management subsurface sensing and antennas in the layered medium It explores new applications of IoT in sewer systems to improve public health foster economic growth and enhance environmental quality and responsibility for the community Internet of Things in Smart Sewer and Drainage Systems Theory and Applications will be a valuable reference for graduate students and academic researchers as well as a hands on guide for wastewater technicians sanitary engineers environmental specialists and related industry practitioners Advanced Multicarrier Technologies for Future Radio Communication Hanna Bogucka,Adrian Kliks,Pawel Kryszkiewicz,2017-08-14 A practical review of state of the art non contiguous multicarrier technologies that are revolutionizing how data is transmitted received and processed This book addresses the advantages and the limitations of modern multicarrier technologies and how to meet the challenges they pose using non contiguous multicarrier technologies and novel algorithms that enhance spectral efficiency interference robustness and reception performance It explores techniques using non contiguous subcarriers which allow for flexible spectrum aggregation while achieving high spectral efficiency and flexible transmission and reception at lower OSI layers These include non contiguous orthogonal frequency division multiplexing NC OFDM its enhanced version non contiguous filter bank based multicarrier NC

FBMC and generalized multicarrier Following an overview of current multicarrier technologies for radio communication the authors examine particular properties of these technologies that allow for more efficient usage within key directions of 5G They examine the principles of NC OFDM and discuss efficient transmitter and receiver design They present the principles of FBMC modulation and discuss key challenges for FBMC communications while comparing performance results with traditional OFDM They move on from there to a fascinating discussion of GMC modulation within which they clearly demonstrate how that technology encompasses all of the advantages of previously discussed techniques as well as all imaginable multi and single carrier waveforms Addresses the problems and limitations of current multicarrier technologies OFDM Describes innovative techniques using non contiguous multicarrier waveforms as well as filter band based and generalized multicarrier waveforms Provides a thorough review of the practical limitations and solutions for evolving and breakthrough 5G communication technologies Explores the future outlook for non contiguous multicarrier technologies as regards their greater industrial realization hardware practicality and other challenges Advanced Multicarrier Technologies for Future Radio Communication 5G and Beyondis an indispensable working resource fortelecommunication engineers researchers and academics as well as graduate and post graduate students of telecommunications At the same time it provides a fascinating look at the shape of things to come for telecommunication industry executives telecom operators regulators policy makers and economists **Spectrum Sharing in Wireless Networks** John D. Matyjas,Sunil Kumar,Fei Hu,2016-11-17 Spectrum Sharing in Wireless Networks Fairness Efficiency and Security provides a broad overview of wireless network spectrum sharing in seven distinct sections The first section examines the big picture and basic principles explaining the concepts of spectrum sharing hardware software function requirements for efficient sharing and future trends of sharing strategies The second section contains more than 10 chapters that discuss differing approaches to efficient spectrum sharing The authors introduce a new coexistence and sharing scheme for multi hop networks describe the space time sharing concept introduce LTE U and examine sharing in broadcast and unicast environments They then talk about different cooperation strategies to achieve mutual benefits for primary users PU and secondary users SU discuss protocols in a spectrum sharing context and provide different game theory models between PUs and SUs The third section explains how to model the interactions of PUs and SUs using an efficient calculation method to determine spectrum availability Additionally this section explains how to use scheduling models to achieve efficient SU traffic delivery The subject of the fourth section is MIMO oriented design It focuses on how directional antennas and MIMO antennas greatly enhance wireless network performance The authors include a few chapters on capacity rate calculations as well as beamforming issues under MIMO antennas Power control is covered in the fifth section which also describes the interference aware power allocation schemes among cognitive radio users and the power control schemes in cognitive radios The sixth section provides a comprehensive look at security issues including different types of spectrum sharing attacks and threats as well as

corresponding countermeasure schemes The seventh and final section covers issues pertaining to military applications and examines how the military task protects its data flows when sharing the spectrum with civilian applications **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 *Dynamic Spectrum Sharing by Opportunistic Spectrum Access with Spectrum Aggregation* Haeyoung Lee,2015 *Dynamic Sharing of Wireless Spectrum* Haibo Zhou,Quan Yu,Xuemin (Sherman) Shen,Shaohua Wu,Qinyu Zhang,2016-09-02 This book focuses on the current research on the dynamic spectrum sharing for efficient spectrum resource utilization which covers the overlay spectrum sharing underlay spectrum sharing and database assisted spectrum sharing related research issues Followed by a comprehensive review and in depth discussion of the current state of the art research literature and industry standardization this book first presents a novel overlay spectrum sharing framework for dynamic utilization of available cellular frequency bands formulates the dynamic spectrum sharing problem as a dynamic resource demand supply matching problem and accordingly develops a distributed fast spectrum sharing algorithm to solve the resource matching problem A self awareness power control approach for multi hop routing selection is proposed which can establish an effective and practical routing selection optimization in secondary access networks and minimize the interference to primary users Finally this book offers dynamic secondary access scheme for database assisted spectrum sharing networks which is targeted to support the prosperous wireless multimedia networking applications by leveraging the TV white spaces of geolocation databases while satisfying QoS guarantees of secondary users The overlay spectrum sharing underlay spectrum sharing and database assisted white spaces spectrum sharing research results that are presented in this book provide useful insights for the design of next generation wireless access networks This book motivates a new line of thinking for efficient spectrum resource utilization and performance enhancements of future wireless access applications Opportunistic Spectrum Sharing System S. S. Kawade,2014 **Sharing RF Spectrum with Commodity Wireless Technologies** Jan Kruys,Luke Qian,2011-08-09 Much energy has been spent on the subject of spectrum scarcity that would threaten to stunt the growth of wireless technologies and services This concern comes on the

heels of the great successes of both cellular communications and consumer oriented communications like Wi Fi and Bluetooth that have changed the way people use computers and communications and that have led to the creation of large new markets for products and services The response of many spectrum regulators throughout the world in addressing these concerns has been to consider releasing more spectrum for unlicensed or for shared use An example is the spectrum that is released by the transition to digital TV the frequencies freed up are destined in part to new applications that would be license exempt A possible beneficiary of new spectrum releases would be the smart grid a networked application of digital sensor and control technology to the energy delivery segment of the energy utility industry This policy has heightened the interests of all involved in spectrum sharing and many proposals are being considered or brought forward However theory in this area is scarce and practice proves resistive of quick solutions A case in point is RLAN radar spectrum sharing in the 5GHz range six years after the ITU R allocated this shared spectrum the rules for sharing as well as the means to verify compliance with these rules are not fully mature Another recent development is the interest in spectrum pricing and trading which tend to focus on the economic aspects of spectrum sharing at the expense understanding of the limitations as well as the technical possibilities of spectrum sharing *Opportunistic Wireless Spectrum Access* Rahman Doost-Mohammady,2014 The limited availability of usable wireless spectrum and the ever increasing demands of high bandwidth data transfer raise concerns on whether current spectrum access regimes can match future communication requirements Moreover most desirable frequency ranges with good channel characteristics are already licensed and purchasing new licenses for small operators is often prohibitively expensive This thesis proposes methods for achieving efficient spectrum access through devising protocols for identifying and sharing unused spectrum analyzing the theoretical bounds of these protocols and implementing these so lutions in practical medical and vehicular environments A significant portion of the thesis is focused on opportunistic spectrum access within licensed frequency bands where cognitive radios transmit on frequencies without inter fering with the primary users in them First a cooperative sensing method based on re inforcement learning technique is designed to efficiently detect spectrum opportunities After identifying portions of the available spectrum a channel allocation technique is de vised for the cognitive radios with quality of service provisioning The supporting analyt ical framework is constructed using Markov process and ensures that radios opportunis tically using the licensed spectrum meet their latency and throughput requirements The analytical framework is tested through traces collected in the wireless medical telemetry service WMTS band and reliability enhancements in possible hospital application areas are quantified A mobile architecture composed of vehicular networks is also investigated where spectrum databases that provide the spectrum availability information are included in the network design Apart from re use of the licensed spectrum this thesis investigates full duplex channel access scheme for improving throughput Full duplex enables simultaneous transmission and reception on the same channel for a single radio which promises doubling of the throughput An analytical framework for the performance of CSMA

CA based channel access for full duplex enabled network of nodes is formulated The closed form expres sions for the average throughput and packet collision probability in such a network is analytically derived and verified through comprehensive simulations **Opportunistic Spectrum Sharing System (OSSS)** Santosh S. Kawade,2014 **Wireless Coexistence for Spectrum Sharing** Hossein-Ali Safavi-Naeini,2016 Much of the spectrum licensed for usage by the regulatory authorities remains idle or heavily underutilized By allowing opportunistic access to these dormant resources spectrum sharing promises to dramatically boost the supply of spectrum that is available for high bandwidth wireless communications This shared access arrangement will lead to the expected coexistence of multiple wireless systems within the same frequency band giving rise to the study undertaken in this dissertation Our work begins by considering TV Whitespaces TVWS which were the first major instance of spectrum sharing to be considered We look at adapting the 802 11 WLAN standard for operation in TVWS bands by incorporating sensing into the Wi Fi MAC layer We use this study to explore the potential of Software Defined Radio systems and the role they play in spectrum sharing systems while identifying the challenges and pitfalls inherent in such implementations Our focus then shifts to spectrum sharing in radar bands First we aim to shrink the exclusion regions as defined by the NTIA by inheriting from the techniques developed for TVWS The key outcome of this work is to provide an analytic framework for the selection of Wi Fi parameters than can deliver the desired radar protection performance This framework supports the aim of maximum spectrum utilization by reducing the areas which are deprived of shared access to radar spectrum The last major result in this dissertation is a detailed study into the impact of radars on communication systems We present what is to our knowledge the first detailed look at the physical layer obstacles that hinder network throughput for devices deployed in radar bands Looking at the two major broadband standards IEEE 802 11 WLAN and 3GPP LTE we identify vulnerabilities that would render networks inoperable in close proximity to radars before providing effective solutions to recover the desired performance The line of investigation in this thesis furnishes some of the solutions that are necessary for the future success of spectrum sharing systems Spectrum Sharing in Wireless Networks John D. Matyjas,Sunil Kumar,Fei Hu,2016-11-17 Spectrum Sharing in Wireless Networks Fairness Efficiency and Security provides a broad overview of wireless network spectrum sharing in seven distinct sections The first section examines the big picture and basic principles explaining the concepts of spectrum sharing hardware software function requirements for efficient sharing and future trends of sharing strategies The second section contains more than 10 chapters that discuss differing approaches to efficient spectrum sharing The authors introduce a new coexistence and sharing scheme for multi hop networks describe the space time sharing concept introduce LTE U and examine sharing in broadcast and unicast environments They then talk about different cooperation strategies to achieve mutual benefits for primary users PU and secondary users SU discuss protocols in a spectrum sharing context and provide different game theory models between PUs and SUs The third section explains how to model the interactions of PUs and SUs using an efficient calculation method to

determine spectrum availability Additionally this section explains how to use scheduling models to achieve efficient SU traffic delivery The subject of the fourth section is MIMO oriented design It focuses on how directional antennas and MIMO antennas greatly enhance wireless network performance The authors include a few chapters on capacity rate calculations as well as beamforming issues under MIMO antennas Power control is covered in the fifth section which also describes the interference aware power allocation schemes among cognitive radio users and the power control schemes in cognitive radios The sixth section provides a comprehensive look at security issues including different types of spectrum sharing attacks and threats as well as corresponding countermeasure schemes The seventh and final section covers issues pertaining to military applications and examines how the military task protects its data flows when sharing the spectrum with civilian applications

Spectrum Sharing in White Spaces Farzad Hessar,2015 Demand for wireless Internet traffic has been increasing exponentially over the last decade due to widespread usage of smart phones along with new multimedia applications The need for higher wireless network throughput has been pushing engineers to expand network capacities in order to keep pace with growing user demands The improvement has been multi dimensional including optimizations in MAC Physical layer for boosting spectral efficiency expanding network infrastructure with reduced cell sizes and utilizing additional RF spectrum Nevertheless traffic demand has been increasing at a much faster pace than network throughput and our current networks will not be able to handle customer needs in near future While assigning additional spectrum for cellular communication has been a major element of network capacity increase the natural scarcity of RF spectrum limits the extend of this solution On the other hand researchers have shown that licensed spectrum that is owned and held by a primary user is heavily underutilized Examples are TV channels in the VHF UHF band as well as radar spectrum in the SHF band Hence a more efficient use of this spectrum is to permit unlicensed users to coexist with the primary owner i e to share the same spectrum if it is not utilized at the current time location Spectrum sharing has received considerable attention in recent years for its potential in improving network capacities Especially with formal opening of TV band frequencies by FCC to unlicensed operation as well as proposals for radar bands to be opened in near future wireless industry is also showing a great deal of interest in these unlicensed bands The main challenge behind spectrum sharing is detection of spectrum opportunities known as white spaces by the secondaries Classic methods are based on spectrum sensing which requires highly sensitive receivers Newer methods that are currently proposed by FCC for TV white space spectrum are the so called DBA approach in which a centralized database determines availability of shared spectrum at any location and time This work is focused on the latter method In this work we have focused on major challenges in spectrum sharing in the white space spectrum First the available capacity that is opened through TV white space spectrum is not clearly understood We define a mathematical framework to evaluate achievable white space capacity in the TV band as a function of location FCC regulation and secondary network parameters We use this framework to simulate available TV white space channels and capacity over the

entire United States and explore its dependency on various parameters Second unlike licensed spectrum available TV white space spectrum is significantly location dependent The number of channels as well as their quality noise and interference floor can severely change from place to place Therefore designing a cellular network that is based on spectrum sharing requires special channel allocation algorithms to consider these variations in to account We define the problem of channel allocation in a spectrum sharing scenarios and explore various solutions Third spectrum sharing rules in dynamic scenarios such as radar bands are not defined Due to rotation of radar antennas the available spectrum is time dependent and coexistence scenario depends on how much information about the time varying primary user radar transmitter is available to the secondary user We introduce a spectrum sharing paradigm with rotating radar transmitters that models radar target detection operation as well as random distribution of secondary WiFi transmitters in the environment We use this model to calculate protection region for the radar as well as achievable throughput Fourth the lack of suitable SDR hardware has made evaluation and prototyping of available white space spectrum very challenging We develop a SDR platform for operation of WiFi devices in the UHF spectrum from 300 MHz to 3 8 GHz band This platform is then utilized for development of fully functional WiFi like networks in UW campuses to evaluate white space opportunities in the UHF spectrum and to provide Internet connectivity to end users **Opportunistic Spectrum Access Using Localization Techniques** Ahmed O. Nasif,2009 The scarcity of radio spectrum poses a significant challenge to the sustained growth of wireless communications since most of the useful radio spectrum is already allocated for licensed users However recent spectrum measurement studies have shown that there are plenty of white spaces or spectrum holes that could be utilized opportunistically by secondary users provided that they do not cause harmful interference to the primary users In this dissertation we develop efficient methods by which a group of secondary users equipped with cognitive radios can determine and access spectrum holes opportunistically based on signal measurements The cognitive radios are frequency agile in that they can dynamically tune to different frequency channels for transmission and reception By ex changing signal strength measurements a group of cognitive radios can calculate maximum likelihood estimates of the location and transmit powers of the primary transmitters in the system We apply the Cramer Rao bound CRB to characterize the error in the primary system parameter estimates The parameter and error estimates are then used to derive an approximation to the Maximum Interference Free Transmit Power MIFTP which is the maximum allowable power that a given cognitive radio can use on a given frequency channel subject to an interference constraint To mitigate interference from multiple cochannel primary transmitters secondary nodes maintain a distributed database that records the location power and error estimates of cochannel nodes for each frequency channel The proposed MIFTP approximation takes into account errors in spectrum sensing such that the approximation becomes more conservative when measurement errors accrue and conversely it becomes more accurate when better measurement data is available The property of being conservative is important since

secondary users must avoid causing harmful interference to primary users We also propose two model identification and measurement clustering criteria to identify the number of cochannel primary transmitters and to cluster the measurements appropriately for more accurate estimation of the primary system parameters Finally we extend the proposed opportunistic spectrum techniques to incorporate angle of arrival information for improved localization accuracy and hence tighter estimates for the MIFTP **Towards Practical Dynamic Spectrum Sharing** Lei Yang,2011 Static spectrum allocation policies of the past have led to an artificial spectrum scarcity problem The ideal solution is dynamic spectrum sharing where wireless devices dynamically access spectrum matching their demands and share spectrum with peers to minimize interference Mechanisms and Games for Dynamic Spectrum Allocation Tansu Alpcan,2013 Presenting state of the art research into methods of wireless spectrum allocation based on game theory and mechanism design this innovative and comprehensive book provides a strong foundation for the design of future wireless mechanisms and spectrum markets Prominent researchers showcase a diverse range of novel insights and approaches to the increasing demand for limited spectrum resources with a consistent emphasis on theoretical methods analytical results and practical examples Covering fundamental underlying principles licensed spectrum sharing opportunistic spectrum sharing and wider technical and economic considerations this singular book will be of interest to academic and industrial researchers wireless industry practitioners and regulators interested in the foundations of cutting edge spectrum management

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