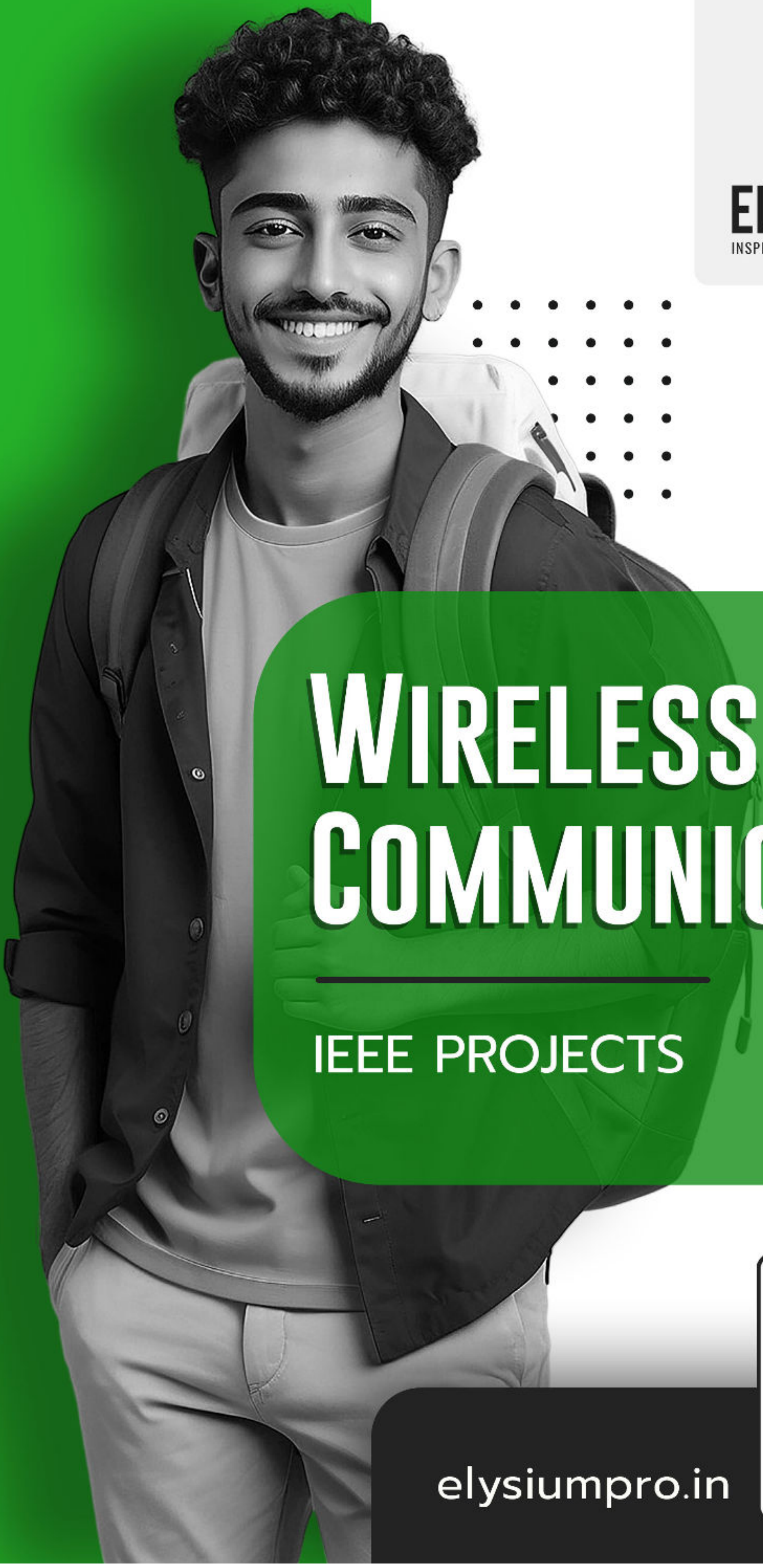
Titles & Abstract

2024- 2025

Advanced Academic Final Year Projects



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EPRO-WC-001

AoI-aware Sensing Scheduling and Trajectory Optimization for Multi-UAV-assisted Wireless Backscatter Networks

This paper considers multiple unmanned aerial vehicles (UAVs) to assist sensing data transmissions from the ground users (GUs) to a remote base station (BS). Each UAV collects sensing data from the GUs and then forwards the sensing data to the remote BS. The GUs frst backscatter their data to the UAVs and then all UAVs forward data to the BS by the nonorthogonal multiple access (NOMA) transmissions. We formulate a multi-stage stochastic optimization problem to minimize the long-term time-averaged age-of-information (AoI) by jointly optimizing the GUs' access control, the UAVs' beamforming, and trajectory planning strategies. To solve this problem, we frst model the dynamics of the GUs' AoI statuses by virtual queueing systems, and then propose the AoI-aware sensing scheduling and trajectory optimization (AoI-STO) algorithm. This allows us to transform the multi-stage AoI minimization problem into a series of per-slot control problems by using the Lyapunov optimization framework.

EPRO-WC-002

AR-RIS-Assisted Communication Radar Coexistence: Analysis and Optimization

It is anticipated that integrated sensing and communication (ISAC) will be a key new technology in wireless communications going forward. Specifically, reciprocal interference severely impairs a communication radar coexistence system. In this work, we propose a simultaneous transmitting and reflecting radar coexistence system with a STAR-RIS to improve communication performance, suppress mutual interference, and provide full space coverage. This is made possible by the advantages of the promising reconfigurable intelligent surface (RIS). In terms of statistical channel state information (CSI), we calculate the feasible rates at the radar and communication receiver side in closed forms, based on the realistic conditions of correlated fading and the existence of numerous user equipments (UEs) at both sides of the RIS. Next, we execute. For both energy splitting (ES) and mode switching (MS) operation protocols, we simultaneously optimise the amplitudes and phase shifts of the STAR-RIS through a projected gradient ascent algorithm (PGAM) with regard to the amplitudes and phase shifts of the surface. The suggested optimisation can be carried out at multiple coherence intervals, which saves sufficient overhead.

EPRO-WC-003

Attacking and Defending Deep-Learning-Based Off-Device Wireless Positioning Systems

This proposed system investigates a new approach to indoor and urban location tracking for wireless devices and ways to trick the system into giving false location information, protecting user privacy, while also exploring methods to defend against such attacks. Develop a new method for indoor and urban location tracking that leverages existing infrastructure (cell towers and Wi-Fi) instead of GPS. Protect user privacy in such a system by proposing methods to intentionally mislead the system and provide false location information, while also investigating ways to defend against these privacy-protecting tricks. This offers advantages indoors but raises privacy concerns since anyone with access to the system could potentially track users.

EPRO-WC-004

Generalized Automatic Modulation Classification for OFDM Systems Under Unseen Synthetic Channels

Automatic modulation classification (AMC) is a crucial technique for the design of intelligent transceivers and has received considerable research attention. Conventional featurebased (FB) methods have the advantage of low computational complexity. However, these methods are highly sensitive to the distribution shifts of the received signal caused by the variation of channel effects and have rarely been studied in orthogonal frequency division multiplexing (OFDM) systems under unseen synthetic channels with multipath fading effects, carrier frequency offset (CFO), phase offset (PO) and additive noise. To solve this problem, this paper proposes a novel FB method using the error vector magnitude (EVM) features for AMC tasks (termed as EVM-AMC), which can achieve reliable classification performance for the communication scenarios considering unseen synthetic channels in OFDM systems. Specifically, we first propose the axisymmetric mapping-based self-circulant differential division (AM-SCDD) algorithm to convert the received signal into the non-negative spectral quotient (NNSQ) sequence, deeply suppressing the synthetic channel effects. Subsequently, we derive the EVM features by analyzing the matched error vectors between the generated NNSQ sequence and the predefined NNSQ constellation symbol (NNSQCS) masks. During this process, a percentile-based filter is utilized to remove the outliers in each matched error vector.

EPRO-WC-005

A Meta-DDPG Algorithm for Energy and Spectral Efficiency Optimization in STAR-RIS-Aided SWIPT

This paper studies a simultaneously transmitting and reflecting reconfigurable intelligent surface (STAR-RIS)-assisted wireless system where a multi-antenna base station (BS) transmits both wireless information and energy-carrying signals to singleantenna users. To explore the trade-off between spectral efficiency (SE) and energy efficiency (EE) in this system, a multi-objective optimization problem (MOOP) is formulated to maximize SE and EE. The beamforming vector at the BS, the power splitting ratio at each user, phase shifts and amplitude coefficients of the STAR-RIS are jointly optimized, subject to the constraints of the maximum transmit power of the BS and the minimum harvested energy of users. To tackle this MOOP, we propose a Meta-DDPG algorithm that combines deep deterministic policy gradient (DDPG) and meta-learning approaches.

EPRO-WC-006

Networked Integrated Sensing and Communications for 6G Wireless Systems

Integrated sensing and communication (ISAC) is envisioned as a key pillar for enabling the upcoming sixth generation (6G) communication systems, requiring not only reliable communication functionalities but also highly accurate environmental sensing capabilities. In this paper, we design a novel networked ISAC framework to explore the collaboration among multiple users for environmental sensing. Specifically, multiple users can serve as powerful sensors, capturing back scattered signals from a target at various angles to facilitate reliable computational imaging. Centralized sensing approaches are extremely sensitive to the capability of the leader node because it requires the leader node to process the signals sent by all the users. To this end, we propose a two-step distributed cooperative sensing algorithm that allows low-dimensional intermediate estimate exchange among neighboring users, thus eliminating the reliance on the centralized leader node and improving the robustness of sensing. This way, multiple users can cooperatively sense a target by exploiting the block-wise environment sparsity and the interference cancellation technique. Furthermore, we analyze the mean square error of the proposed distributed algorithm as a networked sensing performance metric and propose a beamforming design for the proposed network ISAC scheme to maximize the networked sensing accuracy and communication performance subject to a transmit power constraint.

EPRO-WC-007

Frequency-Selective Adversarial Attack Against Deep Learning-Based Wireless Signal Classifiers

For most spectrum sensing applications, deep learning (DL) yields state-of-the-art performance, but it is susceptible to adversarial cases. In light of this fact, we take into a situation of noncooperative communication in which a hacker attempts to identify the type of modulation used in the intercepted signal. This work specifically attempts to reduce the accuracy of the trespasser while ensuring that the intended recipient may still reliably recover the underlying message. Adversarial perturbations are added to the channel input symbols at the encoder to carry out this operation. While in this work, we enriched the meaning of adversarial examples, and first claimed that the imperceptibility of adversarial examples in the field of image classification is constrained to be invisible to a human observer by minimising the l p Filters are imperceptible to wireless communications.

EPRO-WC-008

Experimental Demostration of a MIMO-OFDM Underwater Optical Communication System

Although the underwater optical communication system (UWOC) plays an important role in many marine applications, the acquisition, pointing and tracking (APT) problems are still great challenges in a long or turbid water channel. The Orthogonal Frequency Division Multiplexing (OFDM) and the space-time block coding (STBC) technologies have been introduced in UWOCsystems to improve spectral efficiency and data transmission reliability. On these foundations, a multi-input multi-output (MIMO) mode is proposed and verified in this article to reduce the alignmentrequirement. In experiments, two sets of 450 nm blue laser diodes (LDs) and PIN photodiodes are selected as light sources and receivers, and then parallel light beams are generated and modulatedusing an Alamouti coding for its anti-interference ability. The receiving plane is rotated to simulate the various alignment situations, and the system performance of MIMO-OFDM and single-inputsingle-output OFDM (SISO-OFDM) are compared in tap water and turbid water. The results show that the spatial diversity in MIMO can extend the communication range and its single-sided maximum detection angle range is 92% and 112% higher than the SISO system, respectively.

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EPRO-WC-009

Optimized Routing Protocol Through Exploitation of Trajectory Knowledge for UAV Swarms

Due to its strong ?exibility, easy deployment and extensive connectivity, unmanned aerial vehicle (UAV) swarm has been widely used in emergency communication in recent years, especially in the case when terrestrial communication infrastructures are no longer available. Within a UAV swarm, the design of routing protocol is one of the most challenging problems that enables cooperation among multiple UAVs to perform complex tasks in disaster areas. Nevertheless, the routing protocols reported so far have made the simplifying assumption that the UAV nodes move randomly. In the context of mission-oriented scenarios, such as emergency communication in disaster areas, this assumption appears evidently impractical. On the contrary, for many UAV applications, the trajectories of UAVs are pre-planned in advance through mission planning and trajectory planning.

EPRO-WC-010

Joint Visibility Region and Channel Estimation for Extremely Large-Scale MIMO Systems

In this work, we investigate the joint visibility region (VR) detection and channel estimation (CE) problem for extremely large-scale multiple-input-multiple-output (XL-MIMO) systems considering both the spherical wavefront effect and spatial non-stationary (SnS) property. Unlike existing SnS CE methods that rely on the statistical characteristics of channels in the spatial or delay domain, we propose an approach that simultaneously exploits the antenna-domain spatial correlation and the wavenumber-domain sparsity of SnS channels. To this end, we introduce a two-stage VR detection and CE scheme. In the frst stage, the belief regarding the visibility of antennas is obtained through a VR detection-oriented message passing (VRDOMP) scheme, which fully exploits the spatial correlation among adjacent antenna elements. In the second stage, leveraging the VR information and wavenumber-domain sparsity, we accurately estimate the SnS channel employing the belief-based orthogonal matching pursuit (BB-OMP) method. Simulations show that the proposed algorithms lead to a signifcant enhancement in VR detection and CE accuracy as compared to existing methods, especially in low signal-to-noise ratio (SNR) scenarios.

EPRO-WC-011

A Novel Local and Hyper-Local Multicast Services Transmission Scheme for Beyond 5G Networks

The effciency of the broadcast network is impacted by the different types of services that may be transmitted over it. Global services serve users across the entire network,while local services cater to specifc regions, and hyper-local services have even narrower coverage. Multimedia Broadcast over a Single-Frequency Network (MBSFN) is typically used for global service transmission while existing literature extensively discusses schemes for transmitting local or hyper-local services with or without Single Frequency Network (SFN) gain. However, these schemes fall short when network-wide requests for only local and hyper-local services are made, leading operators to scale down to either Single Cell-Point to Multipoint (SCPtM) or Multi-Frequency Network (MFN). SCPtM is highly susceptible to interference, and MFN requires substantial amounts of valuable spectrum.

EPRO-WC-012

Deep Learning-based Design of Uplink Integrated Sensing and Communication

This Project aim is to design an uplink Integrated Sensing and Communication (ISAC) in 6G wireless networks, focusing on the interplay between sensing echo signals and communication signals. In these networks, signals are received concurrently at the base station (BS). To mitigate interference arising from shared spectrum and hardware resources between sensing and communication functions, we propose a joint design strategy. This strategy aims to maximize the weighted sum of normalized sensing and communication rates. The optimization problem posed is challenging to solve using traditional methods due to its high computational complexity and non-convexity. To improve ISAC performance, we first simplify the design by performing similar transformations on the optimization issue. Then, we develop a deep learning (DL)-based technique. The suggested DL-based system for ISAC in 6G wireless networks is robust and effective, as confirmed by both theoretical analysis and simulation results. For improving the ISAC performance need to customize the system model and then apply NOMA concept for finding the travelling path of the information and then have to apply the deep learning model for the prediction of the system and then finally calculate the error rate for the transmitting and receiving signals.

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EPRO-WC-013

SDOA-Net: An Efficient Deep Learning-Based DOA Estimation Network for Imperfect Array

Electrocardiography (ECG) is a non-invasive tool for predicting cardiovascular diseases (CVDs). Current ECG-based diagnosis systems show promising performance owing to the rapid development of deep learning techniques. However, the label scarcity problem, the co-occurrence of multiple CVDs and the poor performance on unseen datasets greatly hinder the widespread application of deep learning-based models. Addressing them in a unified framework remains a significant challenge. To this end, we propose a multi-label semi-supervised model (ECGMatch) to recognize multiple CVDs simultaneously with limited supervision. In the ECGMatch, an ECGAugment module is developed for weak and strong ECG data augmentation, which generates diverse samples for model training. Subsequently, a hyperparameter-efficient framework with neighbor agreement modeling and knowledge distillation is designed for pseudo-label generation and refinement, which mitigates the label scarcity problem.

EPRO-WC-014

Unleashing Dynamic Pipeline Reconfiguration of P4 Switches for Efficient Network Monitoring

Machine Learning (ML), which is occurring in numerous domains that require effective and efficient data classification, is growing in popularity for network monitoring and control. We can state that ML algorithms are more appropriate for use in the centralised control plane of contemporary networks due to their complexity; nevertheless, they also rely significantly on data, which must be gathered in the data plane. The unavoidable outcome is that there may be a need to move large amounts of data from the data plane to the control plane, which could potentially clog the control communication channel. Designing systems that may minimise the interaction between data and control planes while maintaining acceptable monitoring performance is therefore crucial. By preprocessing traffic data at line rate, the most current generation of data plane programmable switches that support the P4 language can lessen this issue. In this work, we adopt this strategy and suggest P4RTHENON: an architecture that gathers pertinent data in the data plane and mirrors it to the control plane, where sophisticated analysis can be carried out. P4RTHENON reduces the interface between the data and control planes while maintaining high monitoring performance by utilizing P4-native support for runtime data plane pipeline reconfiguration.

EPRO-WC-015

Capacitated Shortest Path Tour-Based Service Chaining Adaptive to Changes of Service Demand and Network Topology

Network service providers have shown a strong interest in using automated network operations that combine software-defined networking (SDN), machine learning (ML), and network functions virtualization (NFV) in order to create sustainable networking. Under resource limitations on nodes and connections, the goal of the service chaining (SC) problem is to build an acceptable service path from an origin node to a destination node where the VNFs are executed at intermediate nodes in the required order. Traffic forwarding between VNFs is made possible by SDN through programmable configurations on forwarding devices, such as switches and routers. We approached the SC problem as an integer linear programme (ILP) in our earlier work using the shortest path tour problem (CSPTP), a more complex form of SPTP with extra limitations on connection and node capacities. In addition, we created Lagrangian heuristics to address the issue by taking into account the trade-off between computational cost and optimality.

EPRO-WC-016

STAR-RIS Aided Secure MIMO Communication Systems

Safeguarding your wireless messages! This research proposes a method to achieve this using a special surface called STAR-RIS. STAR-RIS can both bounce back and transmit radio signals. Beam forming with MMSE (Minimum Mean Square Error) this technique precisely directs the signal from the base station towards the receiver, considering how the STAR-RIS will bounce it back. MMSE ensures the signal reaches the receiver clearly while accounting for the STAR-RIS reflection. Phase Optimization with Majorization-Minimization (MM) this is where the system gets crafty. It separates the reflection properties of each STAR-RIS element into strength (amplitude) and direction (phase). Then, it uses a special MM technique to find the optimal phase shifts for each element. This essentially tailors how the STAR-RIS reflects the signal to weaken it for eavesdroppers but strengthen it for the intended receiver.

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EPRO-WC-017

Towards Real-time Network Intrusion Detection with Image-based Sequential Packets Representation

Innovations in machine learning (ML) and deep learning (DL) have enabled network intrusion detection systems (NIDS) to analyse large amounts of data and identify patterns, which has significantly improved anomaly detection. Either flow-based or packet-based characteristics are used in the training of ML/DL-based NIDS. While packet-based NIDS can analyse data and identify attacks in real-time, flow-based NIDS are best suited for offline traffic analysis. Existing packet-based methods ignore the sequential structure of network communication by analysing packets independently. As a result, biased models with more false positives and negatives are produced. Furthermore, the majority of packet-based NIDS that have been suggested in the literature only record payload data, ignoring important information from packet headers. The identification of header-level attacks, such denial-of-service attacks, may be hampered by this omission.

EPRO-WC-018

Interleaved Training for Massive MIMO Downlink via Exploring Spatial Correlation

Interleaved training is a promising technique for reducing training overhead in massive MIMO systems. This project investigates the influence of channel correlation on interleaved training for single-user massive MIMO downlink. We propose modified beam-domain and antenna-domain interleaved training schemes to optimize training efficiency in correlated channel environments. Analytical expressions for average training length are derived and verified through simulations, providing insights into system performance. Results demonstrate that the proposed schemes significantly reduce training overhead compared to conventional methods.

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EPRO-WC-019

Energy-Efficient Distributed Spiking Neural Network for Wireless Edge Intelligence

Spiking neural networks (SNNs) are particularly appealing for edge intelligence applications where resources are scarce because of their exceptionally low power consumption. This work studies an energy-efficient (EE) distributed SNN in which input is gathered and processed via wireless channels by a number of edge nodes, each of which has a subset of spiking neurons. We define the problem of minimising the energy consumption of edge devices under limited bandwidth and spike loss probability limitations and construct quantitative system models to take advantage of the advantages of the joint design of neuromorphic computing and wireless communications. In particular, a simplified homogeneous SNN is investigated initially, and it is shown that the system has stationary states with a constant firing rate. An approach based on alternating optimisation is then suggested for sharing the computational and communication resources. By using the spike statistics, the techniques are further extended to heterogeneous SNNs.

EPRO-WC-020

FDA-MIMO Transmitter and Receiver Optimization

This project simulates a MIMO-OFDM communication system leveraging 16-QAM modulation to assess its performance and robustness under various conditions. The system includes random binary data generation, convolutional encoding for error correction, and modulation, followed by transmission through a MIMO channel with cyclic prefix to handle inter-symbol interference. At the receiver, the system uses FFT for signal processing, performs channel estimation and equalization, and decodes the transmitted data. The performance is evaluated through key metrics including Bit Error Rate (BER), Signal-to-Noise Ratio (SNR), Packet Error Rate (PER), throughput, Mean Squared Error (MSE), Root Mean Squared Error (RMSE), and Mean Absolute Error (MAE). The analysis provides a comprehensive view of the system's efficiency, reliability, and error characteristics, offering valuable insights into optimizing communication performance in practical scenarios. Additionally, the impact of various optimization algorithms on system performance is explored, highlighting their effects on BER and SNR, which are crucial for enhancing overall communication quality and system robustness. The results aim to inform future developments and improvements in MIMO-OFDM systems for real-world applications.

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EPRO-WC-021

OFDM-Based Active STAR-RIS-Aided Integrated Sensing and Communication System

In recent years, a new technology called Simultaneously Transmitting and Reflecting Reconfigurable Intelligent Surface (STAR-RIS) has gained attention in wireless communication. This technology uses many small devices that can help send and reflect signals, providing better coverage and performance in wireless networks. Our research introduces an advanced version of this technology called Active STAR-RIS (ASTARS), which is part of a system that combines sensing (like radar) and communication (like phone calls or data transfer). The goal is to make both radar detection and communication more efficient. Improving Signal Quality this focus on enhancing the signal-to-noise ratio (SNR), which means we want to make the good signals much clearer compared to the background noise. This helps in detecting objects better and improves how well signals are transmitted. Combining Functions system is designed to work well for both communication (like sending messages) and sensing (like detecting the distance and speed of objects).

EPRO-WC-022

Enhancing Resource Utilization of Non-terrestrial Networks Using Temporal Graph-based

Deterministic routing has emerged as a promising technology for future non-terrestrial networks (NTNs), offering the potential to enhance service performance and optimize resource utilization. However, the dynamic nature of network topology and resources poses challenges in establishing deterministic routing. These challenges encompass the intricacy of jointly scheduling transmission links and cycles, as well as the difficulty of maintaining stable end-to-end (E2E) routing paths. To tackle these challenges, our work introduces an efficient temporal graph-based deterministic routing strategy. Initially, we utilize a time-expanded graph (TEG) to represent the heterogeneous resources of an NTN in a time-slotted manner. With TEG, we meticulously define each necessary constraint and formulate the deterministic routing problem. Subsequently, we transform this nonlinear problem equivalently into solvable integer linear programming (ILP), providing a robust yet time-consuming performance upper bound. To address the considered problem with reduced complexity, we extend TEG by introducing virtual nodes and edges. This extension facilitates a uniform representation of heterogeneous network resources and traffic transmission requirements.

EPRO-WC-023

Robust Resource Allocation for STAR-RIS Assisted SWIPT Systems

A simultaneously transmitting and reflecting reconfigurable intelligent surface (STAR-RIS) assisted simultaneous wireless information and power transfer (SWIPT) system is proposed. More particularly, an STAR-RIS is deployed to assist in the information/power transfer from a multi-antenna access point (AP) to multiple single-antenna information users (IUs) and energy users (EUs), where two practical STAR-RIS operating protocols, namely energy splitting (ES) and time switching (TS), are employed. Under the imperfect channel state information (CSI) condition, a multi-objective optimization problem (MOOP) framework, that simultaneously maximizes the minimum data rate and minimum harvested power, is employed to investigate the fundamental rate-energy trade-off between IUs and EUs. To obtain the optimal robust resource allocation strategy, the MOOP is first transformed into a single-objective optimization problem (SOOP) via the ? -constraint method, which is then reformulated by approximating semi-infinite inequality constraints with the S-procedure.

EPRO-WC-024

Deep Reinforcement Learning for Multi-User RF Charging with Non-linear Energy Harvesters

Radio frequency (RF) wireless power transfer (WPT) is a promising technology for sustainable support of massive Internet of Things (IoT). However, RF-WPT systems are characterized by low efficiency due to channel attenuation, which can be mitigated by precoders that adjust the transmission directivity. This work considers a multi-antenna RF-WPT system with multiple non-linear energy harvesting (EH) nodes with energy demands changing over discrete time slots. This leads to the charging scheduling problem, which involves choosing the precoders at each slot to minimize the total energy consumption and meet the EH requirements. We model the problem as a Markov decision process and propose a solution relying on a low-complexity beamforming and deep deterministic policy gradient (DDPG). The results show that the proposed beamforming achieves near-optimal performance with low computational complexity, and the DDPG-based approach converges with the number of episodes and reduces the system's power consumption, while the outage probability and the power consumption increase with the number of devices.

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EPRO-WC-025

Analysis of IRS-Assisted Downlink Wireless Networks over Generalized Fading

Intelligent Reflecting Surface (IRS) is a communication technology that can control the phase shift and reflection of the incoming signal towards the destination, achieving high spectral efficiency at a low hardware cost. However, the IRS-assisted wireless networks pose fundamental challenges on statistical channel modeling. Communication assisted by the IRS takes the form of a mixture channel, composed of a direct link and cascaded link aided by the IRS, which is often intractable to analyze, requires advanced functions, such as Meijer's G or Fox's H functions, to describe, and only applies to a certain operating frequency or network environment. These limitations motivate the development of a tractable and highly accurate channel model for IRS-assisted wireless networks, but versatile enough to be applied to any frequency band and communication scenario given proper parameterization.

EPRO-WC-026

Enabling Deep Learning-based Physical-layer Secret Key Generation for FDD-OFDM Systems in

Deep learning-based physical-layer secret key generation (PKG) has been used to overcome the imperfect uplink/downlink channel reciprocity in frequency division duplexing (FDD) orthogonal frequency division multiplexing (OFDM) systems. However, existing efforts have focused on key generation for users in a specific environment where the training samples and test samples follow the same distribution, which is unrealistic for real-world applications. This article formulates the PKG problem in multiple environments as a learning-based problem by learning the knowledge such as data and models from known environments to generate keys quickly and efficiently in multiple new environments. Specifically, we propose deep transfer learning (DTL) and meta-learning-based channel feature mapping algorithms for key generation. The two algorithms use different training methods to pre-train the model in the known environments, and then quickly adapt and deploy the model to new environments. Simulation and experimental results show that compared with the methods without adaptation, the DTL and meta-learning algorithms both can improve the performance of generated keys.

EPRO-WC-027

RL-based Relay Selection for Cooperative WSNs in the Presence of Bursty Impulsive Noise

Intelligent Reflecting Surface (IRS) is a communication technology that can control the phase shift and reflection of the incoming signal towards the destination, achieving high spectral efficiency at a low hardware cost. However, the IRS-assisted wireless networks pose fundamental challenges on statistical channel modeling. Communication assisted by the IRS takes the form of a mixture channel, composed of a direct link and cascaded link aided by the IRS, which is often intractable to analyze, requires advanced functions, such as Meijer's G or Fox's H functions, to describe, and only applies to a certain operating frequency or network environment. These limitations motivate the development of a tractable and highly accurate channel model for IRS-assisted wireless networks, but versatile enough to be applied to any frequency band and communication scenario given proper parameterization.

EPRO-WC-028

Control-Oriented Deep Space Communications For Unmanned Space Exploration

In unmanned space exploration, the cooperation among space robots requires advanced communication techniques. In this paper, we propose a communication optimization scheme for a specific cooperation system named the "mother-daughter system". In this setup, the mother spacecraft orbits the planet, while daughter probes are distributed across the planetary surface. During each control cycle, the mother spacecraft senses the environment, computes control commands and distributes them to daughter probes for actions. They synergistically form sensing-communication-computing-control (SC 3) loops. Given the indivisibility of the SC 3 loop, we optimize the mother-daughter downlink for closed-loop control. The optimization objective is the linear quadratic regulator (LQR) cost, and the optimization parameters are the block length and transmit power. To solve the nonlinear mixed-integer problem, we first identify the optimal block length and then transform the power allocation problem into a tractable convex problem. We further derive the approximate closed-form solutions for the proposed scheme and two communication-oriented schemes: the max-sum rate scheme and the max-min rate scheme. On this basis, we analyze their power allocation principles.

EPRO-WC-029

Super-Resolution Estimation of UWB Channels including the Dense Component — An SBL-Inspired Approach

In this paper, we present an iterative algorithmthat detects and estimates the specular components (SCs) andestimates the dense component (DC) of single-input—multipleoutput (SIMO) ultra-wide-band (UWB) multipath channels. Specifically, the algorithm super-resolves the SCs in the delay—angle-of-arrival domain and estimates the parameters of aparametric model of the delay-angle power spectrum characterizing the DC. Channel noise is also estimated. In essence,the algorithm solves the problem of estimating spectral lines(the SCs) in colored noise (generated by the DC and channelnoise). Its design is inspired by the sparse Bayesian learning(SBL) framework. As a result the iteration process contains athreshold condition that determines whether a candidate SC shall beretained or pruned. By relying on results from extreme-valueanalysis the threshold of this condition is suitably adapted toensure a prescribed probability of detecting spurious SCs.

EPRO-WC-030

Frequency-Switchable Routing Protocol for Dynamic Magnetic Induction-Based Wireless

A frequency-switch strategy is introduced into the magnetic induction-based wireless underground sensor network (MI-WUSN) for its high connectivity and network throughput, which then makes routing design more complex and challenging. To this end, we study the frequency-switchable routing design to start a discussion about the high-reliability routing design of MI-WUSN. First, we analyze the frequency-selective property and map the dynamic MI-WUSN into a multilayer network. Then, we take the network throughput and energy consumption into account and formulate the frequency switchable routing decision problem in dynamic MI-WUSN as a constrained optimization problem. Finally, we evaluate how various design parameters of our obtained protocol are affecting the network performance and explore the performance limit.

EPRO-WC-031

A Safe Deep Reinforcement Learning Approach for Energy Efficient Federated Learning

Progressing towards a new era of Artificial Intelligence (AI) -enabled wireless networks, concerns regarding the environmental impact of AI have been raised both in industry and academia. Federated Learning (FL) has emerged as a key privacy preserving decentralized AI technique. Despite efforts currently being made in FL, its environmental impact is still an open problem. Targeting the minimization of the overall energy consumption of an FL process, we propose the orchestration of computational and communication resources of the involved devices to minimize the total energy required, while guaranteeing a certain performance of the model. To this end, we propose a Soft Actor Critic Deep Reinforcement Learning (DRL) solution, where a penalty function is introduced during training, penalizing the strategies that violate the constraints of the environment, and contributing towards a safe RL process.

EPRO-WC-032

Semantic Utility Loss of Information for Energy Efficient Semantic Status Update Communications

Semantic status update communication (SSUC) is envisioned to provide content-aware and energy efficient information delivery. In this paper, we introduce a new metric in the SSUC system, named Semantic Utility Loss (SUL), which captures both age penalty and estimated error for semantic information. By incorporating the knowledge base (KB)-enabled semantic network into a discrete time Markov chain, we investigate the SUL in a time-slotted status update system. The transmitter samples and extracts the semantic information from the physical process, and transmits the status updates. The receiver can update the local KB to keep semantic match with the transmitter and infer or recover the semantic information from received status updates. To minimize the weighted sum of SUL and energy cost incurred by transmitting status update and updating KB, we formulate an infinite horizon average cost Markov Decision Process. We prove that the joint transmission and updating scheduling policy has optimal threshold structure with respect to SUL. Simulation results show that the optimized policy outperforms the zero-wait and sample-at-change policies. Furthermore, we study a practical SSUC application to validate the superiority of proposed framework over the traditional non-semantic status update system in terms of improving the timeliness and reducing the energy consumption.

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EPRO-WC-033

Hybrid Active-Passive RIS Transmitter Enabled Energy-Efficient Multi-User Communications

A novel hybrid active-passive reconfigurable intelligent surface (RIS) transmitter enabled downlink multi-user communication system is investigated. Specifically, RISs are exploited to serve as transmitter antennas, where each element can flexibly switch between active and passive modes to deliver information to multiple users. The system energy efficiency (EE) maximization problem is formulated by jointly optimizing the RIS element scheduling and beamforming coefficients, as well as the power allocation coefficients, subject to the user's individual rate requirement and the maximum RIS amplification power constraint. Using the Dinkelbach relaxation, the original mixed-integer nonlinear programming problem is transformed into a nonfractional optimization problem with a two-layer structure, which is solved by the alternating optimization approach. In particular, an exhaustive search method is proposed to determine the optimal operating mode for each RIS element.

EPRO-WC-034

Privacy and Security in Ubiquitous Integrated Sensing and Communication: Threats, Challenges

Integrated sensing and communication (ISAC) technology is at the forefront of next-generation communication, enhancing applications from intel-ligent transportation to unmanned aerial vehicle surveillance and healthcare through ubiquitous sensing capability. However, the advent of ISAC brings with it a dual-edged challenge. While it opens up new avenues for application, it also raises significant concerns regarding the privacy of sensitive data and the security of systems in an inherently open environment. To navigate these challenges and unlock ISAC's full potential, this article starts with an analysis of the underlying factors that contribute to privacy and security vulnerabilities. It also identifies the technical obstacles that stand in the way of achieving a secure and private ISAC ecosystem within the confines of conventional network frameworks. As a solution, we introduce a security and privacy-preserving network (SPPN), designed to mitigate these potential threats and tackle the technical challenges through a secure framework for information handling and collaborative efforts among trusted parties, ISAC operators, and users

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EPRO-WC-035

Decentralized Federated Learning: A Survey on Security and Privacy

Federated learning has been rapidly evolving and gaining popularity in recent years due to its privacy-preserving features, among other advantages. Nevertheless, the exchange of model updates and gradients in this architecture provides new attack surfaces for malicious users of the network which may jeopardize the model performance and user and data privacy. For this reason, one of the main motivations for decentralized federated learning is to eliminate server-related threats by removing the server from the network and compensating for it through technologies such as blockchain. However, this advantage comes at the cost of challenging the system with new privacy threats. Thus, performing a thorough security analysis in this new paradigm is necessary. This survey studies possible variations of threats and adversaries in decentralized federated learning and overviews the potential defense mechanisms. Trustability and verifiability of decentralized federated learning are also considered in this study.

EPRO-WC-036

Benefits of V2V communication in connected and autonomous vehicles in the presence of delays in

In this paper, we investigate the effect of signal delay in communicated information in connected and autonomous vehicles. In particular, we relate this delay's effect on the selection of the time headway in predecessor-follower type vehicle platooning with a constant time headway policy (CTHP). We employ a CTHP control law for each vehicle in the platoon by considering two cases: cooperative adaptive cruise control (CACC) strategy where information from only one predecessor vehicle is employed and CACC+ where information from multiple predecessor vehicles is employed. We investigate how the lower bound on the time headway is affected by signal transmission delay due to wireless communication. We provide a systematic approach to the derivation of the lower bound of the time headway and selection of the appropriate CTHP controller gains for predecessor acceleration, velocity error and spacing error which will ensure robust string stability of the platoon under the presence of signal delay. We corroborate the main result with numerical simulations.

EPRO-WC-037

DeepSense-V2V: A Vehicle-to-Vehicle Multi-Modal Sensing, Localization, and Communications Dataset

High data rate and low-latency vehicle-to-vehicle (V2V) communication are essential for future intelligent transport systems to enable coordination, enhance safety, and support distributed computing and intelligence requirements. Developing effective communication strategies, however, demands realistic test scenarios and datasets. This is important at the high-frequency bands where more spectrum is available, yet harvesting this bandwidth is challenged by the need for direction transmission and the sensitivity of signal propagation to blockages. This work presents the first large-scale multi-modal dataset for studying mmWave vehicle-to-vehicle communications. It presents a two-vehicle testbed that comprises data from a 360-degree camera, four radars, four 60 GHz phased arrays, a 3D lidar, and two precise GPSs. The dataset contains vehicles driving during the day and night for 120 km in intercity and rural settings, with speeds up to 100 km per hour.

EPRO-WC-038

A Dynamic and Efficient Self-Certified Authenticated Group Key Agreement Protocol for

Authenticated group key agreement (AGKA) protocols protect the security of communications among a group of users. Dutta and Barua proposed a dynamic AGKA protocol, but it fails to the leaving user attacks and the attacks by two malicious users. In this paper, we propose a dynamic AGKA protocol based on the computational Diffie-Hellman problem. The proposed AGKA protocol achieves sound dynamicity and efficiency. With 10 users in a group, the improvements in computation and communication overheads achieve 82.5% and 72.6 %, respectively. Then the proposed AGKA protocol is applied to vehicular ad hoc network (VANET). SC-AGKA, a self-certified authentication and key agreement protocol for VANET is presented. Pseudonyms are employed with care in SC-AGKA to provide conditional privacy. It is suitable for SC-AGKA to protect the vehicular group communications in VANET considering its security strength and efficiency.

EPRO-WC-039

Dynamic Cooperative MAC Optimization in RSU-Enhanced VANETs: A Distributed Approach

This paper presents an optimization approach for cooperative Medium Access Control (MAC) techniques in Vehic-ular Ad Hoc Networks (VANETs) equipped with Roadside Unit (RSU) to enhance network throughput. Our method employs a distributed cooperative MAC scheme based on Carrier Sense Multiple Access with Collision Avoidance (CSMA/CA) protocol, featuring selective RSU probing and adaptive transmission. It utilizes a dual timescale channel access framework, with a "large-scale" phase accounting for gradual changes in vehicle locations and a "small-scale" phase adapting to rapid channel fluctuations. We propose the RSU Probing and Cooperative Access (RPCA) strategy, a two-stage approach based on dynamic inter-vehicle distances from the RSU. Using optimal sequential planned decision theory, we rigorously prove its optimality in maximizing average system throughput per large-scale phase. For practical implementation in VANETs, we develop a distributed MAC algorithm with periodic location updates.

EPRO-WC-040

Intelligent Reflecting Surfaces Assisted Cellular V2X based Open RAN Communications

Open radio access networks (RAN) enhance the capabilities of traditional RAN by introducing features such as interoperability, open interfaces, software/hardware separation, and intelligence. Open RAN has several use cases in cellular vehicle-to-everything communications such as low-latency information exchange between vehicles and RAN intelligence controller (RIC). However, efficient data sharing between vehicles and RIC suffers from the challenges of signal loss due to mobility and dynamic channel conditions. In this regard, intelligent reflecting surfaces (IRS) have emerged as an intriguing concept of reconfigurable and smart environments to improve the performance of wireless communication systems. In the proposed research, our main focus is on a multi-IRS aided single input single output system, where open RAN base stations (BS) convey information to a remote vehicular user. The transmitted signal is reflected by IRSs via multi-hop passive beamforming over pairwise line-of-sight links. To maximize the overall network sum-rate, we propose an IRS assignment method that allocates either a single IRS or multiple IRSs to each BS-user pair.

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EPRO-WC-041

Performance Characterization of Joint Communication and Sensing with Beyond 5G NR-V2X Sidelink

Joint communication and sensing allows to share frequency spectrum, hardware, and signal processing blocks between communication and sensing, providing new radar functionalities through the exploitation of communication signals. This is becoming an important trend also in vehicular communications, where future standardized technologies for connected vehicles can be used to detect targets nearby without overloading the already scarce spectrum with dedicated radar signals. Objective of this paper is to characterize the performance of 5G new radio (NR) vehicle-to-everything (V2X) sidelink, in terms of lower bounds for sensing purposes; specifically, we evaluate the impact of physical and radio access communication parameters on the sensing performance in terms of detection capability and parameter estimation quality. As a result, it is shown how the effect of the presence of multiple vehicles in the scenario, and the inherent resource allocation policies, have a non-negligible impact on the communication and sensing performance.

EPRO-WC-042

End-to-End Autonomous Driving through V2X Cooperation

Cooperatively utilizing both ego-vehicle and infrastructure sensor data via V2X communication has emerged as a promising approach for advanced autonomous driving. However, current research mainly focuses on improving individual modules, rather than taking end-to-end learning to optimize final planning performance, resulting in underutilized data potential. In this paper, we introduce UniV2X, a pioneering cooperative autonomous driving framework that seamlessly integrates all key driving modules across diverse views into a unified network. We propose a sparse-dense hybrid data transmission and fusion mechanism for effective vehicle-infrastructure cooperation, offering three advantages: 1) Effective for simultaneously enhancing agent perception, online mapping, and occupancy prediction, ultimately improving planning performance. 2) Transmission-friendly for practical and limited communication conditions. 3) Reliable data fusion with interpretability of this hybrid data. We implement UniV2X, as well as reproducing several benchmark methods, on the challenging DAIR-V2X, the real-world cooperative driving dataset.

EPRO-WC-043

Unified End-to-End V2X Cooperative Autonomous Driving

V2X cooperation, through the integration of sensor data from both vehicles and infrastructure, is considered a pivotal approach to advancing autonomous driving technology. Current research primarily focuses on enhancing perception accuracy, often overlooking the systematic improvement of accident prediction accuracy through end-to-end learning, leading to insufficient attention to the safety issues of autonomous driving. To address this challenge, this paper introduces the UniE2EV2X framework, a V2X-integrated end-to-end autonomous driving system that consolidates key driving modules within a unified network. The framework employs a deformable attention-based data fusion strategy, effectively facilitating cooperation between vehicles and infrastructure. The main advantages include: 1) significantly enhancing agents' perception and motion prediction capabilities, thereby improving the accuracy of accident predictions; 2) ensuring high reliability in the data fusion process; 3) superior end-to-end perception compared to modular approaches. Furthermore, We implement the UniE2EV2X framework on the challenging DeepAccident, a simulation dataset designed for V2X cooperative driving.

EPRO-WC-044

Virtual Sensor for Real-Time Bearing Load Prediction Using Heterogeneous Temporal Graph Neural Networks

Accurate bearing load monitoring is essential for their Prognostics and Health Management (PHM), enabling damage assessment, wear prediction, and proactive maintenance. While bearing sensors are typically placed on the bearing housing, direct load monitoring requires sensors inside the bearing itself. Recently introduced sensor rollers enable direct bearing load monitoring but are constrained by their battery life. Data-driven virtual sensors can learn from sensor roller data collected during a batterys lifetime to map operating conditions to bearing loads. Although spatially distributed bearing sensors offer insights into load distribution (e.g., correlating temperature with load), traditional machine learning algorithms struggle to fully exploit these spatial-temporal dependencies. To address this gap, we introduce a graph-based virtual sensor that leverages Graph Neural Networks (GNNs) to analyze spatial-temporal dependencies among sensor signals, mapping existing measurements (temperature, vibration) to bearing loads.

EPRO-WC-045

FDA-MIMO Transmitter and Receiver Optimization

This paper addresses the joint design of the transmit parameters (i.e., radar code/frequency increments) and the receive filter in a Frequency Diverse Array (FDA)-Multiple-Input Multiple-Output (MIMO) radar system. The operating environment includes clutter, namely signal-dependent interference tied up to the FDA transmitted waveforms and the antenna array features, along with conventional thermal noise. The chosen optimization policy relies on the constrained maximization of the Signal-to-Interference-plus-Noise Ratio (SINR) which for Gaussian interference is tantamount to maximizing the radar detection performance. In this context, a bespoke Minorization-Maximization (MM)-Maximum Block Improvement (MBI) algorithm is proposed to tackle the resulting constrained non-convex optimization problem. The convergence properties of the resulting procedure are rigorously proven, along with a thorough investigation of the computational complexity for its implementation. Finally, numerical results are provided to show the effectiveness of the new technique under diverse clutter scenarios of practical relevance and in comparison with some counterparts.

EPRO-WC-046

Integrated Sensing and Communication with Massive MIMO: A Unified Tensor Approach for

Benefitting from the vast spatial degrees of freedom, the amalgamation of integrated sensing and communication (ISAC) and massive multiple-input multiple-output (MIMO) is expected to simultaneously improve spectral and energy efficiencies as well as the sensing capability. However, a large number of antennas deployed in massive MIMO-ISAC raises critical challenges in acquiring both accurate channel state information and target parameter information. To overcome these two challenges with a unified framework, we first analyze their underlying system models and then propose a novel tensor-based approach that addresses both the channel estimation and target sensing problems. Specifically, by parameterizing the high-dimensional communication channel exploiting a small number of physical parameters, we associate the channel state information with the sensing parameters of targets in terms of angular, delay, and Doppler dimensions.

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EPRO-WC-047

Exploiting Active RIS in NOMA Networks with Hardware Impairments

Active reconfigurable intelligent surface (ARIS) is a promising way to compensate for multiplicative fading attenuation by amplifying and reflecting event signals to selected users. This paper investigates the performance of ARIS assisted non-orthogonal multiple access (NOMA) networks over cascaded Nakagami-m fading channels. The effects of hardware impairments (HIS) and reflection coefficients on ARIS-NOMA networks with imperfect successive interference cancellation (ipSIC) and perfect successive interference cancellation (pSIC) are considered. More specifically, we develop new precise and asymptotic expressions of outage probability and ergodic data rate with ipSIC/pSIC for ARIS-NOMA-HIS networks. According to the approximated analyses, the diversity orders and multiplexing gains for couple of non-orthogonal users are attained in detail. Additionally, the energy efficiency of ARIS-NOMA-HIS networks is surveyed in delay-limited and delay-tolerant transmission schemes.

EPRO-WC-048

Covert Communication of STAR-RIS Aided NOMA Networks

This article investigates covert communication in simultaneously transmitting and reflecting reconfigurable intelligent surface (STAR-RIS) assisted non-orthogonal multiple access (NOMA) systems, assuming for the sake of being more practical that the successive interference cancellation (SIC) is defective. To assess the covertness performance of the considered system, we first derive closed-form expressions for the detection error probability, the optimal judgment threshold and the average minimum detection error probability of the warden, as well as the outage probability of the NOMA user pair. Then an optimization problem to maximize the effective covert rate (ECR) is proposed. Simulation results verify that the maximum ECR of the considered system could be increased by varying the different proportions of transmission and reflection components of the STAR-RIS.

EPRO-WC-049

Finite SNR Diversity-Multiplexing Trade-off in Hybrid ABCom/RCom-Assisted NOMA Systems

Active reconfigurable intelligent surface (ARIS) is a promising way to compensate for multiplicative fading attenuation by amplifying and reflecting event signals to selected users. This paper investigates the performance of ARIS assisted non-orthogonal multiple access (NOMA) networks over cascaded Nakagami-m fading channels. The effects of hardware impairments (HIS) and reflection coefficients on ARIS-NOMA networks with imperfect successive interference cancellation (ipSIC) and perfect successive interference cancellation (pSIC) are considered. More specifically, we develop new precise and asymptotic expressions of outage probability and ergodic data rate with ipSIC/pSIC for ARIS-NOMA-HIS networks. According to the approximated analyses, the diversity orders and multiplexing gains for couple of non-orthogonal users are attained in detail. Additionally, the energy efficiency of ARIS-NOMA-HIS networks is surveyed in delay-limited and delay-tolerant transmission schemes.

EPRO-WC-050

Achievable Rate Analysis of Intelligent Omni-Surface Assisted NOMA Holographic

This article investigates covert communication in simultaneously transmitting and reflecting reconfigurable intelligent surface (STAR-RIS) assisted non-orthogonal multiple access (NOMA) systems, assuming for the sake of being more practical that the successive interference cancellation (SIC) is defective. To assess the covertness performance of the considered system, we first derive closed-form expressions for the detection error probability, the optimal judgment threshold and the average minimum detection error probability of the warden, as well as the outage probability of the NOMA user pair. Then an optimization problem to maximize the effective covert rate (ECR) is proposed. Simulation results verify that the maximum ECR of the considered system could be increased by varying the different proportions of transmission and reflection components of the STAR-RIS.

EPRO-WC-051

Power-Level-Design-aware Scalable Framework for Throughput Analysis of GF-NOMA in mMTC

This paper proposes a scalable framework to analyze the throughput of the grant-free power-domain nonorthogonal multiple access (GF-NOMA) and presents the achievable performance in the optimized offered load at each power level (called per-level offered load) by using our framework. Our analytical model reflects packet errors caused by power collisions, characterized by GF-NOMA, based on the power level design guaranteeing the required signal-to-interference-and-noise ratio (SINR). This key idea enables analyzing the throughput of a large-scale GF-NOMA system more accurately than the existing analytical models. Also, this key idea enables optimizing the per-level offered load rather than a uniform one in typical optimization problems related to the throughput: the throughput maximization or energy minimization problem with a throughput condition. Our analytical results highlight some key insights into designing future access control methods in GF-NOMA. First, our analytical model achieves an approximation error of only 0.4% for the exact throughput obtained by the exhaustive search at five power levels; the existing analytical model provides an approximation error of 25%. Next, our proposed framework highlights that the optimal per-level offered load restrictively improves the