Xianghao Yu · Chang Li · Jun Zhang ·
Khaled B. Letaief

Stochastic Geometry Analysis of Multi–Antenna Wireless Networks

Stochastic Geometry For Wireless Networks

Tobias Bleicker

Stochastic Geometry For Wireless Networks:

Stochastic Geometry for Wireless Networks Martin Haenggi,2013 Analyse wireless network performance and improve design choices for future architectures and protocols with this rigorous introduction to stochastic geometry **Stochastic Geometry and Wireless Networks** François Baccelli,Bartlomiej Blaszczyszyn,2010 This volume bears on wireless network modeling and performance analysis The aim is to show how stochastic geometry can be used in a more or less systematic way to analyze the phenomena that arise in this context It first focuses on medium access control mechanisms used in ad hoc networks and in cellular networks It then discusses the use of stochastic geometry for the quantitative analysis of routing algorithms in mobile ad hoc networks The appendix also contains a concise summary of wireless communication principles and of the network architectures considered in the two volumes *Stochastic Geometry for Wireless Networks* Martin Haenggi,2013 Analyse wireless network performance and improve design choices for future architectures and protocols with this rigorous introduction to stochastic geometry Stochastic Geometry for Wireless Networks Martin Haenggi,2013 Covering point process theory random geometric graphs and coverage processes this rigorous introduction to stochastic geometry will enable you to obtain powerful general estimates and bounds of wireless network performance and make good design choices for future wireless architectures and protocols that efficiently manage interference effects Practical engineering applications are integrated with mathematical theory with an understanding of probability the only prerequisite At the same time stochastic geometry is connected to percolation theory and the theory of random geometric graphs and accompanied by a brief introduction to the R statistical computing language Combining theory and hands on analytical techniques with practical examples and exercises this is a comprehensive guide to the spatial stochastic models essential for modelling and analysis of wireless network performance **Stochastic Geometry and Wireless Networks** François Baccelli,2009 *Stochastic Geometry and Wireless Networks: Applications* François Baccelli,Bartłomiej Błaszczyszyn,2010-02 This volume bears on wireless network modeling and performance analysis The aim is to show how stochastic geometry can be used in a more or less systematic way to analyze the phenomena that arise in this context It first focuses on medium access control mechanisms used in ad hoc networks and in cellular networks It then discusses the use of stochastic geometry for the quantitative analysis of routing algorithms in mobile ad hoc networks The appendix also contains a concise summary of wireless communication principles and of the network architectures considered in the two volumes

Stochastic Geometry Analysis of Cellular Networks Bartłomiej Błaszczyszyn,Martin Haenggi,Paul Keeler,Sayandev Mukherjee,2018-04-19 Achieve faster and more efficient network design and optimization with this comprehensive guide Some of the most prominent researchers in the field explain the very latest analytic techniques and results from stochastic geometry for modelling the signal to interference plus noise ratio SINR distribution in heterogeneous cellular networks This book will help readers to understand the effects of combining different system deployment parameters on key performance

indicators such as coverage and capacity enabling the efficient allocation of simulation resources In addition to covering results for network models based on the Poisson point process this book presents recent results for when non Poisson base station configurations appear Poisson due to random propagation effects such as fading and shadowing as well as non Poisson models for base station configurations with a focus on determinantal point processes and tractable approximation methods Theoretical results are illustrated with practical Long Term Evolution LTE applications and compared with real world deployment results   Large-scale Wireless Networks Junghoon Lee,2014 Recently the location of the nodes in wireless networks has been modeled as point processes In this dissertation various scenarios of wireless communications in large scale networks modeled as point processes are considered The first part of the dissertation considers signal reception and detection problems with symmetric alpha stable noise which is from an interfering network modeled as a Poisson point process For the signal reception problem the performance of space time coding STC over fading channels with alpha stable noise is studied We derive pairwise error probability PEP of orthogonal STCs For general STCs we propose a maximum likelihood ML receiver and its approximation The resulting asymptotically optimal receiver AOR does not depend on noise parameters and is computationally simple and close to the ML performance Then signal detection in coexisting wireless sensor networks WSNs is considered We define a binary hypothesis testing problem for the signal detection in coexisting WSNs For the problem we introduce the ML detector and simpler alternatives The proposed mixed fractional lower order moment FLOM detector is computationally simple and close to the ML performance Stochastic orders are binary relations defined on probability The second part of the dissertation introduces stochastic ordering of interferences in large scale networks modeled as point processes Since closed form results for the interference distributions for such networks are only available in limited cases it is of interest to compare network interferences using stochastic In this dissertation conditions on the fading distribution and path loss model are given to establish stochastic ordering between interferences Moreover Laplace functional LF ordering is defined between point processes and applied for comparing interference Then the LF orderings of general classes of point processes are introduced It is also shown that the LF ordering is preserved when independent operations such as marking thinning random translation and superposition are applied The LF ordering of point processes is a useful tool for comparing spatial deployments of wireless networks and can be used to establish comparisons of several performance metrics such as coverage probability achievable rate and resource allocation even when closed form expressions for such metrics are unavailable   *Stochastic Geometry Analysis of Multi-Antenna Wireless Networks* Xianghao Yu,Chang Li,Jun Zhang,Khaled B. Letaief,2019-03-27 This book presents a unified framework for the tractable analysis of large scale multi antenna wireless networks using stochastic geometry This mathematical analysis is essential for assessing and understanding the performance of complicated multi antenna networks which are one of the foundations of 5G and beyond networks to meet the ever increasing demands for network capacity Describing the salient properties of the

framework which makes the analysis of multi antenna networks comparable to that of their single antenna counterparts the book discusses effective design approaches that do not require complex system level simulations It also includes various application examples with different multi antenna network models to illustrate the framework s effectiveness   Modeling and Analyzing Wireless Networks Using Stochastic Geometry Junse Lee,2018 Over the past decade stochastic geometric models and most notably the planar Poisson point process PPP model have become popular for the analysis of spectral efficiency in wireless networks in both the D2D and the cellular contexts 1 By modeling base station BS and user locations as spatial point processes stochastic geometry has recently been recognized as a tractable and efficient analytical tool to quantify key performance metrics This tool provides a natural way of defining and computing macroscopic properties of multiuser information theory These properties are obtained by averaging over all node patterns found in a large random network of the Euclidean plane For example some key performance metrics such as signal to interference and noise ratio and data rate depend on the network geometric configurations This tool has thus been widely adopted for analyzing the network performance and broadening network design This thesis proposes new models to represent several new scenarios Three main scenarios are considered 3 D inbuilding networks MIMO adhoc networks and multihop communication under mmWave networks To do so mathematical tools such as Poisson point processes Poisson line processes Boolean models and Poisson bipolar models are used Each model is 1 generative in that it has a clear physical interpretation 2 leads to explicit analytical representations of important wireless performance metrics and 3 highly parametric with parameters expressing the geometric characteristic of the elements of networks Physical interpretations from these models are quite different from previous results The core of this thesis is focused on the effects of correlated shadowing Shadowing is the effect that the received signal power fluctuates due to objects obstructing the propagation path By introducing an independent shadowing term over links it is possible to model the effect of shadow fading Most previous papers analyzing urban networks assume that shadowing fields are independent over links With this assumption it is possible to derive simple closed form expressions of important network performance metrics However this assumption cannot capture that shadowing fields are spatially correlated This thesis goes beyond the independent shadowing approximation and analyzes the effects of correlated shadowing on various performance metrics   **Stochastic Geometry for Modeling, Analysis and Design of Future Wireless Networks** Jing Guo,2016 This thesis focuses on the modeling analysis and design of future wireless networks with smart devices i e devices with intelligence and ability to communicate with one another with without the control of base stations BSs Using stochastic geometry we develop realistic yet tractable frameworks to model and analyze the performance of such networks while incorporating the intelligence features of smart devices In the first half of the thesis we develop stochastic geometry tools to study arbitrarily shaped network regions Current techniques in the literature assume the network regions to be infinite while practical network regions tend to be arbitrary Two well known networks are considered

where devices have the ability to i communicate with others without the control of BSs i e ad hoc networks and ii opportunistically access spectrum i e cognitive networks First we propose a general algorithm to derive the distribution of the distance between the reference node and a random node inside an arbitrarily shaped ad hoc network region which helps to compute the outage probability We then study the impact of boundary effects and show that the outage probability in infinite regions may not be a meaningful bound for arbitrarily shaped regions By extending the developed techniques we further analyze the performance of underlay cognitive networks where different secondary users SUs activity protocols are employed to limit the interference at a primary user Leveraging the information exchange among SUs we propose a cooperation based protocol We show that in the short term sensing scenario this protocol improves the network s performance compared to the existing threshold based protocol In the second half of the thesis we study two recently emerged networks where devices have the ability to i communicate directly with nearby devices under the control of BSs i e device to device D2D communication and ii harvest radio frequency energy i e energy harvesting networks We first analyze the intra cell interference in a finite cellular region underlaid with D2D communication by incorporating a mode selection scheme to reduce the interference We derive the outage probability at the BS and a D2D receiver and propose a spectrum reuse ratio metric to assess the overall D2D communication performance We demonstrate that without impairing the performance at the BS if the path loss exponent on cellular link is slightly lower than that on D2D link the spectrum reuse ratio can have negligible decrease while the average number of successful D2D transmissions increases with the increasing D2D node density This indicates that an increasing level of D2D communication is beneficial in future networks Then we study an ad hoc network with simultaneous wireless information and power transfer in an infinite region where transmitters are wirelessly charged by power beacons We formulate the total outage probability in terms of the power and channel outage probabilities The former incorporates a power activation threshold at transmitters which is a key practical factor that has been largely ignored in previous work We show that although increasing power beacon s density or transmit power is not always beneficial for channel outage probability it improves the overall network performance   *Fundamentals of Ultra-Dense Wireless Networks* David López-Pérez,Ming Ding,2022-06-30 Discover the fundamental characteristics of ultra dense networks with this comprehensive text Featuring a consistent mathematical description of ultra dense small cell networks while also covering real world issues such as network deployment operation and optimization this book investigates performance metrics of coverage probability and area spectral efficiency ASE and addresses the aspects of ultra dense networks that make them different from current networks Insightful intuitions which will assist decision makers as they migrate their services are explained and mathematically proven The book presents the latest review of research outcomes on ultra dense networks based on both theoretical analyses and network simulations includes over 200 sources from 3GPP the Small Cell Forum journals and conference proceedings and covers all other related and prominent topics This is an ideal

reference text for professionals who are dealing with the development deployment operation and maintenance of ultra dense small cell networks as well as researchers and graduate students in communications **Modeling, Analysis, and Optimization of Random Wireless Networks** Hesham Mahmoud Medhat Mahmoud Elsawy,2014 Wireless Stochastic Cellular Networks **Advanced NOMA Techniques for Heterogeneous Cellular Networks** Vimal Bhatia,Zhiguo Ding,Keshav Singh,Amit Baghel,Abhinav Singh Parihar,Deepak Kumar,2026-01-01 This book provides a comprehensive exploration of Non Orthogonal Multiple Access NOMA in Heterogeneous Cellular Networks HCNs focusing on both theoretical foundations and practical considerations It examines critical challenges such as non linear high power amplifiers HPAs and imperfections in successive interference cancellation SIC Furthermore it presents advanced techniques including simultaneous wireless information and power transfer SWIPT with cooperative NOMA and the application of reconfigurable intelligent surfaces RIS for enhancing coverage reliability and energy efficiency The authors also explore advanced research directions including SWIPT enabled cooperation RIS assisted performance analysis and NOMA resilience under impairments suck as impulsive noise Each chapter combines mathematical models performance analysis and design insights to provide a structured understanding of NOMA s role in enabling efficient and reliable communication in next generation networks The primary audience for this book includes professionals in both industry and academia who seek to apply advanced NOMA technologies to improve the performance and efficiency of HCN for 6G and beyond communication systems As a secondary audience graduate students in computer science electronics and communications engineering electrical engineering and related disciplines will also gain both foundational knowledge and exposure to emerging research problems in this rapidly evolving field *On Large Cooperative Wireless Network Modeling Through a Stochastic Geometry Approach* Andres Oscar Altieri,2014 The main goal of this work is to study cooperative aspects of large wireless networks from the perspective of stochastic geometry This allows the consideration of important effects such as the random spatial distribution of nodes as well as the effects of interference and interference correlation at receivers which are not possible when a single link is considered in isolation First some aspects of the performance of the relay channel in the context of a large wireless network are considered Mainly the performance in terms of outage probability OP of a single full duplex relay channel utilizing decode and forward DF or compress and forward when the interference is generated by uniform spatial deployment of nodes modeled as a Poisson point process The OP performance of these two protocols is compared with a point to point transmission and with a half duplex DF protocol Afterwards the case in which more than one transmitter in the network may use a relay is considered The effects of cooperation versus interference are studied when the users use either full duplex DF or point to point transmissions In a second phase this work explores the advantages that could be obtained through out of band device to device D2D video file exchanges in cellular networks These advantages are measured in terms of the fraction of requests that can be served in a time block through D2D thus avoiding a downlink file transfer from the base station For

this a stochastic geometry framework is introduced in which the user file caching policy user pairing strategy and link quality and scheduling issues are considered   *Physical Layer Security in Random Cellular Networks* Hui-Ming Wang,Tong-Xing Zheng,2016-10-04 This book investigates key security issues in connection with the physical layer for random wireless cellular networks It first introduces readers to the fundamentals of information theoretic security in the physical layer By examining recently introduced security techniques for wireless point to point communications the book proposes new solutions to physical layer security based on stochastic geometric frameworks for random cellular networks It subsequently elaborates on physical layer security in multi tier heterogeneous networks With the new modeled settings the authors also verify the security performance with the impact of the full duplex transceivers The specific model design presented here offers a valuable point of reference for readers in related areas In addition the book highlights promising topics and proposes potential future research directions   *Throughput Characterizations of Wireless Networks Via Stochastic Geometry and Random Graph Theory* Jeffrey William Wildman (II),2015 The shared medium of wireless communication networks presents many technical challenges that offer a rich modeling and design space across both physical and scheduling protocol layers This dissertation is organized into tasks that characterize the throughput performance in such networks with a secondary focus on the interference models employed therein We examine the throughput ratio of greedy maximal scheduling GMS in wireless communication networks modeled as random graphs A throughput ratio is a single parameter characterization of the largest achievable fraction of the network capacity region The throughput ratio of GMS is generally very difficult to obtain however it may be evaluated or bounded based on specific topology structures We analyze the GMS throughput ratio in previously unexplored random graph families under the assumption of primary interference Critical edge densities are shown to yield bounds on the range and expected GMS throughput ratio as the network grows large We next focus on the increasing interest in the use of directional antennas to improve throughput in wireless networks We propose a model for capturing the effects of antenna misdirection on coverage and throughput in large scale directional networks within a stochastic geometry framework We provide explicit expressions for communication outage as a function of network density and antenna beamwidth for idealized sector antenna patterns These expressions are then employed in optimizations to maximize the spatial density of successful transmissions under ideal sector antennas We supplement our analytical findings with numerical trends across more realistic antenna patterns Finally we characterize trade offs between the protocol and physical interference models each used in the prior tasks A transmission is successful under the protocol model if the receiver is free of any single significant interferer while physical model feasibility accounts for multiple interference sources The protocol model parameterized by a guard zone radius naturally forms a decision rule for estimating physical model feasibility We combine binary hypothesis testing with stochastic geometry and characterize the guard zone achieving minimum protocol model prediction error We conclude with guidelines for identifying environmental parameter regimes for

which the protocol model is well suited as a proxy for the physical model **An Introduction to Cellular Network Analysis Using Stochastic Geometry** Jeffrey G. Andrews,Abhishek K. Gupta,Ahmad Alammouri,Harpreet S. Dhillon,2023-06-30 This book provides an accessible yet rigorous first reference for readers interested in learning how to model and analyze cellular network performance using stochastic geometry In addition to the canonical downlink and uplink settings analyses of heterogeneous cellular networks and dense cellular networks are also included For each of these settings the focus is on the calculation of coverage probability which gives the complementary cumulative distribution function ccdf of signal to interference and noise ratio SINR and is the complement of the outage probability Using this other key performance metrics such as the area spectral efficiency are also derived These metrics are especially useful in understanding the effect of densification on network performance In order to make this a truly self contained reference all the required background material from stochastic geometry is introduced in a coherent and digestible manner This Book Provides an approachable introduction to the analysis of cellular networks and illuminates key system dependencies Features an approach based on stochastic geometry as applied to cellular networks including both downlink and uplink Focuses on the statistical distribution of signal to interference and noise ratio SINR and related metrics *A Stochastic Geometry Analysis of Cooperative Wireless Networks Powered by Energy Harvesting* Talha Ahmed Khan,2015 Energy harvesting technology is essential for enabling green sustainable and autonomous wireless networks In this report a large scale wireless network with energy harvesting transmitters is considered where a group of transmitters forms a cluster to cooperatively serve a desired user in the presence of co channel interference and noise Using stochastic geometry simple closed form expressions are derived to characterize the outage performance at the user as a function of important parameters such as the energy harvesting rate the energy buffer size and the cluster size for a given cluster geometry The analysis is further extended to characterize the delay due to transmission failure The developed framework is flexible in that it allows the in cluster transmitters to have possibly different energy harvesting capabilities The analytical expressions are first validated using simulations and then used for investigating the impact of different parameters such as cluster and buffer size on outage performance The results suggest that substantial outage performance can in fact be extracted with a relatively small energy buffer Moreover the utility of having a large energy buffer increases with the cluster size as well as with the energy harvesting rate

Computational Modeling and Simulation of Advanced Wireless Communication Systems Agbotiname Lucky Imoize,Webert Montlouis,Mohammad S. Obaidat,Segun I. Popoola,Mohammad Hammoudeh,2024-11-29 The book covers the exploitation of computational models for effectively developing and managing large scale wireless communication systems The goal is to create and establish computational models for seamless human interaction and efficient decision making in beyond 5G wireless systems Computational Modeling and Simulation of Advanced Wireless Communication Systems looks to create and establish computational models for seamless human interaction and efficient decision making in the beyond 5G

wireless systems This book presents the design and development of several computational modeling techniques and their applications in wireless communication systems It examines shortcomings and limitations of the existing computational models and offers solutions to revamp the traditional architecture toward addressing the vast network issues in wireless systems The book addresses the need to design efficient computational and simulation models to address several issues in wireless communication systems such as interference pathloss delay traffic outage and so forth It discusses how theoretical mathematical and experimental results are integrated for optimal system performance to enhance the quality of service for mobile subscribers Further the book is intended for industry and academic researchers scientists and engineers in the fields of wireless communications and ICTs It is structured to present a practical guide to wireless communication engineers IT practitioners researchers students and other professionals

The Enigmatic Realm of **Stochastic Geometry For Wireless Networks**: Unleashing the Language is Inner Magic

In a fast-paced digital era where connections and knowledge intertwine, the enigmatic realm of language reveals its inherent magic. Its capacity to stir emotions, ignite contemplation, and catalyze profound transformations is nothing in short supply of extraordinary. Within the captivating pages of **Stochastic Geometry For Wireless Networks** a literary masterpiece penned by way of a renowned author, readers attempt a transformative journey, unlocking the secrets and untapped potential embedded within each word. In this evaluation, we shall explore the book is core themes, assess its distinct writing style, and delve into its lasting impact on the hearts and minds of those who partake in its reading experience.

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