Mathematical Issues in Communications

Conference Agenda

Sunday, August 17, 2025	**Registration and Check-in**
Saturday, August 23, 2025	**Departure**

Monday, August 18, 2025

8:45 am - 9:00 am	OPENING and GROUP PHOTO	
9:00 am - 10:00 am	**Speaker:** **陶梅霞**	**Chair:** **刘亚锋**
10:00 am - 10:30 am	TEA BREAK	
10:30 am - 11:30 am	**Speaker:** **许杰**	**Chair:** **刘亚锋**
11:30 am - 14:00 pm	LUNCH BREAK	
14:00 pm - 15:00 pm	**Speaker:** **刘凡**	**Chair:** **艾文宝**
15:00 pm - 16:00 pm	**Speaker:** **李洋**	**Chair:** **艾文宝**
16:00 pm - 16:30 pm	TEA BREAK	
16:30 pm - 17:30 pm	**Speaker:** **孙聪**	**Chair:** **艾文宝**
17:30 pm	DINNER BREAK	

Tuesday, August 19, 2025

9:00 am - 10:00 am	**Speaker:** **牛凯**	**Chair:** **沈超**
10:00 am - 10:30 am	TEA BREAK	
10:30 am - 11:30 am	**Speaker:** **黄永伟**	**Chair:** **沈超**
11:30 am - 14:00 pm	LUNCH BREAK	
14:00 pm - 15:00 pm	**Speaker:** **王勇超**	**Chair:** **利强**

15:00 pm - 16:00 pm	**Speaker:** **蒲文强**	**Chair:** **利强**
16:00 pm - 16:30 pm	TEA BREAK	
16:30 pm - 17:30 pm	**Speaker:** **邵明杰**	**Chair:** **利强**
17:30 pm	DINNER BREAK	

Wednesday, August 20, 2025

9:00 am - 10:00 am	**Speaker:** **郭成军**	**Chair:** **Tsung-Hui Chang**
10:00 am - 10:30 am	TEA BREAK	
10:30 am - 11:30 am	**Speaker:** **牛雪妍**	**Chair:** **Tsung-Hui Chang**
11:30 am - 14:00 pm	LUNCH BREAK	
14:00 pm - 15:00 pm	**Speaker:** **刘亮**	**Chair:** **王治国**
15:00 pm - 16:00 pm	**Speaker:** **张硕闻**	**Chair:** **王治国**
16:00 pm - 16:30 pm	TEA BREAK	
16:30 pm - 17:30 pm	**Speaker:** **宋恩彬**	**Chair:** **王治国**
17:30 pm	DINNER BREAK	

Thursday, August 21, 2025

9:00 am - 10:00 am	**Speaker:** **许威**	**Chair:** **蔡曙**
10:00 am - 10:30 am	TEA BREAK	
10:30 am - 11:30 am	**Speaker:** **秦飞**	**Chair:** **蔡曙**
11:30 am - 14:00 pm	LUNCH BREAK	
14:00 pm - 15:00 pm	**Speaker:** **陈俊挺**	**Chair:** **崔原豪**
15:00 pm - 16:00 pm	**Speaker:** **林静然**	**Chair:** **崔原豪**
16:00 pm - 16:30 pm	TEA BREAK	

16:30 pm	DINNER BREAK

Friday, August 22, 2025

9:00 am - 10:00 am	**Speaker:** **蔡曙**	**Chair:** **王治国**
10:00 am - 10:30 am	TEA BREAK	
10:30 am - 11:30 am	**Speaker:** **张博洋**	**Chair:** **王治国**
11:30 am - 14:00 pm	LUNCH BREAK	
14:00 pm - 16:00 pm	**FREE DISCUSSION**	
16:00 pm - 17:30 pm	**CLOSING CEREMONY**	
17:30 pm	DINNER BREAK	

Presentation Details

陶梅霞，上海交通大学，中国
Title: GeNeRT: 面向低空信道智能建模的可泛化神经射线追踪
Abstract: 随着低空经济和 6G 的快速发展，低空智联网已成为新一代网络基础设施的重要组成。由于低空场景频繁切换、电波传播影响因素复杂，准确、实时的信道模型是低空智联网部署的重要前提。本报告将介绍一种融合物理知识和神经网络的低空信道智能建模方法---GeNeRT。该方法通过构建三维环境语义地图，并设计嵌入神经网络的射线追踪框架，来实现准确快速的信道建模。初步实验表明，该方法能有效提升信道建模的物理精度与空间泛化能力。

许杰，香港中文大学（深圳），中国
Title: 6D Channel Knowledge Map Construction via Bidirectional Gaussian Splatting
Abstract: This talk presents a novel approach for constructing high-dimensional channel knowledge maps (CKMs) from sparse channel measurements. Unlike conventional 2D/3D CKM methods that rely on fixed base station configurations, we introduce a six-dimensional (6D) CKM framework capable of modeling wireless

channels across dynamic transmitter and receiver locations in 3D space. Inspired by bidirectional Gaussian splatting (BiGS) for optical radiance field reconstruction under dynamic illumination, we propose bidirectional wireless Gaussian splatting (BiWGS)—a novel method that represents virtual scatterers and environmental obstacles using Gaussian ellipsoids. These ellipsoids inherently capture the bidirectional scattering patterns and complex attenuation profiles of wireless channels, enabling accurate modeling of signal propagation under varying transceiver configurations. Numerical results demonstrate that BiWGS achieves spatial spectrum prediction accuracy comparable to state-of-the-art 3D CKM methods (e.g., WRF-GS) while simultaneously enabling 6D CKM construction. This breakthrough accomplishes dimensional expansion without compromising prediction fidelity, paving the way for more adaptive and dynamic wireless network optimization.

刘凡，东南大学，中国

Title: Sensing With Random Communication Signals

Abstract: The Integrated Sensing and Communications (ISAC) paradigm is anticipated to be a cornerstone of the upcoming 6G networks. In order to optimize the use of wireless resources, 6G ISAC systems need to harness the communication data payload signals, which are inherently random, for both sensing and communication (S&C) purposes. This talk will provide a comprehensive technical overview of the signal processing methodologies for ISAC transmission with random communication signals. We begin by introducing the deterministic-random tradeoff (DRT) between S&C from an information-theoretic perspective, emphasizing the need for specialized signal processing techniques tailored to random ISAC signals. Building on this foundation, we review the core signal models and processing pipelines for communication-centric ISAC systems, and analyze the average squared auto-correlation function (ACF) of random ISAC signals, which serves as a fundamental performance metric for multi-target ranging tasks. Drawing insights from these theoretical results, we outline the design principles for the three key components of communication-centric ISAC systems: modulation schemes, constellation design, and pulse shaping filters. The goal is to either enhance sensing performance without compromising communication efficiency or to establish a scalable tradeoff between the two. Finally, we conclude by highlighting several open challenges and future research directions in the field of sensing with communication signals.

李洋，大湾区大学，中国

Title: Massive Random Access for Internet-of-Things: From Single-Cell to Cell-Free Massive MIMO

Abstract: In the era of modern machine-type communications (MTC), efficiently identifying active Internet-of-Things (IoT) devices during the random access phase is crucial. Existing single-cell activity detection methods face significant computational complexity and delays, making real-time implementation difficult. The challenge

intensifies with cell-free massive MIMO due to asynchronous IoT devices over large areas and capacity-limited fronthaul links. This talk will explore deep learning techniques for single-cell activity detection, ensuring real-time implementation and adaptability across varying device numbers. For cell-free massive MIMO, I will introduce a communication-efficient end-to-end learning framework that maintains high detection performance with minimal fronthaul overhead. These advancements promise to enhance the efficiency and reliability of IoT networks, paving the way for more robust MTC systems.

孙聪，北京邮电大学，中国

Title: Location optimization of RIS aided broadcast channel

Abstract: Reconfigurable intelligent surface (RIS) is a popular technology for 6G. The joint optimization model of RIS location and parameter for RIS aided multi-user broadcast channel is proposed. With highly nonlinear objective function and discrete phase constraints, it is formulated as a mixed integer programming problem. The Courant penalty function technique from optimization and the maximum ratio transmission technique from communication are applied for problem simplification. Then the RIS parameters are updated in closed form, and its location variables are solved through the trust region method. Numerical tests show solid improvement of the quality of service by the new model compared to the work which only optimizes RIS parameters. The advice of RIS location is also provided.

牛凯，北京邮电大学，中国

Title: 语义信息理论与方法

Abstract: 通信与智能的融合是信息技术的重要趋势，语义信息是未来通信系统交互的新媒介。本报告首先介绍了语义信息的本质特征-同义性，然后简要概述了语义信息论的基本框架，包括语义信息的度量体系，以及三个语义编码的基本定理，指出语义通信的性能极限。最后，介绍了语义编码传输的系统框架，引入了基于同义映射的变分推断方法并展示了语义编码性能优势。可以预见，语义通信将成为未来通信的新范式，具有广阔的应用前景。

王勇超，西安电子科技大学，中国

Title: Design of Artificial Interference Signals for Covert Communication Aided by Multiple Friendly Nodes

Abstract: In this paper, we consider the scenario of covert communication aided by multiple friendly interference nodes. The objective is to conceal the legitimate communication link under the surveillance of a warden. We propose a novel strategy for generating artificial noise signals. In the absence of accurate channel fading information between the friendly interference nodes and the legitimate receiver, we leverage the statistical information of channel coefficients to optimize the basis matrix of the artificial noise signals space. The optimization aims to design artificial noise

signals within the space to facilitate covert communication while minimizing the impact on the performance of legitimate communication. Due to the non-convex nature of the basis matrix constraints, the optimization problem is challenging to solve. Therefore, we employ the Riemannian optimization framework to analyze the geometric structure of the basis matrix constraints and transform the original non-convex optimization problem into an unconstrained problem on the complex Stiefel manifold for solution. Specifically, we utilize the Riemannian Stochastic Variance Reduced Gradient (R-SVRG) algorithm on the complex Stiefel manifold to solve the problem, significantly reducing the computational burden per iteration compared to full gradient algorithms. Additionally, we theoretically prove the convergence of the proposed algorithm to a stationary point. Finally, the performance of the proposed artificial noise strategy can be evaluated through numerical simulations, and compared to the Gaussian artificial noise strategy without optimization, the proposed strategy significantly improves covert performance.

程磊，浙江大学，中国

Title: 水声探测-通信环境场张量空时智能

Abstract: 复杂水声环境信息的精准获取是可靠探测与通信的前提。然而，在大范围的海域内，现有海洋立体观测网获取的观测数据稀疏而带噪，亟需发展先进的多维水声环境场空-时表征、重构与生成技术, 精准恢复“对声传播敏感”的环境场精细结构（涡旋、湍流、内波等）。针对现有方法多维信息利用不足的挑战，本报告将以矩阵模型的多维拓展 — 张量模型为基石，开展与大语言模型与计算机视觉的交叉研究，介绍与深度内在学习、 自监督技术、贝叶斯学习、神经微分方程, 以及扩散模型等前沿人工智能模型的协同建模与算法设计研究，以及在深海无人系统中的应用，并探讨未来研究方向。

蒲文强，深圳市大数据研究院，中国

Title: Optimistic Thompson Sampling for No-Regret Learning in Unknown Games

Abstract: We study the problem of learning to play a repeated multi-player game with an unknown reward function and bandit feedback, a setting that exemplifies the curse of multi-player due to the exponential growth of the joint action space. The central challenge arises from the need to balance exploration and exploitation under bandit feedback while strategically responding to other players. To address this, we propose Thompson Sampling-based algorithms that leverage available information about opponents' actions and reward structures, resulting in a significant reduction in regret bound. Building on these insights, we introduce the Optimism-then-NoRegret framework, which encompasses various game algorithms as special cases. Simulation evaluations on three distinct types of games show that our proposed algorithms consistently and substantially outperform standard baselines.

邵明杰，中国科学院数学与系统科学研究院，中国

Title: Quantized Signal Sensing: Identifiabilityand Algorithms
Abstract: In this talk, we explore sensing from quantized signals, focusing on quantized linear regression (QLR), which has applications in signal processing, data analysis, and wireless communication. We introduce formulations for maximum-likelihood estimation (MLE) and amplitude retrieval (AR), highlighting challenges with integrals and nonsmooth objective functions. We discuss algorithm designs. For quantized MIMO detection, we present an efficient branch-and-bound method that reduces complexity compared to exhaustive search. For parameter estimation, we reveal a hidden relationship between EM and proximal gradient methods, offering insights into EM convergence and facilitating the development of novel accelerated schemes. Additionally, we introduce a deep unfolding adaptation to enhance performance and efficiency, supported by a theoretical explanation of the activation function. Simulation results demonstrate the effectiveness of our approaches.

郭成军，华为技术有限公司，中国
Title: TBA
Abstract: TBA

牛雪妍，华为技术有限公司，中国
Title: Scaling, Editing, and Reasoning with Memory in Large Language Models
Abstract: In recent years, AI technologies represented by large language models (LLMs) has risen rapidly. Therefore, it is necessary to rethink the classical information theory framework, which is centered on reliable communication issues, and explore Level-2 information theory, that is, information theory oriented towards semantics. This talk starts from the semantic perspective of communications, using token as the core concept instead of bit, to discuss the rate-distortion-perception trade-off in information theory, application of generative models, Transformer memory capacity, and information theoretic interpretation of key mechanisms such as prompt compression and knowledge editing of LLMs.

刘亮，香港理工大学，中国
Title: Fundamental Limit for Channel Estimation Overhead in Conventional and Beyond Diagonal RIS Aided Communication
Abstract: To reap the tremendous beamforming gain promised by the reconfigurable intelligent surface (RIS), accurate channel state information (CSI) is necessary. However, the overhead to estimate the channels associated with a huge number of RIS atoms is significant. In this talk, we will reveal some hidden channel properties in RIS aided communication and leverage these properties to characterize the overhead to perfectly estimate the cascaded user-RIS-base station (BS) channels in the noiseless case. Interestingly, we will show that the channel estimation overhead in the

conventional RIS aided communication and that in the new beyond diagonal RIS aided communication are in the same order, although the latter requires the estimation of far more channel coefficients.

张硕闻，香港理工大学，中国

Title: ISAC Exploiting Prior Distribution Information: Optimized Beamforming and How Many Sensing Beams are Needed?

Abstract: In wireless sensing or integrated sensing and communication (ISAC) systems, the exact values of the parameters to be sensed are generally unknown before sensing is performed. This leads to unknown channels associated with the sensing targets, which pose new challenges for the beamforming design. On the other hand, the distribution of the parameters to be sensed can be practically acquired a priori based on target properties or statistical analysis. This talk will present a new beamforming optimization framework for wireless sensing or ISAC systems based only on the prior distribution information about the parameters to be sensed. Specifically, we are going to discuss a series of interesting questions as follows. Firstly, for a sensing-only system, with various possible values for each parameter to be sensed, each with a potentially different probability, how to design transmit beamforming and how many sensing beams are needed? We will unveil a novel "probability-dependent power focusing" effect in the optimized beamforming design. Secondly, for an ISAC system with dual-functional beams for sensing and communication, how many dual-functional beams are needed for achieving an optimal trade-off between sensing and communication? Thirdly, for an ISAC system with potentially dedicated sensing beams, when are sensing beams needed and how many sensing beams are needed? Finally, we will reveal the role of such prior distribution information in various other practical problems such as the placement design of sensing anchors as well as the beamforming designs in systems with limited radio frequency (RF) chains, reconfigurable surface, or physical-layer security consideration.

宋恩彬，四川大学，中国

Title: A Globally Convergent Algorithm for Linear Minimax Regret Estimation of Deterministic Parameters with Bounded Data Uncertainties

Abstract: Estimating an unknown deterministic parameter vector with a linear estimator in a noisy linear model is well known in statistics. This talk studies the open problem, i.e., developing the minimax regret estimator in the presence of bounded data uncertainties for more general classes of weighting matrices, where the regret is the difference between the mean squared error (MSE) attainable without knowledge of the true parameters and the optimal MSE attainable with such knowledge. Firstly, we establish that the minimax regret (MR) problem is equivalent to a semidefinite relaxation minimax regret (SDR-MR) problem, utilizing SDR techniques and exploring deeper into the relation between the parameter vector in the regret and

rank-one matrix. This equivalence forms the cornerstone of our analysis. Subsequently, we investigate the existence of a saddle point for the SDR-MR problem's objective function, and directly obtain the MR estimator if one exists. Otherwise, we proceed to employ the projected subgradient method, with the sublinear rate of convergence, to obtain the MR estimator. Notably, the main challenges stem from some non-convex problems involved in the above process, which are effectively addressed by our algorithm designed for SDP with a single linear fractional. Simulations demonstrate the effectiveness of the MR estimator and validate our theoretical results.

许威，东南大学，中国

Title: 数字与模拟融合的通信计算一体化理论方法

Abstract: 面向未来移动通信网络激增的计算需求，空中计算凭借其利用多址信道模拟叠加特性实现空中频谱复用计算的突出优势，被视为关键使能技术。然而，模拟信号与主流数字系统无法兼容，且其固有缺陷导致可靠性与鲁棒性受限。为此，引入数字信号，通过编码与调制的联合设计，构建数字空中计算技术，成为突破其实际部署瓶颈的关键。本报告系统阐述其统一的编码-调制数学框架，并提出一种基于二进制补码的理论最优信源编码方法；进一步地，首次引入 RS 信道编码设计，构建可纠错的精准计算架构，并搭建试验平台验证。最后，探索并展望空中叠加计算任务在信息理论层面的性能极限及其逼近的编码设计路径。

秦飞，中国科学院大学，中国

Title: 电磁理论与信号系统理论融合的新体制信道研究方法

Abstract: 无线信道依托电磁波构建，但是在历史沿革上却选择依托信号与系统构建其研究范式，以冲激响应作为信道表征，仅具备给定收发天线端口间的表达能力，损失了空间域信息。与此同时，全波计算则放弃了电磁波传播时序过程的表达能力，多以收敛后空间能量分布为系统输出，事实上放弃了时间域信息，后者则为信道过程的核心表达。随着新型计算技术的发展，已具备了探索电磁理论与信号系统理论融合的新体制信道测量、建模、与模拟方法的可能性，其研究成果有望支撑 Massive MIMO、FAS 等新一代无线通信核心技术。

陈俊挺，香港中文大学（深圳），中国

Title: 基于无标签数据的无线电地图盲构建与利用

Abstract: How to enhance the intelligence for wireless communication networks? One promising direction is to fuse more environmental information to the network, such as building radio maps, a data model that describes the wireless communication quality between any transmitter and receiver location pair. The technology has been successfully used for network planning, spectrum management, and fingerprint localization for over 20 years. However, conventional radio map techniques were limited to power spectrum maps and require precise location labels for construction and application. In this talk, we attempt the following two questions: Can we

reconstruct and update a radio map from pilot sequences without precise location labels, and can radio map help reduce pilots for CSI tracking. We will start from an indoor scenario, where we develop a region-based radio map from received signal strength (RSS) measurements without location labels. A signal subspace model with a sequential prior is constructed for the RSS data, and an integrated segmentation and clustering algorithm is developed, which is shown to find the globally optimal solution in a special case. We demonstrate a reduction of region localization error by roughly 50% compared to existing schemes. In the outdoor scenario, we study the problem of radio-map-embedded CSI tracking and radio map construction without the assumptions of stationary CSI statistics and precise location labels. Using radio maps as the prior information, we develop a radio-map-embedded switching Kalman filter (SKF) framework that jointly tracks the location and the CSI with adaptive beamforming for sparse CSI observations under reduced pilots. For radio map construction without precise location labels, the location sequence and the channel covariance matrices are jointly estimated based on a Hidden Markov Model (HMM). An unbiased estimator on the channel covariance matrix is found. Numerical results on ray-traced MIMO channel datasets demonstrate that using 1 pilot in every 10 milliseconds, an average of over 80% of capacity over that of perfect CSI can be achieved for a user moving at 36 km/h at a 20 dB signal-to-noise ratio (SNR). Furthermore, the proposed radio-map-embedded CSI model can reduce the localization error from 30 meters from the prior to 6 meters for radio map construction.

林静然，电子科技大学，中国

Title: Position Recommendation Aided Admission Control and Beamforming for Mobile Users: Stay Here or Move to a Better Position?

Abstract: In this work, we propose a position recommendation aided admission control (PRA-AC) approach to enhance network serving capabilities. Unlike most current admission control studies which merely explore how to efficiently identify the users that should be rejected, PRA-AC further suggests some positions with better communication conditions for them, where the previously-rejected users may be allowed to access the network. To address this, let us consider a network where multiple multi-antenna base stations~(BSs) try to serve multiple single-antenna users. Subject to the constraints of BS transmit power budget and user quality-of-service~(QoS), we optimize the transmit beamformer and the channel with each user jointly to minimize total network power cost, with a sparse penalty evaluating the mismatch between the optimized user channel and the referential channel (the channel with original user position). The non-zero mismatch indicates that the user is inadmissible currently, but may access network after moving to the position with the channel closest to the optimized result. To solve the challenging non-convex problem, we design a penalty dual decomposition~(PDD)-based algorithm that achieves a stationary point efficiently. Numerical results validate that with the help of PRA-AC, most previously-rejected users can re-gain satisfactory

services at the recommended positions.

蔡曙，南京邮电大学，中国

Title: Reconfigurable Intelligent Surface-Enhanced AmBC and Symbiotic Radio Hybrid Systems

Abstract: 本研究提出了一种基于可重构智能表面（RIS）的增强型反向散射通信混合系统。该系统独特地结合了共生无线电（SR）和环境反向散射通信（AmBC）的特性：主接收机（PRx）联合解调主发射机（PTx）和 RIS 反向散射设备（RIS-BDx）的信息；而反向散射接收机（BRx）则通过能量检测器解调 RIS-BDx 的信息。 我们首要解决了系统内 PTx 发射波束赋形（TBF）与 RIS 反射系数（RC）的联合优化问题，目标在于最小化发射功率以满足性能要求。该问题因众多常数模约束和高阶约束而具有挑战性。基于对问题结构的深入挖掘，我们将其分解为包含速率平衡约束的子问题，并设计了一种线性复杂度的交替优化（AO）算法。 进一步，我们拓展算法以解决包含保密速率约束的 TBF-RC 设计问题，保护主信息不被 BRx 解调。这种安全传输需求凸显了该混合系统与传统 SR 系统的关键区别（传统 SR 中 BRx 通常需解调主信息）。 仿真结果有效验证了所提系统和算法的高效性、安全性和低计算复杂度。

张博洋，中国科学院数学与系统科学研究院学，中国

Title: A Gradient Guided Diffusion Framework for Chance Constrained Programming

Abstract: Chance constrained programming (CCP) is a powerful framework for addressing optimization problems under uncertainty. In this paper, we introduce a novel Gradient-Guided Diffusion-based Optimization framework, termed GGDOpt, which tackles CCP through three key innovations. First, GGDOpt accommodates a broad class of CCP problems without requiring the knowledge of the exact distribution of uncertainty—relying solely on a set of samples. Second, to address the nonconvexity of the chance constraints, it reformulates the CCP as a sampling problem over the product of two distributions: an unknown data distribution supported on a nonconvex set and a Boltzmann distribution defined by the objective function, which fully leverages both first- and second-order gradient information. Third, GGDOpt has theoretical convergence guarantees and provides practical error bounds under mild assumptions. By progressively injecting noise during the forward diffusion process to convexify the nonconvex feasible region, GGDOpt enables guided reverse sampling to generate asymptotically optimal solutions. Experimental results on synthetic datasets and a waveform design task in wireless communications demonstrate that GGDOpt outperforms existing methods in both solution quality and stability with nearly 80% overhead reduction.