CSNDSP2026

Conference »Program

2026 15th International Symposium on Communication Systems, Networks and Digital Signal Processing (CSNDSP) Program

Wednesday, July 15

Wednesday, July 15 8:45 - 9:10

Opening Session

Room: Pentland

Wednesday, July 15 9:10 - 10:00

Plenary Talk 01: Prof. Muhammad Imran,"Towards 6G: Advances in Wireless Communications and Signal Processing"

Room: Pentland

Wednesday, July 15 10:00 - 11:00

Coll1-01: Free Space Optics

Room: Prestonfield

Measurement of the Turbulent Channel Superoperator Acting on Single-Photon Polarization States Employing Quantum Process Tomography

Carlos Guerra-Yánez (Czech Technical University, Czech Republic); Tomáš Novák (Czech Technical University in Prague, Czech Republic); Dong Nhat Nguyen (TNO, The Netherlands); Zabih Ghassemlooy (Northumbria University, United Kingdom (Great Britain)); Josef Vojtech (CESNET, a.l.o., Czech Republic); Stanislav Zvanovec (Czech Technical University in Prague, Czech Republic)

Quantum process tomography (QPT) allows for the estimation of the quantum superoperator by performing multiple measurements using different input states. In this work, we estimate the superoperator that characterizes free-space propagation through atmospheric turbulence. For that, we propose the use of a fiber-based projective measurement station and a heralded single photon source to implement a proof-of-concept QPT device. We present a theoretical analysis of the setup and perform an experimental QPT of the atmospheric turbulence quantum channel acting on the polarization state for 5 different turbulence conditions. Our tests conclude that turbulence has a negligible impact on the polarization state of the photons transmitted through the channel, obtaining a probability for the identity operator close to 95% in all the turbulence conditions measured.

Quantum Key Distribution over Free Space Optical Satellite Links in the 6G Era

Vasilis K. Papanikolaou (Friedrich-Alexander-University Erlangen-Nuremberg, Germany); Alexis Alfredo Dowhuszko (Aalto University, Finland); Mate Galambos (Budapest University of Technology

and Economics, Hungary); Carlos Guerra-Yánez (Czech Technical University, Czech Republic); Henrique M Salgado (University of Porto & INESC Porto, Portugal); Goran T Đorđević (University of Nis, Serbia); Philipp Kleinpaß (German Aerospace Center (DLR), Germany); Niek Doelman (TNO High-Tech Industry, The Netherlands)

Satellite-based free-space optical links can act as time-varying optical wireless interconnects that distribute quantum resources across space-terrestrial infrastructures, complementing the 6G vision of integrated non-terrestrial networks. Among quantum communication services, Quantum Key Distribution (QKD) is the most mature and is therefore adopted as an illustrative use case. This paper develops an attenuation-centric framework for satellite QKD based on weak-coherent-pulse BB84. The considered system model links orbital geometry and optical terminal parameters to an equivalent channel transmissivity, which governs detection statistics, quantum bit error rate (QBER), and secret key generation through secrecy bounds. We derive the secret-fraction cutoff behavior with respect to channel attenuation and show how it induces time-dependent secret key rates during satellite overpasses. Numerical results using orbital data and representative parameters from the 'Micius' mission show that the minimum slant range over the one-month observation window spans approximately 400-2400 km; approximately 34% of passes have minimum slant ranges below 900 km, and favorable passes yield secret key rates on the order of a few kbps. The proposed modeling approach provides a link-level building block for future network-level studies, where scheduling and routing of quantum-secured services can be informed by predicted key generation windows over satellite optical interconnects.

Flat-Earth Model Accuracy for Turbulence Effects in Optical Space-Ground Links

Agustin E Gonzalez Uriarte (Ecole Centrale Méditerranée, France & FCFM, Chile); Ali Khalighi (Ecole Centrale Méditerranée, France); Nicolas Perlot (Fraunhofer Heinrich-Hertz Institute, Germany)

Free-space optical communication is emerging as a key technology for space-ground links due to its potential to support extremely high data rates. However, atmospheric turbulence remains a major impairment, significantly degrading link reliability and performance. Accurate modeling of turbulence effects in an analytically tractable way is therefore essential for the design and evaluation of these systems. This paper investigates the impact of Earth modeling assumptions on the estimation of key turbulence-related parameters. Specifically, we compare the widely used flat-Earth approximation with a more accurate round-Earth model. Established analytical expressions from the literature are employed for the flat-Earth case and extended to the round-Earth geometry. Through comprehensive numerical analysis, we evaluate the accuracy of both models in predicting parameters such as the scintillation index, Fried parameter, and isoplanatic angle. The results show that the flat-Earth approximation provides accurate estimates for low zenith angles, making it suitable for preliminary analysis and certain operational scenarios. However, for zenith angles exceeding approximately 60°, significant discrepancies arise between the two models, and even, the flat-Earth model may exhibit non-physical behavior. These findings highlight the importance of adopting a round-Earth model for accurate performance evaluation of optical space links at high zenith angles.

Robustness of Quantum Trellis-Coded Modulation for Intra-Satellite Communications Under Radiation and Burst Noise

Sebastián Seguel and Ismael Soto (University of Santiago, Chile); Arun Majumdar (San Diego Consulting, USA)

The reliability of intra-satellite data buses is critical for operation in high-radiation environments, where current standards such as SpaceWire and block codes like Reed-Solomon (RS) exhibit significant inefficiencies under burst-error conditions and short telecommand traffic. This work develops a theoretical framework for Quantum Trellis-Coded Modulation (QTCM) as a resilient optical bus architecture. Simulations conducted over a Gilbert-Elliot channel model indicate that entanglement distributed memory improves structural robustness, yielding an estimated sustained 25% reduction in Bit Error Rate (BER) under severe degradation scenarios representative of the South Atlantic Anomaly.

Comparative analysis further shows that QTCM can achieve up to 4.5× higher bandwidth efficiency than RS for 32-bit telecommands while maintaining marginal deterministic latency below 5 µs, enabling applicability to high frequency Attitude and Orbit Control Systems (AOCS). Finally, a hybrid FPGA-photonic implementation based on Silicon Nitride (SiN) technology is proposed, demonstrating compatibility with strict Size, Weight, and Power (SWaP) constraints through a theoretically estimated 44% optical power reduction.

Secret-Key Generation Scheme Controlled by Atmospheric Turbulence, Background Radiation, and Pointing Error

Ivan B. Djordjevic (Florida State University, USA); Goran T Đorđević (University of Nis, Serbia)

In our previous works, we showed that cryptosystems controlled by random scintillation fluctuations caused by atmospheric turbulence can overcome the limitations present when quantum key distribution (QKD) and post-quantum cryptography (PQC) are applied. We demonstrated that these systems can be superior to QKD and PQC in terms of the secret-key rate (SKR). In this paper, we compare performance of a modified secret-key generation (SKG) scheme with a conventional physical-layer security (PLC) scheme in the presence of a beam wandering effect. These pointing errors are not taken into account during the initialization process; instead, their effect on the secret-key capacity (SKC) is analyzed after the initialization process. Using coherent balanced detection as an example, we demonstrate that the modified SKG scheme can achieve significantly higher SKC values compared to the conventional PLC schemes. For sufficiently high SNR, the SKC of conventional PLC is improved by beam wandering effect. In the case of modified SKG scheme, the degradation of SKC for large pointing errors is substantial. For SNR of 25 dB, if the standard deviation of misalignment increases from 0 cm (perfect alignment) to 15 cm, the SKC decreases from 8.2 bit/s/Hz/dim. to 2.8 bit/s/Hz/dim.

Wednesday, July 15 10:00 - 11:00

GT-01: DSP for Biomedical applications

Room: Pentland East

Real-Time Visual Fatigue Monitoring System via Facial Landmark Analysis and Blink Rate Tracking

Lídices Reyes-Hung (University of Santiago of Chile & Centre for Multidisciplinary Research in Telecommunication Technologies, Chile); Benjamin San-Martin (Universidad de Santiago de Chile, Chile); Ismael Soto (University of Santiago, Chile)

Screen-induced visual fatigue has emerged as a significant health concern in the digital age, marked by a notable reduction in blink rate during sustained cognitive tasks. This study details the development of a cost-effective, non-invasive system for real-time detection of ocular strain and drowsiness. Utilizing facial landmark extraction, the system calculates the eye aspect ratio to monitor and quantify blink frequency per minute. Bibliometric analysis reveals an exponential increase in research activity in this domain, underscoring its clinical and ergonomic importance. Experimental results indicate that blink frequency declines to critical levels, ranging from 7 to 15 blinks per minute, during periods of intense digital engagement. To address this issue, an automated early-warning system was implemented to deliver user notifications and promote behavioral modifications, thereby reducing the risk of computer vision syndrome.

Accelerometric Data Functional Decomposition for Motion Symmetry Evaluation

Ales Prochazka (Univ Chem & Technol Prague, Czech Republic); Tereza Tumová (University of Chemistry and Technology, Czech Republic); Irena Šindelářová (Czech Technical University, Czech

Republic); Hana Charvatova (UTB Zlin, Czech Republic); Oldrich Vysata (Faculty Hospital Hradec Kralove, Czech Republic); Vladimír Mařík (Czech Technical University, Czech Republic)

Evaluation of motion symmetry is an important aspect of rehabilitation, fitness monitoring, and the detection of neurological disorders. In the simplest case, objective assessment of movement can be performed through the analysis of accelerometric data acquired by a single accelerometer. This paper presents a methodology for data acquisition using a wearable sensor embedded in a smartphone, wireless signal transmission, and subsequent computational analysis based on spectral analysis and wavelet decomposition at a selected level. The proposed methodology is applied to the estimation of gait symmetry using data collected during walking along a selected route. The study focuses on the analysis of motion data relevant to the detection of stability disorders associated with neurological problems, with the aim of providing additional information for biomedical specialists. Symmetry estimation is performed by analyzing the ratio of energy in selected frequency regions and in wavelet bands corresponding to odd and even steps during walking, combined with artificial intelligence techniques. Neural networks provided the best performance in distinguishing left and right steps, achieving an accuracy higher than 90%. The results demonstrate the potential of computational intelligence for the detection of specific neurological disorders and for diagnostic support in clinical practice. In addition, the proposed general tools may also find applications in engineering and robotics.

Early Diagnosis of Neurodegenerative Diseases Using Video-Oculography

Batuhan Yilmaz (Galatasaray University, Turkey); Lejla Koric (Institut of Neuroscience Timone, Marseille, France); Mouloud Adel (Universite Aix-Marseille, France)

Video-oculography (VOG) provides a fast, non-invasive way to quantify eye-movement and pupil responses linked to how the brain samples and interprets visual information. We propose a task-free, emotionally valenced viewing paradigm for automatic screening of neurodegenerative disorders. Participants freely viewed a curated set of IAPS (International Affective Picture System) images spanning positive/negative/neutral valence and face/object content while gaze and pupil signals were recorded. From these recordings, we derived compact oculomotor and pupillary descriptors that capture spatial viewing allocation, eye movements, pupil dynamics, and frequency dynamics, and used them to discriminate healthy controls from amnestic mild cognitive impairment (aMCI), behavioral-variant frontotemporal dementia (bvFTD), and posterior cortical atrophy (PCA). Best configurations achieved mean subject-level accuracies of 0.871±0.085 for healthy controls (CTR) versus aMCI, 0.817±0.060 for CTR versus bvFTD, and 0.786±0.060 for CTR versus PCA, supporting affect-sensitive free-viewing VOG as a low-burden complementary screening signal.

Learning Entropy with ICA Preprocessing for Assessment of Postural Instability in Stroke: A Pilot Study

Oldrich Vysata (Faculty Hospital Hradec Kralove, Czech Republic); Libuše Smetanová, Berenika Lenta Guðbjartsdóttir and David Matyáš (University Hospital in Hradec Králové, Czech Republic); Hasan Dizman (Istanbul Arel University, Turkey); Ales Prochazka (Univ Chem & Technol Prague, Czech Republic)

This pilot study investigates Learning Entropy (LE) combined with Independent Component Analysis (ICA) for assessing postural instability in stroke survivors. Triaxial gyroscope data were recorded from a C7-mounted IMU during four stance tasks in 42-47 stroke patients and 9-10 healthy controls (counts vary by condition due to one incomplete healthy-control session and exclusion of recordings shorter than 5 s; see Methods). The normalized Learning Entropy of the Model rate (LEM/N) was computed using an adaptive LMS predictor on 5-s windows. We compared (1) direct LE on raw channels versus (2) LE on spectrally-sorted ICA components. The ICA+LE approach consistently yielded higher effect sizes (Cohen's d = 0.44-0.75) than direct LE (d = 0.11-0.66), with the best discrimination in narrow-base eyes-open standing (2stand, IC1: d = 0.69, area under the receiver operating characteristic curve (AUC) = 0.75, p = 0.013). Although no comparisons survived FDR correction, partly attributable to the small control group, sensitivity analysis confirmed the robustness of the effect direction (Stroke > Healthy).

These preliminary results suggest that ICA preprocessing enhances LE-based postural assessment, improving discrimination of pathological sway dynamics.

CT Windowing and Explainability in Detection of Pulmonary Embolism from CTPA

Deep Ashish Jariwala and Kshirasagar Naik (University of Waterloo, Canada)

Pulmonary embolism (PE) is a life-threatening obstruction of the pulmonary arteries that requires early diagnosis to prevent hemodynamic collapse and death. Computed tomography pulmonary angiography (CTPA) is the clinical gold standard for PE detection, and deep learning methods have shown promise for automated triage. However, most prior work emphasize network architectures, while the role of CT (Computed Tomography) preprocessing-particularly window-level/window-width (WL/WW) transformations-is less studied despite its clinical importance in radiology. We conduct a controlled study to evaluate how CT preprocessing pipelines, ranging from a HU (Hounsfield Units)-normalized grayscale baseline to eight clinically inspired multi-window pseudo-RGB fusion strategies, affect slice-level PE classification and gradient-based interpretability. Using a fixed DenseNet121 model and identical data splits across all variants, preprocessing is isolated as the sole experimental variable. While performance differences are modest, Grad-CAM and saliency maps exhibit substantial and systematic variation across windowing strategies, revealing shifts in attention and sensitivity within pulmonary vascular regions. These results demonstrate that CT preprocessing materially influences the visual rationale underlying model predictions, motivating preprocessing-aware interpretability for clinically trustworthy AI systems.

Wednesday, July 15 10:00 - 11:00

SS01-01: Integrated Sensing and Communications for 6G

Room: Pentland West

Periodogram Characterization for Blind Cyclostationary Analysis of LFM-ISAC Waveforms

Shreesh Mohalik and Ahmet Burak Ozyurt (University of Edinburgh, United Kingdom (Great Britain)); John Thompson (University of Edinburgh & Univ of Edinburgh, United Kingdom (Great Britain))

Periodogram-based techniques are widely used for blind signal parameter estimation, yet most existing works apply them heuristically without an analytical characterization of the resulting spectral statistics. Such blind estimation, performed without prior knowledge of transmission parameters, is particularly relevant for integrated sensing and communications (ISAC) systems that leverage linear frequency modulated (LFM) waveforms embedded with M-ary phase-shift keying (MPSK) symbols. Despite the widespread use of periodogram-based processing for tasks such as symbol rate estimation and constellation classification in these systems, a theoretical formulation of the periodogram for symbol-embedded LFM waveforms is largely unexplored. To address this gap, this study presents a closed-form analytical derivation of the mean periodogram for LFM-MPSK signals, explicitly accounting for additive noise, unsynchronized observation, flat fading, and random symbol sequences. The resulting expression enables direct characterization of spectral features associated with embedded communication parameters. As an illustrative example, a closed-form approximation for the probability of correct symbol rate detection is derived using the proposed periodogram model. Simulation results validate the analysis and demonstrate the effectiveness of the formulated periodogram for blind parameter estimation across a wide range of signal-to-noise ratios.

Ultra-Fast Device-Free Visible Light Sensing and Localization via Reflection-Based ΔRSS and Deep Learning

Helena Serpi (Department of Materials Science, University of Patras, Greece); Tanya Politi (University of Patras, Greece)

We propose an Ultra-Fast in terms of real-time inference latency, Device-Free Visible Light Sensing and Positioning system based on received signal strength (RSS) measurements in indoor visible light communication (VLC) environments. A single LED transmitter and a ceiling-mounted photodetector array are used to capture human-induced perturbations of the optical Radio Environment Map (REM) through reflection-based ΔRSS profiles. The proposed approach operates entirely in the power domain and does not perform channel estimation or channel impulse response reconstruction; instead, localization is achieved by learning an inverse mapping from REM perturbations to spatial position. A multi-architecture deep neural network ensemble is trained offline to exploit complementary spatial and cross-sensor characteristics of the RSS fingerprints. The innovative system is evaluated in a fixed indoor environment with a single target, demonstrating mean positioning errors below 10 cm for walking trajectory and approximately 10-11 cm for randomly sampled positions, while achieving millisecond-scale inference latency suitable for real-time edge deployment. The system is highly adaptive and ready to serve different real-world sensing and positioning scenarios using one or more ML based models from the library of multi-architecture deep neural network ensembles we have developed.

A Deployment-Oriented Perspective on Terahertz 6G Systems Within 6G-TERAFIT

Christos Tselios, Vassilis Tsakanikas, Georgios Alogdianakis, Angelos Smyrilios and Theodoros Skandamis (University of Peloponnese, Greece); Hemalatha Vulchi (Universidad Carlos III de Madrid, Spain & IT - Instituto de Telecomunicações, Aveiro, Portugal); Issa Elfergani and Jonathan Rodriguez (Instituto de Telecomunicações, Portugal); Raed A Abd-Alhameed (University of Bradford, United Kingdom (Great Britain)); Christos P. Antonopoulos (University of Peloponnese, Greece); Nikolaos Voros (University of Peloponesse, Greece)

Terahertz (THz) bands are a promising technology for 6G wireless systems due to their large bandwidth and sensing capabilities. However, key challenges in channel modeling, hardware impairments, and large-scale system integration increase the complexity of deployable THz architectures. In this paper, we present our deployment-oriented perspective developed within the 6G-TERAFIT project, which is needed to bridge the realism gap. While the project covers multiple technological layers of THz-based 6G systems, our contribution focuses on hardware-aware system-level modeling, AI-driven robust optimization, physics-informed dataset strategies, cross-layer co-design, and experimentally driven model calibration.

An RSSI Dataset Leveraging Machine Learning Based LoS/NLoS Classification and ISAC Paradigm Towards Obstacle Detection

Theodoros Skandamis, Konstantinos Antonopoulos, Panagiotis Barelas, Panagiotis Efstathioy and Christos P. Antonopoulos (University of Peloponnese, Greece); Nikolaos Voros (University of Peloponesse, Greece)

Accurately detecting human presence indoors is a critical challenge for a variety of applications, from intelligent building management to assisting the elderly and enhancing security and safety. This paper puts forward the development and evaluation of a novel dataset based on RSSI measurements from Bluetooth Low Energy (BLE) communication between a transmitter and a receiver. The dataset captures both human presence and absence conditions at multiple distances (ranging from 0.5 m to 4.0 m), incorporating a variety of scenarios for each location. By observing through statistical analysis of the signal distribution, the differentiation of the propagation patterns between the line-of-sight (LoS) and non-line-of-sight (NLoS) cases is validated. As an additional contribution, supervised machine learning techniques (Random Forest, k-NN, SVM) are applied to automatically determine the binary propagation condition, achieving high levels of accuracy. The presented approach does not require additional sensors or handheld devices, thus being aligned with the Integrated Sensing and Communication (ISAC) paradigm of future 6G infrastructures, leveraging existing Radio Frequency (RF)

networks for simultaneous communication and sensing of the environment. To encourage reproducibility and promote further exploration of BLE-based indoor sensing, the complete dataset has been released for unrestricted use by the research community.

Low-Complexity Optical Synchronization for ISAC Networks Leveraging Delta-Sigma Modulation

Ebrahim Darabi (Universidade de Aveiro, Portugal & Instituto de Telecomunicações, Portugal); Bruno Tavares Brandão (Instituto de Telecomunicações, Portugal & Universidade de Aveiro, Portugal); Beatriz Oliveira (Instituto de Telecomunicacoes & Universidade de Aveiro, Portugal); Fernando Guiomar (Instituto de Telecomunicações, Portugal); Paulo P Monteiro (Universidade de Aveiro & Instituto de Telecomunicações, Portugal)

The sixth generation (6G) communication is expected to support integrated sensing and communication (ISAC) networks, requiring sub-30 centimeters localization accuracy. This level of localization accuracy requires sub-nanosecond synchronization between the Remote Radio Head (RRH) and the Distributed Unit (DU). The existing synchronization techniques, such as satellite-based methods, synchronous Ethernet (Sync-E), and Precision Time Protocol (PTP), face limitations in terms of cost, precision, complexity, vulnerability, and indoor operability. In this paper, a low complexity optical fiber-based synchronization system model for ISAC networks is proposed using ΔΣ over fiber (ΔΣoF). The proposed architecture provides network synchronization while simultaneously distributing the clock and performing data transmission, compensating for fiber time-of-flight, particularly that caused by temperature fluctuations. By dynamically detecting the round-trip clock phase offset in a closed feedback loop at the DU and applying phase correction to the outgoing ΔΣ Modulator (ΔΣM) signal, precise synchronization between the DU and RRH is achieved. A MATLAB®/ Simulink® simulation demonstrates that the proposed scheme effectively compensates for thermal delay variations and maintains RRH clock synchronization with picosecond (ps) accuracy, indicating that the proposed architecture is a promising approach for future 6G ISAC network synchronization.

Wednesday, July 15 11:30 - 12:30

Coll2-01: Optical Fiber Devices and Sensing applications

Room: Prestonfield

A U-Shaped Coreless Fibre Architecture for High Sensitivity Immunosensing of Staphylococcus Aureus

Adeel Faruq and Haili Ma (Northumbria University, United Kingdom (Great Britain)); Stephen Todryk (School of Geography and Natural Sciences, United Kingdom (Great Britain)); Edward Fox (School of Geography and Natural Sciences Northumbria University, United Kingdom (Great Britain)); Hanna Bawab (School of DACI Northumbria University, United Kingdom (Great Britain)); Antony Antoniou (School of Geography and Natural Sciences Northumbria University, United Kingdom (Great Britain)); Yingchao Liu, Richard Fu and Zabih Ghassemlooy (Northumbria University, United Kingdom (Great Britain)); Yuliya Semenova (Technological University Dublin, Ireland); Qiang Wu (Northumbria University, United Kingdom (Great Britain))

Staphylococcus Aureus is a leading pathogenic bacterium associated with a wide spectrum of hospital and community acquired infections. Rapid, sensitive detection of this pathogen is of paramount importance. Herein, we report a label-free optical fibre biosensor built using a single-mode-coreless fibre with a U-shaped tapered architecture for S. aureus detection. Enhanced evanescent field interaction resulting from the contrast of fibre tapering and U-bend geometry is used to achieve high refractive index sensitivity of up to 2565 nm/RIU. Different waist diameter fibres were fabricated and comprehensively characterised, with the 9µm waist showing the best sensitivity. Targeted bacterial

detection is achieved through selective bacterial recognition using a porcine immunoglobulin (Ig) G antibody functionalised fibre surface via silanisation and carbodiimide coupling chemistry. The functionalised sensor shows stable optical performance in phosphate buffered saline and distinct; concentration dependent wavelength shifts up to 0. 9 nm for 2460 CFU/mL S. Aureus detection range. Signal amplification by nanobead conjugation further improved the sensitivity ~2 × of the biosensor at lower bacterial concentrations. The sensor offers a compact, robust, and highly sensitive platform for rapid point-of-care biosensing applications.

Marker-Based Alignment for a Plastic Optical Fibre-Based Visible Light Communication Link in Robotics

Natalia Hernandez-Yanez (Universidad de Santiago de Chile, Chile); Raul Zamorano-Illanes (Northumbria University, United Kingdom (Great Britain)); Cristóbal Carreño (Université de Lorraine, France); Qiang Wu (Northumbria University, United Kingdom (Great Britain)); Nicolas Krommenacker (Université de Lorraine, France); Ismael Soto (University of Santiago, Chile); Zabih Ghassemlooy (Northumbria University, United Kingdom (Great Britain))

In robotic manipulation tasks localisation and alignment is critical, particularly in indoor environments with inteference from multiple devices. This work presents a marker-based alignment approach for a plastic optical fibre-based visible light communication link applied to a robotic arm. The proposed method combines computer vision and optical wireless communication by using 6x6 ArUco markers for estimating distance and pose respect to an onboard camera mounted on the robotic arm, enabling real-time localisation. In parallel, the system is designed to support VLC through a plastic optical fibre, open in one end, facilitating simultaneous alignment and data transmission.

Cascaded FBG Ultra-High Sensitivity Temperature Sensor Based on Envelope-Free Vernier Technology

Haili Ma (Northumbria University, United Kingdom (Great Britain)); Cong Shi, Wenxi Yang, Yulun Zhang and Yicun Yao (Liaocheng University, China); Meng Zhang (Northumbria UNiversity, United Kingdom (Great Britain)); Zabih Ghassemlooy (Northumbria University, United Kingdom (Great Britain)); Jinhui Yuan (University of Science & Technology Beijing, China); Richard Fu (Northumbria University, United Kingdom (Great Britain)); Zhen Tian and Liqiang Zhang (Liaocheng University, China); Yiming Shen (Technological University Dublin, Ireland & Eblana Photonics, Ireland); Minghong Wang (Liaocheng University, China); Qiang Wu (Northumbria University, United Kingdom (Great Britain))

To overcome the inherent sensitivity limitation of fibre Bragg grating (FBG) sensors and expand their applications in ultra-high-precision temperature measurement, this paper proposes an envelope-free optical vernier technology based on peak position recognition. The proposed scheme generate a comb-like spectrum by inscribing five cascaded FBGs with different central wavelengths in the core of a single-mode fibre using a femtosecond laser, and achieves the vernier effect through theoretical design of a virtual reference arm. Focusing on the performance of temperature sensing in the ultra-high sensitivity amplification range, experimental results show that the maximum sensitivity can reach 4846.62 pm/°C, which is an improvement of 486.61 times over a single FBG sensor. Compared with the traditional vernier effect, this method retains the high spectral quality factor of FBG, while offering a simple structure and adjustable sensitivity. It offers a new high-sensitivity sensing solution for scenarios such as structural health monitoring and high-precision aerospace temperature measurement.

An Optical Sensing Algorithm for Silicon Carbide Epitaxial Layer Thickness Based on Multi-Beam Interference Correction

Chenlu Hou (North China University of Water Resources and Electric Power, China)

Conventional infrared interferometry for silicon carbide epitaxial layer thickness measurement is flawed by ignoring multi-beam interference. This paper proposes a corrected optical sensing algorithm. The

algorithm builds a dynamic refractive index model via the Sellmeier equation, calculates optical path and phase differences, derives the thickness formula through differential analysis, and adopts Savitzky-Golay filtering and spectral sub-band processing for noise reduction and feature extraction. Tests on two samples show a thickness deviation of only 0.003 μm between 10° and 15° incidence angles. Monte Carlo simulations confirm the algorithm's relative error ≤ ±0.54% and data processing time ≤ 0.3 s. In conclusion, the algorithm enhances measurement accuracy and stability, enabling non-destructive real-time detection for semiconductor production lines.

3D-Printed Light Coupling Microlens for Photonic Integrated Circuits

Wenlei Chen, Liu Dejun, Chenyang Su, Changwen Xu, Huang Ziyi, Longhui Huang, Yiping Wang and Changrui Liao (Shenzhen University, China)

High-throughput wafer-level testing of photonic integrated circuits requires efficient and reproducible fiber-to-chip coupling. Here, we demonstrate a freeform periscope microlens fabricated by two-photon polymerization directly on the facet of a standard single-mode fiber. The monolithic structure combines a total-internal-reflection mirror for beam redirection with a freeform refractive surface for mode shaping, enabling compact vertical coupling to silicon photonic waveguides without additional optics. Experimental characterization using on-chip photodetectors verifies a coupling enhancement of approximately 20% compared to bare-fiber references, achieving an optimal coupling loss of 2.21 dB. 1-dB alignment tolerances were measured with ±1.6 μm in the x plane and ±0.6 μm in the y plane. The proposed approach provides a compact and scalable optical interface for high-throughput wafer-level probing and dense packaging of photonic integrated circuits.

Wednesday, July 15 11:30 - 12:30

SS01-02: Integrated Sensing and Communications for 6G

Room: Pentland West

QDRL Based RIS Assisted Optical Beamforming for Interference Mitigation in Dense Urban 6G LEO NTN Systems

Haymanot Derebe Bizuneh (Adama Science and Technology University, Ethiopia); Ram Sewak Singh (Galgotias University, India); Demissie Jobir Gelmecha and Bayisa Taye Mulatu (Adama Science and Technology University, Ethiopia)

Dense urban areas have challenges for sixth-generation (6G) Low Earth Orbit (LEO) Non-Terrestrial Networks (NTN), including signal blockage, atmospheric attenuation, and beam misalignment. To address these issues, this paper an analysis of a Quantum Deep Reinforcement Learning (QDRL)-based Reconfigurable Intelligent Surface (RIS) assisted optical beamforming model for dense urban 6G LEO-NTN systems. The proposed model jointly optimizes RIS phase shifts, optical beam steering angles, and transmit power allocation using a quantum-enhanced policy optimization method. A hybrid state-action model is developed considering satellite altitude, azimuth and elevation angles, line-of-sight (LOS), non-line-of-sight(NLOS), and urban atmospheric attenuation. The QDRL agent maximizes a long-term reward function formulated over performance evaluation parameter of Signal-to-Interference-plus-Noise Ratio (SINR). The optical channel modeled using free-space optical (FSO) propagation with atmospheric attenuation, geometric spreading, and RIS-induced phase reconfiguration gains. Simulation results of the QDRL-RIS optical beamforming model best performance as compared conventional DRL and static RIS models of SINR, and coverage probability. The model mitigates urban blockages and environmental impairments while improving speed and quantum policy optimization. These results confirm the proposed model for enabling reliable, high-capacity in future dense urban 6G LEO-NTN systems.

SEG-JPEG: Simple Visual Semantic Communications for Remote Operation of Automated Vehicles over Unreliable Wireless Networks

Sebastian Donnelly (Oxford Brookes University, United Kingdom (Great Britain)); Ruth Anderson (Oxfordshire County Council, United Kingdom (Great Britain)); George Economides (UK Government, United Kingdom (Great Britain)); James Broughton, Peter Ball, Alexander Rast and Andrew Bradley (Oxford Brookes University, United Kingdom (Great Britain))

Remote Operation is touted as being key to the rapid deployment of automated vehicles. Streaming imagery to control connected vehicles remotely currently requires a reliable, high throughput network connection, which can be limited in real-world remote operation deployments relying on public network infrastructure. This paper investigates how the application of computer vision assisted semantic communication can be used to circumvent data loss and corruption associated with traditional image compression techniques. By encoding the segmentations of detected road users into colour coded highlights within low resolution greyscale imagery, the required data rate can be reduced by 50 % compared with conventional techniques, while maintaining visual clarity. This enables a median glass-to-glass latency of below 200 ms even when the network data rate is below 500 kbit/s, while clearly outlining salient road users to enhance situational awareness of the remote operator. The approach is demonstrated in an area of variable 4G mobile connectivity using an automated last-mile delivery vehicle. Results indicate that large-scale deployment of remotely operated automated vehicles could be possible even on the often constrained public 4G/5G mobile network, providing the potential to expedite the nationwide roll-out of automated vehicles.

Toward Robust ISAC Beam Tracking: Experimental OFDM-Enhanced Monopulse AoA Estimation with Reduced Tracking Variability

Georgios Alogdianakis, Christos Tselios and Angelos Smyrilios (University of Peloponnese, Greece); Nikolaos Voros (University of Peloponesse, Greece); Christos P. Antonopoulos (University of Peloponnese, Greece)

In this paper, we propose an experimental Orthogonal Frequency Division Multiplexing (OFDM)-assisted extension of the monopulse methodology that reduces estimation fluctuations in Angle of Arrival (AoA) estimation by exploiting multiple subcarrier-derived monopulse ratios within a single transmission frame. The proposed methodology effectively enhances the angular stability based on frequency-domain averaging. A low-cost Software-Defined Radio (SDR) platform is used in experiments that obtain real-life over-the-air measurements to prove that it can be adopted by a wide range of Commercial Off-The-Shelf (COTS) embedded systems. The results highlight substantial performance improvements compared to the conventional single-ratio monopulse estimation, achieving up to 30% reduction in Root Mean Square Error (RMSE) and Standard Deviation (STD) and 43% reduction in Mean Absolute Error (MAE). The suggested approach maintains the low complexity of classical monopulse tracking while significantly enhancing robustness, making it suitable for real-time AoA estimation in future 6G positioning and Integrated Sensing and Communication (ISAC) systems leveraging a wide range of COTS devices.

Integrated Sensing and Communication Limits over Optical Wireless Channels

Mohammadamin Baniasadi (The University of Edinburgh, United Kingdom (Great Britain)); Juncheng Li (University of Edinburgh, United Kingdom (Great Britain)); Muhammad Nafees (The University of Edinburgh, United Kingdom (Great Britain)); John Thompson (University of Edinburgh & Univ of Edinburgh, United Kingdom (Great Britain)); Majid Safari (University of Edinburgh, United Kingdom (Great Britain))

This paper studies fundamental limits of integrated sensing and communication (ISAC) in optical wireless communication (OWC) systems. Specifically, it investigates the sensing-communication tradeoff as a capacity-distortion optimization problem, which involve amplitude-constrained, nonnegative, real-valued signals affected by additive white Gaussian noise. We derive optimality conditions for the input distribution and show that the capacity-achieving distribution is unique at the

output and discrete with finite support. Based on this structural property, we develop a numerical optimization algorithm to compute the optimal mass points, their probabilities and the capacity-distortion tradeoff. Numerical results for representative sitting and walking user-orientation scenarios illustrate how the achievable communication rate varies with the sensing distortion requirement and the peak-amplitude constraint. The results provide insights into the inherent sensing-communication tradeoff and contribute to the efficient design of optical ISAC systems.

Secure FMCW-Based ISAC Transmission

Murat Temiz, Colin Horne, Matthew Ritchie and Christos Masouros (University College London, United Kingdom (Great Britain))

This paper proposes a sensing-centric waveform design and system architecture for secure integrated sensing and communication (ISAC) systems. The proposed framework jointly addresses physical-layer data security and sensing privacy by embedding information within radar waveforms while limiting the sensing capabilities of unauthorized receivers. Specifically, index modulation (IM) and phase coding (PC) are incorporated into frequency-modulated continuous-wave (FMCW) chirps, and the ambiguity functions of the chirps are specifically designed to improve sensing privacy. As a result, unauthorized passive sensing devices experience severe degradation in target detection and range estimation performance, thereby mitigating the risk of unauthorized surveillance. Simulation results demonstrate that the proposed scheme supports high data rates while simultaneously enhancing communication security and sensing privacy.

Wednesday, July 15 11:30 - 12:30

SS07-01: Camera-Based Optical Wireless Communication Systems

Room: Pentland East

Fabric as Optical Diffuser for Wearable LEDs in Optical Camera Communications Systems

Eleni Niarchou (Universidad de Las Palmas de Gran Canaria, Spain); Vicente Matus (IDeTIC-ULPGC, Spain); Victor Guerra (Wooptix, Spain); Jose Rabadan (IDeTIC-ULPGC, Spain); Rafael Perez (Universidad de Las Palmas de Gran Canaria, Spain)

Wearable light-emitting diodes (LEDs) have recently emerged as promising transmitters for optical camera communications (OCC), enabling data transmission by being integrated into garments or accessories. In this work, we investigate the use of fabrics as optical diffusers for wearable LED transmitters in OCC systems. First, we develop an experimental testbed for angular radiation pattern characterization of textile-covered LEDs, enabling systematic measurement of horizontal emission profiles. Secondly, we derive a fabric diffuser model that analytically relates the native LED radiation pattern to the resulting garment-level emission, capturing the angular redistribution introduced by the fabric in a physically motivated framework. Thirdly, we propose a sewing pattern design methodology that supports the practical embedding of LEDs in garments while preserving optical performance and wearability. Finally, we demonstrate that flexible fabrics have the potential to be used as efficient optical diffusers in wearable OCC devices, thereby providing possibilities for developing more user-friendly and robust devices.

Beacon Identification Using Noise Spectra in Optical Camera Communication

Miguel Rêgo (University of Aveiro, Portugal & Instituto de Telecomunicações, Portugal); Alexis Alfredo Dowhuszko (Aalto University, Finland); Luis Nero Alves (DETI, Universidade of Aveiro,

Portugal & Instituto de Telecomunicações, Portugal); Pedro Fonseca (University of Aveiro, Portugal & Instituto de Telecomunicações, Portugal)

This paper proposes a novel method to identify visible light beacons using rolling shutter Optical Camera Communication (OCC), particularly suited for Visible Light Positioning (VLP) scenarios. Instead of the standard approaches of modulating the light source with a square wave, binary sequence or M-Pulse Amplitude Modulation (PAM) sequence, we propose that each beacon transmits filtered pseudo-random noise samples with a unique spectral signature. This allows us to circumvent the problem of having a low number of samples per image and the lack of time synchronisation between them, since there is no need for temporal alignment of random samples. The proposed concept was experimentally validated for a distance of up to 5 m, and the results showed that the probability of correct beacon identification increased with the number of images used. Furthermore, all beacons were correctly identified when using at least 10 images. These results indicate that this new proposed approach increases the number of beacons that can be identified, provided that a suitable number of images are used.

Global-Shutter Pulse Amplitude Modulation for Optical Camera Communications in Intra-Satellite Links

Jaime Aranda Cubillo (Universidad de Las Palmas de Gran Canaria, Spain); Vicente Matus (IDeTIC-ULPGC, Spain); Jose Rabadan (ULPGC, Spain); Rafael Perez-Jimenez (IDeTIC, Las Palmas University of Technology, Spain)

Optical Camera Communication (OCC) is a candidate technology for short-range intra-satellite links due to electromagnetic immunity and reduced harness complexity. In frame-wise reception (global-shutter operation), OCC throughput is constrained by the camera frame rate, motivating higher spectral-efficiency modulation at a fixed symbol clock. This work investigates M-ary pulse-amplitude modulation (PAM) for frame-based OCC and presents an end-to-end GS-PAM system, including the transmitter/receiver architectures, a statistically driven training method for selecting PAM intensity levels under camera noise and quantization constraints, and a frame-based demodulation pipeline for synchronization, amplitude estimation, quantization, and symbol reconstruction. Laboratory line-of-sight experiments demonstrate error-free transmission of 1,000 random ASCII characters using 4-PAM, achieving a twofold throughput increase over binary modulation under identical reception settings. An estimated SNR of at least 22 dB indicates sufficient margin for reliable multi-level detection. These results support PAM as an effective approach for improving throughput in low-rate, high-reliability intra-satellite OCC links.

Comparative Analysis of PWM and FM-Based Modulation Techniques for Sensor Data Transmission in Optical Camera Communications

Jorge Neto (Universidade de Aveiro, Portugal); Miguel Rêgo (University of Aveiro, Portugal & Instituto de Telecomunicações, Portugal); Atiya Fatima Usmani (University of Aveiro, Portugal); Ernesto Ventura (Universidade de Aveiro, Portugal); Luis Nero Alves (DETI, Universidade of Aveiro, Portugal & Instituto de Telecomunicações, Portugal)

This work investigates Pulse-Width Modulation (PWM) and Frequency Modulation (FM) as analog modulation schemes suitable for rolling shutter cameras. A theoretical and simulation framework is developed to model the rolling-shutter sampling process and evaluate signal reconstruction performance. The influence of key system parameters, including carrier frequency, modulating signal bandwidth, modulation index, and camera line sampling rate, is analyzed using the root-mean-square error (RMSE). Additionally, the impact of rolling-shutter line timing jitter is examined. Results show that FM provides lower reconstruction error under nominal conditions, while PWM exhibits greater robustness under large timing jitter. These findings highlight important trade-offs when selecting modulation schemes for OCC-based sensing systems.

Wednesday, July 15 2:00 - 2:50

Plenary Talk 2: Prof. Ana I. Perez Neira. "Airborne Computation: The Next Leap for Wireless Networks and AI"

Room: Pentland

Wednesday, July 15 2:50 - 4:00

Coll1-02: Optical Wirelress positioning/ localisation

Room: Prestonfield

Passive Retroreflector-Based Optical Multilateration for Three-Dimensional UAV Localization

Khadijeh Ali Mahmoodi (Gustave Eiffel University, France & Schiller International University, France); Bastien Béchadergue and Luc Chassagne (University of Versailles Saint-Quentin-en-Yvelines, France); Mohammed Elamassie (Ozyegin University, Turkey)

This paper presents a three-dimensional (3D) unmanned aerial vehicle (UAV) localization framework based on optical round-trip time (RTT) ranging and multilateration. Multiple fixed optical transmitters estimate distances via laser reflections from a UAV equipped with passive retroreflectors, enabling infrastructure-assisted localization without active onboard hardware or additional energy consumption. The system model incorporates additive Gaussian ranging noise, and the localization problem is formulated as a nonlinear least-squares estimation problem. Monte Carlo simulations demonstrate a median localization error of approximately 0.055 m, with 90% and 95% of errors below 0.11 m and 0.14 m, respectively, under centimeter-level ranging noise. The results show that localization accuracy depends on transmitter geometry and UAV altitude, with errors increasing at higher altitudes and under larger noise levels. Furthermore, increasing the number of transmitters improves accuracy through enhanced measurement redundancy. The results provide practical design guidelines for optical UAV tracking systems.

Visible Light-Based Joint Position and Orientation Estimations Using Photodiode Array and Artificial Neural Network

Juan A Apolo (UPV Universitat Politècnica de València, Spain); Beatriz Ortega (ITEAM Research Institute, Spain); Vicenc Almenar (Universidad Politecnica De Valencia, Spain); Sujan Rajbhandari (University of Strathclyde, United Kingdom (Great Britain))

This paper presents the performance analysis of novel visible light-based position and orientation estimation techniques using a photodiode array in combination with a supervised artificial neural network (ANN). Using a validated simulation framework calibrated using experimental imaging multiple-input multiple-output (MIMO) system, position and orientation estimation performance is evaluated for imaging and non-imaging MIMO with 2×2 to 5×5 photodiode arrays and angular diversity receivers (ADR) with square frustum geometry. The 5×5 imaging MIMO receiver achieves a positioning root mean square (RMS) error of 20.0 mm with orientation errors of 3.5°, 1.5°, 1.6° (yaw, pitch, roll) at 90% CDF, outperforming non-imaging 5×5 MIMO (17.0 mm positioning with 28.0° yaw error). The ADR with 45° photodiode tilt angle delivers a positioning accuracy of 6.9 mm while maintaining an orientation error of 3.9°, 1.2°, 1.2°. The 90°-tilt configuration, equivalent to a non-imaging system, degrades to 11.1 mm positioning and 8.6° yaw error.

Ontology-Driven Social Digital Twins with OCC Localisation for Real-Time Customer-Service Operations

Moises Segura-Cedres and Desiree Manzano-Farray (ULPGC, Spain); Eleni Niarchou (Universidad de Las Palmas de Gran Canaria, Spain); Carmen Lidia Aguiar (IDeTIC-ULPGC, Spain); Rafael Perez-

Jimenez (IDeTIC, Las Palmas University of Technology, Spain)

Customer-service operations are people-intensive, fast-changing and strongly shaped by where customers and staff are located relative to semantic service zones. Conventional analytics in customer attention-oriented services typically remain retrospective and weakly grounded in the spatial semantics of service delivery. This paper proposes a localisation-driven Social Digital Twin (SDT) for front-end services that couples an ontology-based semantic core with real-time sensing and human-centred constraints. The SDT integrates Optical Camera Communication (OCC) indoor positioning-treated as a stream of space-time events-and wearable-derived physiological indicators of staff workload via a vendor-agnostic, property-oriented REST API. OCC observations are normalised, mapped to a canonical 3D reference frame and classified into semantic zones to derive trajectories, dwell segments and queue-related indicators, whilst wearable windows are aggregated into interpretable workload states. Ontology-backed fusion and rule-based reasoning support near real-time KPIs and explainable recommendations for queue management and workload balancing under privacy-preserving design assumptions. A prototype implementation and an evaluation strategy combining logged traces with realistically synthesised scenarios are presented to assess localisation, zone classification and the operational utility of SDT-derived indicators. The results illustrate how OCC-centred sensing can underpin deployable SDTs for hospitality front desks, enabling operational decision support while maintaining strict identity governance and zone-level privacy.

Wednesday, July 15 2:50 - 4:00

GT-02: Radar Technology

Room: Pentland East

24 GHz mmWave Radar Certification Standard Pre-Screening

Jorik De Bruycker and Gilles Verschueren (KU Leuven, Belgium); Uwe Maaß (Fraunhofer IZM, Germany); Tim Claeys and Nobby Stevens (KU Leuven, Belgium)

mmWave radar has seen widespread adoption in several sectors. In particular, 24 GHz radar modules have become increasingly available as low-cost Commercial off-the-shelf (COTS) solutions. However, ensuring regulatory compliance for these devices necessitates expensive measurement procedures. This work addresses the need for effective and economical pre-screening by measuring the spectral emissions for a representative selection of 24 GHz COTS radar modules. The results show that 2 out of 6 tested modules exhibit out-of-band emissions, demonstrating that the presented pre-screening method can effectively eliminate non-compliant modules before expensive regulatory full certification testing.

On the Added Value of mmWave Radar Within Indoor Logistic Environments

Gilles Verschueren, Jorik De Bruycker and Nobby Stevens (KU Leuven Science, Engineering and Technology Group, Gent, Belgium); Marc Juwet (KU Leuven Science, Engineering and Technology Group, Belgium)

Speed and Separation Monitoring (SSM) is a key enabler for productivity in human-robot collaborative applications, yet its industrial use remains limited by the difficulty of reliably obtaining human-related motion parameters. Although recent research explores AI-based perception to address this challenge, the probabilistic nature and lack of certification of AI methods prevent their deployment as safety-critical systems. This work investigates deterministic strategies for improving SSM efficiency without relying on AI, focusing on zone-adaptation techniques and sensing capabilities that remain fully compatible with functional-safety standards. The work contributes (1) a structured analysis of how motion-adaptive zone formulations can reduce conservatism in current SSM implementations, and (2) a performance-oriented comparison of safety-certified LiDAR and radar sensors regarding velocity

measurement. The analysis shows that while LiDAR continues to dominate industrial practice, radar offers several complementary advantages that may significantly enhance SSM performance. These findings motivate further exploration of deterministic, safety-compliant processing methods.

The Semantic Proximity Trap: Investigating Contrastive Learning for Open Set Radar Activity Recognition

Reda El Hail (KU Leuven, Belgium); Quinten Van Baelen (Ku Leuven, Belgium); Anton Lambrecht (IDLab, Ghent University-Imec, Belgium); Eli De Poorter (Ghent University & Imec, Belgium); Peter Karsmakers (KU Leuven, Belgium)

Open Set Recognition (OSR) is the task of correctly classifying known classes that are encountered during training, while simultaneously rejecting instances from unknown classes that were absent from the training data. OSR in radar-based Human Activity Recognition (HAR) faces a significant challenge: the physical and kinematic similarity between known and unknown motions. While contrastive learning effectively clusters known activities into discriminative manifolds, it inadvertently creates "attractor regions" that pull in semantically similar but previously unseen activities. In this paper, we investigate this "Semantic Proximity Trap" using Frequency-Modulated Continuous-Wave (FMCW) radar data. We demonstrate that while contrastive objectives can achieve high closed-set accuracy, they fail to provide sufficient rejection space for "Near-Set" unknown activities. Our results, visualized via t-SNE, reveal that unknown motions often collapse into the clusters of known classes due to shared micro-Doppler characteristics, presenting a fundamental hurdle for robust open-world deployment.

A Real-Time Embedded mmWave Radar System for Contactless Tremor Assessment

Haoxuan Li and Tiantao Jiang (Heriot-Watt University, United Kingdom (Great Britain)); Rui Fan (First Affiliated Hospital of Chongqing Medical University, China); Liang Chen (Zhongshan Hospital of Wuhan University, China); Anne Bernassau (Heriot-Watt University, United Kingdom (Great Britain)); Kevin Chetty (University College London, United Kingdom (Great Britain)); Wenda Li (Heriot Watt University, United Kingdom (Great Britain))

Tremor is a common symptom of Parkinson's disease and other movement disorders. This paper presents a real-time, contactless tremor quantification system using a 60 GHz frequency-modulated continuous-wave (FMCW) millimeter-wave (mmWave) radar integrated with Raspberry Pi platforms. A medical-grade transcutaneous electrical nerve stimulation (TENS) device induces repeatable tremor-like oscillations in forearm muscles at prescribed stimulation frequencies. The embedded pipeline performs clutter suppression, range-Doppler processing, range-gated spectral analysis, and peak detection. Multi-channel spectral fusion improves robustness to background motion. The system outputs dominant frequency, normalised peak strength, and spectral energy concentration. Experiments on healthy volunteers undergoing TENS stimulation show stable dominant-frequency tracking across practical stand-off distances and incidence angles up to ±60 ◦ . Range-gated analysis separates concurrent oscillatory foci, including those at identical frequencies. On embedded hardware, the end-to-end processing latency per frame is below 50 ms with power consumption below 5 W, enabling continuous, non-invasive monitoring in clinical and home settings.

Synthetic Aperture Based Moving Targets Localization Using Mobile OTFS Radar

Ali T. Göktaş and Mikko Valkama (Tampere University, Finland); Bo Tan (University College London (UCL), United Kingdom (Great Britain))

This paper proposes a low-complexity localization framework for moving targets using a single-antenna mobile radar platform with orthogonal time-frequency space (OTFS) waveforms. Unlike conventional approaches requiring antenna arrays or multistatic configurations, the proposed method exploits synthetic aperture (SA) motion to estimate target positions from estimated delay-Doppler (DD) parameters. An efficient DD tracking algorithm is introduced to incrementally update delay and Doppler estimates across OTFS blocks, avoiding full re-estimation and reducing computational

overhead. Then, a geometry-based localization strategy reconstructs the target coordinates from the quadratic curvature of the slant-range trajectory during the aperture-synthesizing period. Simulation results demonstrate the impacts of the synthesis aperture, platform and target velocities on the achievable localization accuracy.

A Wing-Borne MIMO Radar

Aleksandr Kharin and Sergey Karamov (Novus Converged Aerospace Ltd., United Kingdom (Great Britain))

Using 3D scanning radars is essential for aircraft. MIMO radars significantly simplify their installation in aircraft while significantly increasing equivalent resolution. However, implementing MIMO elements in wings poses a significant challenge due to their deflection, which degrades the radar images or makes it unusable. The objective of our study was to research and develop a method for configuring 3D imaging MIMO radars in the wings of various aircraft, taking into account arbitrary deflections. We examined radar images obtained by radar due to arbitrary deflections of aeroplane wings. Deflection includes both static and dynamic effects, particularly flutter. A mathematical model of a radar installed in deformable wings has been developed. We propose a method for compensating the MIMO model calculation for deflections, which restores the original radar image. We provide a calculation of the accuracy of the method depending on the accuracy of the sensors. We demonstrate that using simple sensors that measure arbitrary wing deflection, high-quality radio imaging can be obtained using MIMO radar. The proposed method is invariant to both the radar frequency range and the aircraft size.

Wednesday, July 15 2:50 - 4:00

Invited talk: First Transatlantic Telecommunication Cable: the Victorian "Apollo" Project

Room: Prestonfield

Wednesday, July 15 2:50 - 4:00

SS08: Towards 6G-Advanced Technologies for Future Ubiquitous Communications

Room: Pentland West

A Conditional Variational Framework for Channel Prediction in High-Mobility 6G OTFS Networks

Mohsen Kazemian and Jürgen Jasperneite (Technische Hochschule Ostwestfalen-Lippe, Germany)

This paper proposes a machine learning (ML)-based method for channel prediction in high-mobility orthogonal time frequency space (OTFS) channels. In these scenarios, rapid variations caused by Doppler spread and time-varying multipath propagation lead to fast channel decorrelation, making conventional pilot-based channel estimation methods prone to outdated channel state information (CSI) and excessive overhead. Therefore, reliable channel prediction methods become essential to support robust detection and decoding in OTFS systems. In this paper, we propose conditional variational autoencoder for channel prediction (CVAE4CP) method, which learns the conditional distribution of OTFS delay-Doppler channel coefficients given physical system and mobility parameters. By incorporating these parameters as conditioning information, the proposed method enables the prediction of future channel coefficients before their actual realization, while accounting for inherent channel uncertainty through a low-dimensional latent representation. The proposed framework is evaluated through extensive simulations under high-mobility conditions. Numerical results

demonstrate that CVAE4CP consistently outperforms a competing learning-based baseline in terms of normalized mean squared error (NMSE), particularly at high Doppler frequencies and extended prediction horizons. These results confirm the effectiveness and robustness of the proposed approach for channel prediction in rapidly time-varying OTFS systems.

Curriculum Self-Supervised Learning for BD-RIS Optimization in Multi-User MIMO Systems

Darian Pérez-Adán (Universidade da Coruña, Spain); Dariel Pereira-Ruisanchez and Óscar Fresnedo (University of A Coruña, Spain); Ignacio Santamaria (University of Cantabria, Spain); Luis Castedo (University of A Coruña, Spain); John Thompson (University of Edinburgh & Univ of Edinburgh, United Kingdom (Great Britain))

Beyond-diagonal reconfigurable intelligent surfaces (BD-RISs) enable full coupling among surface elements, offering enhanced performance compared to conventional RIS but introducing challenging structural and optimization constraints. This paper proposes a curriculum-based self-supervised (SS) deep learning (DL) approach for joint BD-RIS configuration and water-filling precoder optimization in multi-user (MU) multiple-input multiple-output (MIMO) uplink systems. The proposed method directly maximizes the sum rate without relying on labeled data, while enforcing BD-RIS feasibility constraints by design. A curriculum strategy progressively transitions from isotropic to water-filling-based power allocation, enabling stable and effective training. Simulation results based on realistic 3GPP channel models show that the proposed approach outperforms state-of-the-art methods in sum rate, reduces computational complexity, and improves user fairness.

Robust Channel Estimation in OTFS Systems Using Embedded Pilots and DFT-Based Interpolation

Andres Reyes-Castro and Lianet Mendez-Monsanto (Universidad Carlos III de Madrid, Spain); Maria Julia Fernandez-Getino Garcia (University Carlos III of Madrid, Spain); Ana Garcia Armada (Universidad Carlos III de Madrid, Spain); Kun Chen-Hu (Universidad de Alcalá, Spain & Universidad Carlos III de Madrid, Spain)

Orthogonal Time-Frequency Space (OTFS) modulation stands out as a robust waveform for Integrated Sensing and Communications (ISAC) scenarios in Sixth Generation (6G) networks, effectively converting doubly selective fading channels into a slowly varying response in the Delay-Doppler domain. However, conventional channel estimation techniques struggle with fractional Doppler shifts, which cause severe inter-Doppler interference and spectral leakage, significantly degrading both sensing and communications performance. In this work, we propose a robust OTFS channel estimation framework that relies on an embedded pilot and addresses fractional Doppler effects. First, delays are precisely identified by employing a threshold-based detection on the pilot response. Then, by using a discrete Fourier transform (DFT)-based interpolation approach that allows the identification of superimposed frequencies, it is possible to separate and accurately estimate fractional Doppler shifts associated with the same delay. Finally, these delay and Doppler estimates are used to compute the channel gains for data equalization. Simulation results confirm that the proposed method offers superior performance compared to conventional embedded pilot estimation techniques, achieving higher accuracy and improved robustness under realistic 6G operating conditions.

Analyzing 5G Sidelink for Emergency Braking Applications

Jesús Suárez Montoro (Universidad Carlos III de Madrid, Spain); Víctor P. Gil Jiménez (University Carlos III of Madrid, Spain); Vladimir K. Poulkov (Technical University of Sofia, Bulgaria); Maria Julia Fernandez-Getino Garcia (University Carlos III of Madrid, Spain)

Vehicle-to-vehicle (V2V) communication is a key element in enabling advanced road safety applications, such as emergency braking alerts, where reliability and latency requirements are particularly stringent. In recent years, various studies have analyzed the use of LTE- and 5G-based V2V technologies, demonstrating the potential of direct vehicle-to-vehicle links to reduce delays compared to network-assisted solutions. In this context, 5G Sidelink emerges as a particularly promising

technology thanks to its low latency, high reliability, and ability to operate directly through the PC5 interface, without the need for network infrastructure. This paper evaluates the performance of 5G Sidelink applied to an emergency braking scenario, analysing its viability from an end-to-end perspective. A system model based on a chain of vehicles in a straight line is proposed, where braking information is propagated via multi-hop sidelink communications. Based on this model, key metrics such as end-to-end correct reception probability and associated latency are analysed as a function of Signal to noise ratio (SNR) level. The results show the existence of a critical SNR threshold above which reliability levels close to 100% and latencies compatible with road safety applications are achieved. The impact of the number of hops on end-to-end communication is also discussed.

Group-Regularized Atomic Norm Minimization for Widely Separated MIMO Radar

Rafael Santos and Daniel Castanheira (University of Aveiro, Portugal); Adão Silva (Instituto de Telelcomunicações, Portugal); Atílio Gameiro (Instituto de Telecomunicações / Universidade de Aveiro, Portugal)

We propose a Group-Regularized Atomic Norm minimization (GRAN) framework for spectral estimation and target localization in widely separated MIMO (WS-MIMO) radar. GRAN combines the off-grid accuracy of atomic-norm minimization with a group-sparsity regularizer that enforces global consistency across spatially distributed receivers, thereby addressing the complementary weaknesses of existing atomic-norm (AN) and Group Lasso (GL) approaches. The proposed formulation jointly reconstructs the continuous-domain spectra of all receivers while enforcing physically consistent target locations, reducing spurious solutions and improving robustness in compressed settings. Numerical experiments demonstrate that GRAN retains the low-SNR advantage of GL while avoiding its high-SNR performance saturation caused by off-the-grid errors. At the same time, GRAN consistently outperforms the AN approach by a constant margin. These gains translate into improved position estimates, showing that GRAN provides a practical and computationally tractable solution for exploiting the global structure of WS-MIMO radar systems without incurring discretization-induced errors.

3D Indoor Positioning Techniques for mmWave Distributed MIMO Systems Under Multipath Propagation

Mohd Adnan (University of Aveiro, Portugal); Adão Silva (Instituto de Telelcomunicações, Portugal); Rui Dinis (Universidade Nova de Lisboa & Nova IT, FCT-UNL, Portugal); Lukasz Krzymien (Nokia Solutions and Networks, Poland)

Accurate 3D indoor positioning for millimeter-wave (mmWave) distributed MIMO (D-MIMO) systems remains a challenging problem due to severe multipath propagation, non-line-of-sight (NLoS) conditions, and timing uncertainties across distributed access points. Although mmWave communication provides high spatial and temporal resolution, reflections and interference can significantly degrade the reliability of angle and delay-based measurements in practical indoor environments. This paper proposes a 3D indoor positioning framework for mmWave distributed multiple-input multiple-output (D-MIMO) systems, exploiting spatial and temporal information to improve robustness under such conditions. Using the multiple signal classification (MUSIC) algorithm, the framework first estimates the angle-of-arrival (AoA) and then computes time-difference-of-arrival (TDoA) measurements with respect to a reference access point (AP). By formulating the position estimation problem as a TDoA-based weighted least-squares optimization, the framework estimates the user location by minimizing the mismatch between measured and geometry-based TDoA values. Simulation results in a realistic indoor mmWave environment demonstrate the effectiveness of the proposed framework in terms of high positioning accuracy under line-of-sight (LoS) conditions and robust performance in the presence of weak reflection interference.

Wednesday, July 15 4:30 - 5:30

Coll1-03:OWC system design and implementation

Room: Prestonfield

CMOS Design of an Homodyne Receiver for Multi-Band Carrierless Amplitude and Phase Signals

Carlos Silva (Universidade de Aveiro, Portugal); Luis Rodrigues (Institute of Telecommunications of Aveiro, Portugal & Universidade de Aveiro, Portugal); José Luís Vieira Cura (University of Aveio, Portugal); Luis Nero Alves (DETI, Universidade of Aveiro, Portugal & Instituto de Telecomunicações, Portugal)

This paper presents the design and validation of a fully integrated Complementary Metal-Oxide-Semiconductor (CMOS) analog demodulation for multi-band Carrierless Amplitude and Phase (m-CAP) modulation in Visible Light Communication (VLC) systems. To address the high power consumption and complexity of digital receivers, the proposed architecture performs quadrature demodulation and sub-band selection entirely in the analog domain. Implemented in a 65 nm process, the receiver integrates a linearized folded Gilbert-cell mixer, a wide-range quadrature ring oscillator (11.8 kHz to 1.01 MHz) and an 8th-order Switched-Capacitor (SC) Bessel filter. Simulation results demonstrate a conversion gain of -1.87 dB with effective clock leakage suppression below -90 dBV. The SC filter achieves over 80 dB of stopband rejection with less than 0.1% deviation from the target 5 kHz cutoff, while the quadrature voltage controlled oscillator (QVCO) maintains a phase noise of -105.4 dBc/Hz at 100 kHz offset. These results confirm the feasibility of low-power, high-selectivity integrated VLC receivers for IoT applications.

Side-Emitting Fiber Coil Receiver for Wide Field-of-View Optical Wireless Communication

Matej Komanec (Czech Technical University in Prague, Czech Republic); Jakub Formánek (Czech Technical University of Prague, Czech Republic); Carlos Guerra-Yánez (Czech Technical University, Czech Republic)

Wide Field of View (FOV) light receiver is considered one of the key components in Optical Wireless Communication (OWC), as it eliminates constraints imposed by the source and/or receiver´s FOV. In this paper, we further develop the side-emitting fiber-based distributed light receiver concept by proposing a new side-emitting fiber coil structure. For a proof-of-concept demonstration, we analyze the Bit Error Rate (BER) performance of an OWC uplink. We successfully transmit a 910 nm signal with On-Off Keying (OOK) modulated data at 100 kbps over a 35 cm free-space path, with pre-Forward error correction (FEC) BER below the HD-FEC limit for a net-coding gain of 9.19 dB and a target post-FEC BER of 10−15, for a source-receiver angular position ranging from 0° to 180°. This first result of a side-emitting fiber coil receiver opens a new area of distributed light-antenna 3D design possibilities for indoor scenarios, in particular for sensor networks that do not require higher data rates and will benefit from a possibly omnidirectional light receiver.

Flexible Organic Photovoltaic Cell Receiver Models in Optical Wireless Channel Simulations

Mahdi Dor Emami (Université de Poitiers, France & CNRS, XLIM, Poitiers, France); Lilian Aveneau (University of Poitiers, France & Laboratoire XLIM, CNRS, France); Pierre Combeau (Université de Poitiers, CNRS, XLIM, Poitiers, France); Hervé Boeglen (University of Poitiers XLIM CNRS 7252, France); Stéphanie Sahuguède (XLIM UMR CNRS 7252 - University of Limoges, France); Anne Julien-Vergonjanne (University of Limoges & XLIM CNRS 7252, France)

Organic photovoltaic (OPV) cells are a promising solution for autonomous Internet of Things (IoT) applications thanks to their energy-harvesting and communication capabilities, as well as their ability to be printed on flexible substrates and therefore adapt to any support shape. In order to evaluate the performance of these systems, it is essential to be able to model and simulate such sensors in tools based on Monte Carlo ray tracing methods. This article proposes two new receiver models for curved

OPV cells: a discretized cylinder model (Dcyl) and an analytical cylinder model (Acyl). These models are compared with a previous approach that required multiple simulations, each using a flat rectangular receiver, which was complex and error-prone due to the sequential setup of scenes. The results indicate that the Dcyl model offers greater flexibility than the previous approach but is less accurate than the Acyl model. Furthermore, the Acyl model demonstrates faster computation times than the Dcyl model. Our findings suggest that the proposed models enable more efficient simulation of curved OPV cells, opening new perspectives for IoT applications.

Highly Insulating Optocoupler for 5 Gbps Full-Duplex Data Transmission

Kai Schmieder (Fraunhofer Institute for Photonic Microsystems IPMS, Germany); Tobias Schneider (Fraunhofer Institute for Photonic Microsystems, Germany); René Kirrbach (Fraunhofer IPMS, Germany); Jens Knobbe (Fraunhofer Institut für Photonische Mikrosysteme, Germany); Max Haymann-Pohl and Lorenz Reuschel (Fraunhofer IPMS, Germany)

Optocouplers are widely used for data transfer and galvanic separation. However, for data rates of 100 Mbps or beyond and/ or an electrical isolation in the double-digit kV-range, the selection is severely limited, and the costs increase dramatically. In this paper, we describe our GigaCoupler approach eliminating these bottlenecks and demonstrate a 5 Gbps full-duplex data transmission in combination with an outstanding small form factor of 5 mm x 5 mm.

Innovative Small-Scale PV Modeling: Optimizing the Single-Diode Approach for Sub-Watt Systems

Matthew B Brown, Wai Pang Ng, Arash Bahrami and Jing Jiang (Northumbria University, United Kingdom (Great Britain)); Matthew Townson (Northumbria University, Great Britain, United Kingdom (Great Britain))

Internet of Things (IoT) energy-harvesting-nodes operating in the ultra-low-power (ULP), sub-watt (<1 W) domain rely on small-form-factor photovoltaics (PV) and typically operate under low irradiance, making accurate behavioral PV modeling essential for reliable energy availability prediction. We propose a robust parameter extraction method for the single-diode model (SDM) for sub-watt systems, reducing behavioral variability under parameter uncertainty in ULP PV systems. This method employs the Dogleg trust-region algorithm with calibrated diode ideality factor (n). Device-calibrated values of n = 1.1 provide a good approximation of the current-voltage (I-V) curve, while n = 1.7 improves agreement under load. Under standard test conditions (STC) (1000 W/m^2, 25 °C), the model reproduces current-voltage (I-V) and power-voltage (P-V) characteristics, yielding root mean square error (RMSE) values of 0.0169 A and 0.017 W, and mean absolute percentage error (MAPE) values of 7.49% and 4.18%. The method is assessed under relevant environmental conditions and predicts power under varying irradiance with an RMSE of 0.0192 W (MAPE 11.73%). Comparison with Photovoltaic Geographical Information System (PVGIS) shows that linear irradiance scaling can misrepresent low-light behavior. In contrast, the proposed SDM captures nonlinearities and environmental effects, yielding closer agreement under ULP-relevant operating conditions. This improved behavioral fidelity enables more reliable energy forecasting, supporting robust system design and batteryless IoT deployments.

Microcontroller-Based UOWC Modem: A Pathway to a Low-Cost, Real-Time Underwater Optical Wireless Connectivity

Egecan Guler (The University of Edinburgh, United Kingdom (Great Britain)); Wasiu O. Popoola (University of Edinburgh, United Kingdom (Great Britain))

This paper presents the design, implementation and in-lab experimental demonstration of a complete, low-cost underwater optical wireless communication (UOWC) system. The system is used in an in-lab experiment to establish a low-latency water-to-air UOWC link, successfully transmitting realtime video from a submerged sensor node to a surface station using commercial off-the-shelf components such as a Raspberry Pi 4B. A key innovation is an angle diversity receiver (ADR) that provides a wide field-of-

view (FoV), ensuring a stable link. Experimental results show successful 18 frames per second (fps) video streaming with a resolution of 640 × 480 in the underwater channel, demonstrating the potential applications for battery-operated sensor nodes or Autonomous Underwater Vehicles (AUVs) where latency and power efficiency is crucial. This work demonstrates a pathway to bringing high-bandwidth connectivity to the subseas environment.

Wednesday, July 15 4:30 - 5:30

GT-03: Signal processing

Room: Pentland East

A Low-Component-Count E5CHB-Based Integrated Energy Source Converter

Prabir Ranjan Kasari (National Institute of Technology Agartala, India); Subhadeep Bhattacharjee (National Institute of Technology, Agartala, Tripura, India); Bikram Das and Abanishwar Chakrabarti (NIT AGARTALA, India)

This paper presents a modified enhance cascaded five-level H-bridge inverter computable for solar energy integration into the grid. There is growing interest in cascaded enhanced inverters owing to their high power efficiency and compact form. This converter is unique compared to its counterpart, as a five-level output voltage is achievable by using only a single dc source. Moreover, this converter provides a boost output voltage, which can be attained/achieved with a low-rated source of energy. Generation of five-level and voltage enhancement are achieved in this topology with five turnoff devices, two diodes, two capacitors and merely adding an inductor. This feature ensures that the converter is suitable for the solar photovoltaic system. This paper provides an in-depth analysis of the proposed enhanced cascaded inverters. The simulation and experimental results are provided for validation.

Explainable AI Based Feature Selection Method for Energy Harvesting Assisted IoT Network

Huijun Tang (Durham University, United Kingdom (Great Britain)); Wang Zeng (Hanghzou Dianzi University, China); Min Xue (Heidelberg University, Germany); Junhui Du (Tianjin University, China); Zhizhou He (University of Surrey, United Kingdom (Great Britain)); Pengfei Jiao (Hangzhou Dianzi University, China); Huaming Wu (Tianjin University, China); Hongjian Sun (Durham University, United Kingdom (Great Britain))

Energy Harvesting (EH)-assisted Backscatter IoT networks offer a promising solution for sustainable connectivity but face complex optimization challenges. While Deep Reinforcement Learning (DRL) provides a viable model-free solution, its black-box nature often obscures the underlying decision mechanisms, leading to redundant state representations and inefficient resource usage. To address these challenges, we propose XAI-LyDRL, a novel framework that integrates Lyapunov optimization with explainable artificial intelligence (XAI)-based feature selection. We derive three key mechanistic insights: (1) we empirically verify that the agent implicitly internalizes physical path-loss models, rendering explicit geometric distance features redundant; (2) we unveil a regime-dependent attention mechanism where the policy dynamically shifts focus from queue stability to channel quality based on resource constraints, confirming theoretical consistency with Lyapunov optimization; and (3) we identify effective state sparsity where optimal actions are primarily driven by bottleneck users. Guided by these insights, we construct a streamlined policy that prunes 40% of the state space. Simulation results demonstrate that this lightweight design achieves comparable stability and throughput to full-scale models while providing an empirical foundation for scalable deployment in resource-constrained edge devices.

Energy-Aware and Flexible Optical Data Stream Processing: A Study of the Averaging Operator in Free Space

Wenfei Huang, Meike Hofmann and Peter Amthor (Technische Universität Ilmenau, Germany); Boris Koldehofe (University of Marburg, Germany)

Infinite data streams in modern applications place great demands on data computation and movement resources in conventional digital infrastructure, resulting in a trend of steeply increasing energy consumption. Optical computing provides an alternative by performing computation during light propagation, potentially alleviating the energy overhead inevitable with digital electronics. In this study, we make a first step towards this goal by implementing the averaging operator, a core primitive of stream processing, based on free-space optical computing. Our results demonstrate a high level of accuracy (relative error of approximately 2%) across various input types. Regarding energy consumption, we found that the optical implementation scales extremely well and is more efficient than digital computation for processing high-dimensional data. This hints at a practical methodology for mapping various stream aggregation operations onto optical hardware.

Frequency Nonlinearity Compensation of FM LIDAR System Using Hilbert Transform and Interpolation Resampling

Lingjuan Zhang (Beijing University of Posts and telecommunications, China); Jinhui Yuan (University of Science & Technology Beijing, China); Kuiru Wang and Binbin Yan (Beijing University of Post and Telecommunication, China); Xinzhu Sang (Beijing University of Posts and Telecommunications, China); Qiang Wu (Northumbria University, United Kingdom (Great Britain))

FMCW lidar measures distance using time-varying frequency modulation, and its linearity affects resolution. We employed the Hilbert transform, frequency-domain interpolation resampling, and an auxiliary interferometer (with a 0.315 m arm length difference) to compensate for frequency nonlinearity, thereby achieving a 25-fold improvement in spatial resolution and verifying its feasibility under low-bandwidth conditions.

Zero-Shot Distracted Driver Detection via Vision Language Models with Double Decoupling

Takamichi Miyata (Chiba Institute of Technology, Japan); Sumiko Miyata (Institute of Science Tokyo, Japan); Andrew Morris (Loughborough University, United Kingdom (Great Britain))

Distracted driving is a major cause of traffic collisions, calling for robust and scalable detection methods. Vision-language models (VLMs) enable strong zero-shot image classification, but existing VLM-based distracted driver detectors often underperform in real-world conditions. We identify subject-specific appearance variations (e.g., clothing, age, and gender) as a key bottleneck: VLMs entangle these factors with behavior cues, leading to decisions driven by who the driver is rather than what the driver is doing. To address this, we propose a subject decoupling framework that extracts a driver appearance embedding and removes its influence from the image embedding prior to zero-shot classification, thereby emphasizing distraction-relevant evidence. We further orthogonalize text embeddings via metric projection onto Stiefel manifold to improve separability while staying close to the original semantics. Experiments demonstrate consistent gains over prior baselines, indicating the promise of our approach for practical road-safety applications. Code is available at https://github.com/mtakamichi/ZVL-DDD.

Wednesday, July 15 4:30 - 5:30

SS05-01: Optical and Wireless Sensor Networks for 6G

Room: Pentland West

Pyenlight: A Library for Modeling Communication and Energy Harvesting of Hybrid Optical Wireless / Radio-Frequency Indoor Networks

Alexandros Aslanidis (Harokopio University of Athens, Greece); Christos Giachoudis (Ecole Centrale Méditerranée, France); Thomas Kamalakis (Harokopio University of Athens, Greece)

The rapid growth of next-generation self-sustainable Internet of Things devices and networks leads to radio-frequency (RF) spectrum congestion. Hybrid wireless networks that combine optical and radio technologies are considered as a promising solution that requires precise simulation techniques for efficient design. This paper presents Pyenlight, an open-source Python library for simulating such systems with different physical layers and explicit energy modeling. The library models optical wireless communications, RF transceivers and channels, as well as reconfigurable intelligent surfaces and dual-function photovoltaic panel receivers allowing the combined study of data transfer and energy harvesting. Exploiting a numpy-based vectorized architecture, Pyenlight can handle large-scale simulations and complex tasks related to energy consumption and harvesting optimization.

Digital Twin Orchestrated Software Defined Networks for Handling Denial of Service Attacks in IoT Applications

Satish Kumar Modalavalasa (Czech Technical University in Prague, Czech Republic); Carlos Guerra-Yánez and Shivani Rajendra Teli (Czech Technical University, Czech Republic); Luis Miguel Giraldo and Joaquin Perez (Universitat de Valencia, Spain); Zabih Ghassemlooy (Northumbria University, United Kingdom (Great Britain)); Stanislav Zvanovec (Czech Technical University in Prague, Czech Republic)

The paper discusses the implementation and analysis of a digital-twin-orchestrated preemptive-switching scenario for sensor-data transmission over physical network interface links. The experimental setup in this work uses physical interface connections based on radio and optical interfaces, defined by the standards of IEEE 802.11n wireless local area network (WLAN) and IEEE 802.15.7-based visible light communications, respectively. Data transmission at physical interfaces is managed using a software-defined network controller that defines traffic flows based on processing commands from the network digital twin, which is modeled for telemetry analysis and decision making. The statistical average of the measurements shows a delay of less than 200 ms for achieving the switching procedure. The implementation provides benefits for wireless sensor networks and the Internet of Things, improving the availability and resilience of sensor nodes by complementing radio-sensitive environments for critical data transmission.

Integrated Sensing and Communications Using a Plastic Optical Fibre on a Robotic Arm

Raul Zamorano-Illanes and Haili Ma (Northumbria University, United Kingdom (Great Britain)); Klara Eollos-Jarosikova (Czech Technical University in Prague, Czech Republic); Qiang Wu (Northumbria University, United Kingdom (Great Britain)); Stanislav Zvanovec (Czech Technical University in Prague, Czech Republic); Zabih Ghassemlooy (Northumbria University, United Kingdom (Great Britain)); Natalia Hernandez-Yanez (Universidad de Santiago de Chile, Chile); Ismael Soto (University of Santiago, Chile)

This work explores visible light communications for integrated sensing and communication using a 1 m long plastic optical fibre (POF) attached to a robotic arm. The proposed low-cost architecture uses the RS-485 protocol at 9600 bps with a unipolar NRZ-format for intensity modulation of a light-emitting diode and a photodiode at a camera as receivers (Rxs). Bending-induced optical power variations are investigated for joint angle estimation through fibre curvature-induced attenuation. Using automatic gain control at the receiver allows maintaining a constant signal-to-noise ratio (SNR) of 26 dB across the full motion range, thereby providing a gain improvement of 7.59 dB at maximum attenuation. Using a rolling shutter camera the radiated light from POF is captured with a measured SNR of 11.3 dB at the exposure time of 0.4 ms.

Analysis of Positioning Performance Degradation Under Receiver Model Mismatch in PV-Based VLP

Julian Solis, Raul Zamorano-Illanes, Zabih Ghassemlooy and Qiang Wu (Northumbria University, United Kingdom (Great Britain)); Xicong Li (University of Glasgow, United Kingdom (Great Britain)); Stanislav Zvanovec (Czech Technical University in Prague, Czech Republic); Hoa Le Minh (Northumbria University, United Kingdom (Great Britain))

Visible light positioning using photovoltaic (PV) cells offers a promising solution for energy-autonomous indoor localization. However, PV cells exhibit limited frequency response and nonlinear characteristics, introducing systematic performance differences due to batch-to-batch variations. This paper investigates the impact of inter-PV variation on the positioning accuracy using experimental measurements and an analytical framework based on model misspecification theory. Using this framework, the trade-off between the linearisation and positioning error was evaluated. The results show that the inter-PV variance reaches 1.85%, limiting the achievable accuracy, where the bias introduces an error up to 19 cm at distances over 1.5 m. This is reduced by over 90% using angle diversity. These findings were experimentally validated using a pyramid receiver, demonstrating a 54% reduction average error with the designed receiver and an average of 3.16 cm error over a 1.6 m x 1.6 m area.

1 Gbit/s LiFi over Powerline Using VCSEL Arrays

Atiyeh Pouralizadeh (Fraunhofer Heinrich Hertz Institute & Technische Universität Berlin, Germany); Malte Hinrichs (Fraunhofer Heinrich Hertz Institute, Germany); Dennis Goodson (Fraunhofer Institute for Telecommunications Heinrich Hertz Institute, Germany); Lennert Bober and Christoph Kottke (Fraunhofer Heinrich Hertz Institute, Germany); Ronald Freund (Fraunhofer HHI, Germany); Volker Jungnickel (Fraunhofer Heinrich Hertz Institute & Technische Universität Berlin, Germany); Andrea M Tonello (University of Klagenfurt, Austria)

We demonstrate a LiFi over powerline link reaching 1.007 Gbit/s, utilizing an amplify-and-forward scheme with OFDM and optimal bit and power-loading. Both LED- and VCSEL-based LiFi transmitters are investigated for wireless link lengths up to 2 m to assess the performance under practical indoor conditions. Over a cascaded 0.8 m LED link with powerline deployed under a wall, a net data rate of 516 Mbit/s with LDPC FEC rate of 5/6 is achieved. At the same received power level, a cascaded PLC-VCSEL link reaches a net data rate of 924 Mbit/s. We also manage for the first time to reach 1.007 Gbit/s using LiFi over powerline for a 30 cm link length with a single photodiode receiver.

Thursday, July 16

Thursday, July 16 9:10 - 10:00

Plenary talk 3: Prof. Martin Dawson "Micro-LEDs for optical wireless communication and digital lighting"

Room: Pentland

Thursday, July 16 10:00 - 11:00

SS03-01: Teletraffic Models, Traffic Engineering and Network Optimization

Room: Pentland East

On Cell-Size Distributions in Poisson-Voronoi Tessellations and Resource-Sharing Fractions in Cellular Networks

Yusuke Miyamori, Koki Takahashi, Guanzhou Chen and Shigeo Shioda (Chiba University, Japan)

In cellular networks modeled by stochastic-geometry, a typical user is more likely to lie in a larger Voronoi cell than a uniformly selected cell. This "zero-cell bias" matters because larger cells tend to contain more competing users and may degrade user performance. We study the area distribution of the zero-cell (the Voronoi cell containing the origin) generated by a stationary point process on the plane, with an emphasis on the Poisson-Voronoi tessellation. Starting from the widely used one-parameter Ferenc-Néda gamma fit for the typical-cell area, we derive a Palm (size-biased) transform to obtain a Palm-consistent PDF of the zero-cell area. We then refine the one-parameter model by (i) moment matching to reproduce the reported mean zero-cell area and (ii) maximum-likelihood estimation using simulated samples of both typical- and zero-cell areas, while preserving Palm consistency. Using these fitted distributions, we evaluate the resource-sharing fraction when users divide radio resources within each cell. The resource-sharing fraction is expressed as an integral of the Laplace transform of the zero-cell area and admits a closed form under the Ferenc-Néda family. Numerical results show that the parameter-optimizing this metric depends on user density, and that the relative performance of the refinements versus the original Ferenc-Néda parameter varies across density regimes. We also compare with a three-parameter generalized-gamma fit, which attains consistently high accuracy at the cost of numerical integration.

MDT-Based Automated Antenna Tilt and Cell Overlap Optimization in Live LTE/5G Networks

Armen Ayvazyan (Ucom, Armenia); Lilia Husikyan (National Polytechnic University of Armenia, Armenia); Narek Velitsyan (Yerevan State University, Armenia)

This paper presents a field-implemented and validated solution for automated antenna tilt optimization and cell overlap reduction using Minimization of Drive Tests (MDT) data collected from commercial user equipment. The proposed closed-loop algorithm leverages real user radio measurements obtained via Geo Interface Tracer to dynamically adjust antenna tilt, reducing inter-cell interference and improving signal quality. Field results from a live network demonstrate significant improvements in overlap reduction, SINR distribution, and mobility performance.

Average Sojourn Time of Bundle Considering SDA Behavior in DTN

Fumika Matsuo, Sumiko Miyata and Katsunori Yamaoka (Institute of Science Tokyo, Japan)

This study evaluates the performance of Delay Tolerant Networking (DTN), which ensures reliable communication under long delays and frequent disruptions such as in space communications. In DTN, the Licklider Transmission Protocol (LTP) aggregates multiple bundles into a block. However, previous research has analyzed only block-level queues and disregarded the bundle waiting time required for block formation, thereby underestimating the average sojourn time. In contrast, the proposed model provides a theoretical foundation for determining the aggregation size. By identifying the discrepancies in sojourn time estimation compared to the previous study, this work helps prevent unintended queue overflow and bundle loss caused by TTL expiration. To this end, we formulate a model that maps bundle arrival and aggregation to a bulk-service queueing system, which allows for the accurate evaluation of average delay and queue length, including the formation time. Numerical results and simulations demonstrate that the proposed model yields larger average number of customers in the system and longer sojourn time than those reported in the previous study. The high degree of agreement between the analytical and simulation results validates the accuracy of the proposed model.

Intersymbol Interference-Free Nyquist Pulse Shaping Using Quadratic Bézier Curves

Dimitrios Tyrovolas (University of Patras, Greece); Shayan Majumder (Heriot-Watt University, United Kingdom (Great Britain) & LibreCube, Germany); Spyridon Nektarios Daskalakis (Heriot-Watt

University, United Kingdom (Great Britain)); George K. Karagiannidis (Aristotle University of Thessaloniki, Greece); Stylianos D. Asimonis (University of Patras, Greece)

This paper introduces a novel family of intersymbol interference (ISI)-free Nyquist pulses constructed using quadratic Bezier curves. In contrast to conventional pulse shaping approaches that rely on fixed trigonometric or polynomial basis functions, the proposed design methodology exploits the inherent geometric flexibility of Bezier curves to precisely control the frequency response roll-off characteristics. This framework introduces a tunable control point whose coordinates are systematically optimized to minimize the bit error rate (BER) under conditions of symbol timing uncertainty. Comprehensive numerical evaluations demonstrate that the resulting Optimal Bezier Pulse (OBP) achieves superior performance compared to the classical raised-cosine pulse and other state-of-the-art parametric pulse designs across a wide range of roll-off factors, exhibiting enhanced robustness against timing jitter impairments.

On Blocking Probabilities in an Erlang Loss System with Server Failures and a Single Repair Facility

Konstantinos Lolis (Hellenic Open University, Greece); Marinos Vlasakis and Ioannis Moscholios (University of Peloponnese, Greece); Eirini Keramidi (University of the Peloponnese, Greece); Dimitris Uzunidis (National Centre of Scientific Research Demokritos, Greece); Georgios Bouloukakis (University of Patras, Greece & Télécom SudParis, IP Paris, France); Michael D. Logothetis (University of Patras, Greece)

Loss models of fixed capacity constitute a fundamental tool in teletraffic theory, with the classical Erlang loss model being widely used for dimensioning purposes. However, practical communication systems often experience time-varying capacity due to server failures and repairs, which significantly affects Call Blocking Probabilities (CBP). This paper studies an Erlang loss system where busy servers may fail. Failed servers are repaired by a single shared repair facility, while in-service calls are lost upon server failure. Three approaches for determining CBP are reviewed. The first one provides exact results through the solution of a 2D Markov chain but is computationally demanding for large systems. The second, known as the performability method, offers a simple approximation but allows failures of idle servers. The third approximate approach employs state aggregation and restricts failures to busy servers. These two approximate solutions offer computational efficiency, but they cannot ensure consistently accurate performance. To circumvent this limitation, we propose a novel method for the exact and efficient determination of CBP. Through analytical comparisons, we evaluate the accuracy of the approximate methods against the proposed one. Results show that: 1) the third approach consistently outperforms the performability method and 2) the proposed method outperforms the approximate methods.

Thursday, July 16 10:00 - 11:00

SS08/SS10/SS11: Advanced RF and Optical Technologies for 6G

Room: Pentland West

Millimeter-Wave Optical Fiber/FSO Fronthaul Network Deployment with Hollow Core Fiber

Jan Bohata, Jan Vocílka, Stanislav Zvanovec and Matej Komanec (Czech Technical University in Prague, Czech Republic); Radan Slavík (ORC, University of Southampton, United Kingdom (Great Britain))

This paper presents a millimeter-wave (mmW) radio-over-fiber (RoF) fronthaul network employing hollow-core fiber (HCF) in combination with an outdoor free-space optical (FSO) link. Owing to its inherent advantages over standard single-mode fiber (SSMF), such as lower state-of-the-art attenuation, nonlinearity, latency, and chromatic dispersion in the commonly used C-band, HCF represents a promising candidate for future fronthaul networks, in addition to its increasing adoption in

data center applications. A 64-quadrature amplitude modulation (64-QAM) signal at a carrier frequency of 25 GHz was used to transmit data over the proposed fronthaul network consisting of a 1 km-long HCF link followed by the outdoor 100 m long FSO segment. The system performance was evaluated in terms of error vector magnitude (EVM) and phase noise under different erbium-doped fiber amplifier (EDFA) settings compensating for the fronthaul link losses. The minimum achieved EVM was as low as 3.7 % for a signal bandwidth of 20 MHz at a carrier frequency of 25 GHz.

1.5 Gbps Optical Wireless Communications Using Far-Ultraviolet-C Micro-Light Emitting Diodes

Hichem Zimi and Jonathan McKendry (University of Strathclyde, United Kingdom (Great Britain)); Sina Babadi (University of Cambridge, United Kingdom (Great Britain) & Cambridge University, United Kingdom (Great Britain)); Isaac N. O. Osahon (LiFi Research and Development Centre, United Kingdom (Great Britain) & University of Cambridge, United Kingdom (Great Britain)); Othman Isam Younus (University of Cambridge, United Kingdom (Great Britain) & IEEE Member, United Kingdom (Great Britain)); Jan Ruschel, Jens Rass and Sven Einfeldt (Ferdinand-Braun-Institut, Germany); Harald Haas (University of Cambridge, United Kingdom (Great Britain)); Martin Dawson, Sujan Rajbhandari and Johannes Herrnsdorf (University of Strathclyde, United Kingdom (Great Britain))

We demonstrate a far-UVC optical wireless communication system employing µLED transmitters emitting at 235 nm. Reducing the device dimensions to the micro-metre regime decreases the active area, enabling higher current densities and lower junction capacitance, which together enhance the modulation bandwidth relative to conventional large-area AlGaN LEDs. The resulting improvement in high-speed performance allows the intrinsic bandwidth limitations of deep-ultraviolet emitters to be mitigated. Using these µLEDs in a short-range free-space link, data rates of up to 1.5 Gbps are achieved. These results highlight the potential of far-UVC µLED technology for compact, solar-blind optical wireless communication systems requiring high data throughput.

Few-Mode Reception and Coherent Digital Combining for Turbulence-Resilient FSO Links

Davide Recano (Instituto de Telecomunicações, Portugal); Manuel Freitas (University of Aveiro, Portugal); Gil Fernandes (Instituto de Telecomunicações, Portugal); Andrea Carena (Politecnico di Torino, Italy); Paulo P Monteiro (Universidade de Aveiro & Instituto de Telecomunicações, Portugal); Fernando Guiomar (Instituto de Telecomunicações, Portugal)

This work investigates turbulence-resilient coherent free-space optical (FSO) communication using receiver-side spatial diversity enabled by a multi-plane light converter (MPLC). The proposed approach combines mode-selective few-mode reception with coherent digital combining to mitigate turbulence-induced fading without adaptive optics or increased transmitted power. After turbulent propagation, the received beam is decomposed by the MPLC into four Hermite-Gaussian (HG) modes (HG00, HG01, HG10, HG11), which are coherently combined in digital signal processing (DSP) using a multiple-input single-output (MISO) equalizer. Experimental results under progressively increasing turbulence strength show that multi-mode combining significantly stabilizes the received signal by reducing deep fades and suppressing bursty error events. Bit Error Rate (BER) statistics demonstrate a clear diversity gain: transitioning from single-mode reception (HG00) to four-mode combining shifts the median BER from 4.29×10^{-3} to 1.19×10^{-4} (approximately 36× improvement). Two-mode combining already provides a substantial intermediate gain. These results confirm that MPLC-based mode-selective reception with coherent digital combining offers a practical and scalable solution to enhance reliability in coherent FSO links under atmospheric turbulence.

Remote Photonics Heterodyning for Seamlessly Converged Fibre-RF Networks with Sub-6 GHz/mmW Access

Jaime Romero (Universitat Politecnica de Valencia, Spain); Jose Mora (Universidad Politécnica de Valencia, Spain); Luis Vallejo (Bangor University, United Kingdom (Great Britain)); Beatriz Ortega

(ITEAM Research Institute, Spain); Jianming Tang (Bangor University, United Kingdom (Great Britain))

This paper proposes a spectrally efficient, scalable, and cost-effective convergent radio-over-fiber (RoF) architecture designed to support the seamless coexistence of baseline services over sub-6 GHz and advanced services by mmW as the coverage and capacity layers, respectively. The proposed transmitter leverages: a) external modulator (MZM)- based optical remodulation of data-carrying optical signals produced by free-running directly modulated lasers (DML), and b) remote heterodyne detection (RHD)-based generation of mmW carriers. The dual-stage modulation allows for simultaneous transmissions of both baseline and advanced services. The demonstrated network drastically simplifies the optical network unit (ONU) by eliminating the need for complex local oscillators (LOs) or synchronization loops at the receiver. Experimental validations demonstrate successful simultaneous transmissions of two independent 500 MHz 16-QAM OFDM data streams, operating at 2.4 GHz for direct detection and 35.5 GHz for mmW access, confirming the system's suitability for next-generation flexible access networks.

Online UAV Trajectory Planning Under QoS Constraints to Mobile Users in Urban Environments

Chenrui Qiu (London South Bank University, United Kingdom (Great Britain)); Loizos Kanaris (Sigint Solutions Ltd, Cyprus); Yongxu Zhu (Southeast University, China); Tasos Dagiuklas (London South Bank University, United Kingdom (Great Britain))

This paper studies real-time trajectory planning and radio resource allocation for a single uncrewed aerial vehicle (UAV) serving multiple mobile ground users in an urban environment. The downlink system considers heterogeneous user mobility, where independent users and group users coexist and interact. To ensure reliable communication, quality-of-service (QoS) constraints are imposed by requiring the instantaneous data rate of each user to satisfy a minimum threshold whenever feasible. A capacity limited high-altitude platform (HAP)-assisted wireless fronthaul is further considered to capture practical network-side transmission limitations. Under these constraints, the UAV updates its position at each time slot, while QoS-aware bandwidth and power are jointly allocated under total bandwidth and transmit power constraints to maximize system throughput. Due to user mobility and urban blockages, the resulting problem is highly nonconvex and time-varying. An online reinforcement learning (RL) based approach is adopted for real-time UAV trajectory optimization. Simulation results show that the proposed method satisfies the QoS, fronthaul, and radio resource constraints and achieves a balanced trade-off between throughput and user fairness.

Thursday, July 16 10:00 - 11:00

SS12: Performance-centric Design of ML-DL Systems across IoT Edge and Cloud

Room: Prestonfield

Lightweight Hybrid ML-Based RAT Steering for Immersive HTC in WiFi-6G Networks

Bharat Agarwal (Emerson/NI, Germany); Gabriel-Miro Muntean (Dublin City University, Ireland)

This paper introduces ML-HNSA, a hybrid heuristic and machine learning-based framework designed for intelligent, context-aware Radio Access Technology (RAT) selection in heterogeneous wireless environments supporting Holographic-Type Communications (HTC). Unlike previous works that focus solely on predictive accuracy, ML-HNSA combines domain-specific QoS thresholds and application-aware scoring with supervised learning models to make adaptive and interpretable RAT decisions. A labeled dataset comprising 1,000 samples (derived from over 5,000 raw simulation data points after filtering and validation) was generated via ns-3.40 simulations under realistic network conditions and diverse user contexts. Five ML models-Decision Tree, Random Forest, SVM, Logistic Regression, and K-

Nearest Neighbors- were evaluated on predictive accuracy, computational complexity, and real-time suitability. Random Forest achieved the highest F1-score (92.7%), while Decision Tree offered the best trade- off between accuracy (88.5%), latency, and interpretability. The results validate the feasibility of deploying lightweight, application-specific RAT selection mechanisms at the network edge, advancing the state of QoE-aware, adaptive connectivity for next-generation immersive media applications.

Optimizing Magnetic Resonance Image Segmentation Through Scalable Deep Learning and Hierarchical Data Management

Lídices Reyes-Hung (University of Santiago of Chile & Centre for Multidisciplinary Research in Telecommunication Technologies, Chile); Gabriel Trinke (Universidad de Santiago de Chile, Chile); Ismael Soto (University of Santiago, Chile); Joel Serey (Universidad de Santiago de Chile, Chile)

Automated glioma segmentation in multi-modal magnetic resonance imaging (MRI) is critical in clinical neuro-oncology, yet it is challenged by large data volumes, tumor heterogeneity, and class imbalance. This study proposes an efficient and scalable system based on an optimized 2D U-Net architecture, integrated within a data engineering workflow utilizing HDF5. This integration enables processing large MRI datasets without loading the entire dataset into memory. The proposed method is evaluated on the public BraTS2020 benchmark using T1, T1ce, T2, and FLAIR modalities. The model achieved a Dice coefficient of 0.884, sensitivity of 0.851, specificity of 0.992, and an average Hausdorff distance of 4.2 mm on the test set. These results indicate segmentation accuracy consistent with expert annotations. Training was stable and converged within 15 epochs, attributed to the use of a Coefficient Dice loss function and batch normalization. Computationally, the 2D approach reduced the number of trainable parameters to approximately 7.8 million, allowing training and inference on consumer-grade GPUs with less than 8 GB of memory. The findings suggest that integrating an efficient model with optimized data management achieves a balance between segmentation accuracy and computational efficiency, making this approach suitable for resource-constrained clinical environments.

Performance Prediction of Data-Rebalancing Actions in Sharded NoSQL Clusters

Georgios Paterakis (University of Patras, Greece); Efstratios Ntallaris (Foundation for Research and Technology, Greece); Kostas Magoutis (Forth-ICS, Greece); Ioannis Moscholios (University of Peloponnese, Greece); Georgios Bouloukakis (University of Patras, Greece & Télécom SudParis, IP Paris, France)

Scalable storage systems typically provide mechanisms for re-distributing data over time to ensure a balanced storage allocation. Such mechanisms have traditionally been considered as background activities meant to run at low priority, to avoid penalizing applications accessing storage. In this work, we focus on an alternative design point where data re-distribution is run as a high-priority activity, meant to re-balance data at the full speed allowed by the newly added resources. Such rapid redistribution has become viable in recent years due to the rise of low-overhead technologies in the networking and disk storage space. A challenge in such a scenario is to schedule data transfer flows to newly added nodes in a way that fully and efficiently utilizes network, CPU, and disk resources in the new nodes, while avoiding overload. To understand the impact of different parameters of the rebalance process, such as the number of simultaneous senders, we develop a queueing network (QN) model of the process used in MongoDB, and describe a preliminary evaluation of performance prediction by the QN model via simulations.

An Efficient Dual-Specialist Framework for Real-Time Epileptic Seizure Detection and Prediction

Peter A. AKor, Hadi Larijani, Rajiv R. Singh, Muhammad Usman and Enemali Godwin (Glasgow Caledonian University, United Kingdom (Great Britain))

Real-time epileptic seizure monitoring requires simultaneous detection and prediction capabilities, yet existing systems address only one task, leading to either delayed response or excessive false alarms. This paper presents a dual-specialist deep learning framework that performs concurrent seizure

detection and prediction through three key innovations: (1) seizure-sensitive preprocessing with cross-frequency coupling detection and adaptive channel weighting, (2) complementary dual-specialist architecture where a detection specialist optimizes for rapid response while a prediction specialist optimizes for conservative forecasting, and (3) probabilistic temporal state machine providing interpretable risk assessment through four clinical states with sustained evidence validation. Evaluation on the CHB-MIT database using Leave-One-Seizure-Out crossvalidation across 20 patients (98 seizures, 851.1 hours) demonstrates 99.2% sensitivity, 99.7% specificity, and 0.31/h false alarm rate with 7.9-minute average warning time, achieved with 1.2M parameters and 1.58M multiply-accumulate operations. Real-time Raspberry Pi 4 deployment achieves 108.0 ± 13.5 ms inference latency, validating practical edge deployment. The framework demonstrates potential for wearable seizure monitoring applications with improved false alarm control.

Thursday, July 16 11:30 - 12:30

Coll2-02: Optical Fiber Devices and Sensing applications

Room: Pentland East

Instrument Development of All Fiber Coherent Raman Scattering Microspectroscopy

Junfeng Jiang, Jinchao Dou, Wei Cheng, Genming Dong, Xiaoshuang Dai, Kun Liu and Shuang Wang (Tianjin University, China); P. Yan (Shenzhen University, China); Jinying Ma (Tianjin University of Technology and Education, China); Xin Zhou (Tianjin Medical University General Hospital, China); Hengfeng Yan (Inno Laser Technology, China); Qiang Fu and Jianbin Yang (Shenzhen University, China); Youjian Song (Tianjin University, China)

We propose and demonstrate a coherent Raman scattering (CRS) fiber format configuration in source, transmission and probe. A wide-range tunable fiber-based optical parametric oscillators (FOPO) synchronously pumped by a tunable mode-locked fiber laser (TMFL) is developed as the CRS laser source. And the feasibility of its application is verified through the coherent anti-Stokes Raman scattering (CARS) signal detection. A hollow-core anti-resonance fiber (HC-ARF) with low loss in the excitation wavelength band of coherent Raman scattering is developed. And based on the specially fabricated HC-ARF, a microsphere-based fiber focusing probe is developed, and the piezoelectric-driven scanning of the optical fiber probe is studied, holding significant potential for applications in nonlinear optical imaging such as CRS imaging.

High-Spatial-Resolution Phase-Chaos Brillouin Optical Correlation-Domain Sensing

Yahui Wang, Jian Li, Lijun Qiao and Mingjiang Zhang (Taiyuan University of Technology, China)

A novel Brillouin optical correlation-domain analysis scheme based on a phase-chaos laser is proposed and experimentally demonstrated to eliminate the intrinsic noise structure of the light source. By reducing the interference from amplitude fluctuation and correlation characteristics on the extraction of a pure Brillouin gain in the traditional chaos, the signal-to-noise ratio is improved. Simulations show a 6.88 dB signal-to-background ratio (SBR) improvement over 100 km sensing range. Experimentally, the PCL is generated, yielding a Brillouin frequency shift accuracy of ±0.64 MHz, a 10.77 dB SBR increase over 1.4 km, and a 4.8 mm spatial resolution with 290,000 effective sensing points.

SPR-TFBG Fibre-Optic Sensor for Nitrite Detection: Simulation and Wavelength-Shift Quantification

Liliana Martínez (University of San Juan Argentina, Argentina); Milagros E. Romero and Facundo Amarfil (Universidad Católica de Cuyo, Argentina); Natalia Hernandez-Yanez (Universidad de Santiago de Chile, Chile); Raul Zamorano-Illanes (Northumbria University, United Kingdom (Great

Britain)); Ismael Soto (University of Santiago, Chile); Qiang Wu (Northumbria University, United Kingdom (Great Britain))

This paper presents a simulation-based evaluation of a surface plasmon resonance (SPR) sensor based on tilted fibre Bragg gratings (TFBGs) for nitrite detection. The proposed framework combines a wavelength-shift calibration model with a low-complexity quantification algorithm, enabling direct mapping from the SPR resonance wavelength shift to nitrite concentration. Simulation results reveal a clear logarithmic relationship between the SPR wavelength shift and analyte concentration, supporting reliable inverse estimation. The simulated transmission spectra demonstrate that refractive index variations induced by nitrite binding produce well-resolved and monotonic SPR resonance shifts, which can be robustly extracted in the wavelength domain. This wavelength-based sensing metric reduces sensitivity to amplitude fluctuations and baseline drift, making the approach suitable for practical fibre-optic sensing scenarios. Overall, the results establish a consistent theoretical and algorithmic basis for SPR-TFBG-based nitrite sensing and provide a foundation for future experimental validation and real-time monitoring applications.

Real-Time Optical Performance Monitoring of Microcomb-Based WDM Signals Using a Fourier-Domain Vector Oscilloscope

Li Lun (Hong Kong Polytechnic University, Hong Kong); Chi Zhang (Huazhong University of Science and Technology, China); Hwa-yaw Tam and Chao Lu (The Hong Kong Polytechnic University, Hong Kong)

We demonstrate synchronous real-time optical performance monitoring of microcomb-based WDM signals via a Fourier-domain optical vector oscilloscope. Frequency-to-time mapping with chirped coherent detection enables single-acquisition retrieval of multi-channel amplitude and phase information without local oscillator source sweeping. Experimental characterization of 16 × 40 Gbit/s QPSK signals verifies a scalable approach for high-capacity microcomb-enabled transmission systems.

A Symmetrical Three-Pulse Differential Cross-Spectrum BOTDR Sensor for High BFS Resolution with Sub-Meter Spatial Resolution

Intan Fatimah Sasila Ghadzali, Ain Nabihah Mohammad Rihan and Mohd Saiful Dzulkefly Zan (Universiti Kebangsaan Malaysia, Malaysia); Yosuke Tanaka (Tokyo University of Agriculture and Technology, Japan); Mohd Hadri Hafiz Mokhtar, Norhana Arsad and Ahmad Ashrif A. Bakar (Universiti Kebangsaan Malaysia, Malaysia)

This paper explains the proof-of-concept of a symmetrical three-pulse configuration integrated with our previously proposed differential cross-spectrum (DCS) technique to enhance Brillouin frequency shift (BFS) resolution in a Brillouin optical time domain reflectometry (BOTDR) sensor. By symmetrically embedding two 10 ns auxiliary pulses around a central 2 ns pulse, the proposed method effectively increases the spontaneous Brillouin scattering (SpBS) interaction compared to the conventional DCS-BOTDR method, without broadening the effective pulse duration. Experimental results over 1.16 km single-mode fiber demonstrate a sub-meter spatial resolution measurement of 0.2 m and an identification of an 8 m heated section. The heated section is also accurately resolved with a measured BFS of 29 MHz that corresponds to about 29 °C of temperature difference. Statistical analysis across varying acquisition settings (5,000 to 20,000 averages) confirms the stability of the enhancement, with the three-pulse configuration providing a consistent 3.0 dB in SNR improvement over the conventional method. At 20,000 times of average, the technique achieved 1.62 MHz BFS resolution measurement, confirming its effectiveness for high-precision distributed temperature sensing.

Thursday, July 16 11:30 - 12:30

GT-04: 6G Communications

Room: Prestonfield

Joint Direct Time-of-Flight Ranging and Communications with Pulse Position Modulation

Callum T Geldard (STMicroelectronics Edinburgh, United Kingdom (Great Britain))

This paper presents a method of achieving simultaneous data transmission and direct time of flight (DToF) ranging based on pulse position modulation (PPM). The implementation of the technique is described and its performance is evaluated using Monte-Carlo simulation. It is demonstrated that combining the two techniques in a single transmitted waveform does not degrade the performance of PPM whilst providing a solution to the range ambiguity problem in DToF ranging.

A Nullspace-Fitting Method for Time Synchronization in Multipath 5G NR Systems

Maryam Bacha (Western Sydney University, Australia); Qi Cheng (Western Sydney Unversity, Australia); Ranjith Liyanapathirana (Western Sydney University, Australia)

Most existing time synchronization methods are developed for single-path 5G NR channels. They do not provide satisfactory timing performance for multipath channels. One method was proposed for wireless LAN systems. In principle, it can be used for time synchronization for 5G NR systems. However, an ill-conditioning is encountered in our implementation of that method. Hence, a nullspace-fitting method is proposed for time synchronization in multipath channels, using the first symbol of the synchronization signal/PBCH block (SSB) of 5G NR systems. This method can provide a range of the initial time instants of the first symbol of the SSB. It significantly outperforms some existing methods in time synchronization.

Deep Learning Based Co-Channel Interference Mitigation for Satellite Communication Systems

Mirela Fetescu (Joanneum Research, Austria & Graz University of Technology, Austria); Johannes Ebert (Joanneum Research, Austria); Martin Winter (Joanneum Research Forschungsgesellschaft mbH, Austria); Franz Teschl (Graz University of Technology, Austria)

Co-channel interference (CCI) has become a primary performance limiter in modern high throughput satellite (HTS) systems, where aggressive frequency reuse causes users, especially near beam edges or overlapping regions, to receive interfering signals with power comparable to the desired one. Therefore, this paper presents a deep learning (DL) receiver for CCI mitigation in DVB-S2/S2X satellite links. A two-satellite scenario is considered in which the desired and interfering signals share the same carrier and traverse an additive white Gaussian noise (AWGN) channel. The database consists of a large symbol level of clean and interfered complex baseband sequences with a DVB-S2/S2X compliant RadioLAB simulation chain. A 1D U-net is trained as a modulation agnostic reconstruction model on the real and imaginary parts of the received symbols, enabling soft decision decoding after interference mitigation. Frame error rate (FER) performance is evaluated for different modulation formats, interferer bandwidth ratios, and signal-to-noise ratio (SNR) levels, and compared against a no-mitigation baseline, with selected results also benchmarked against a classical Wiener filter approach. The proposed DL approach leads to significant information gains for narrowband or simpler modulated interferers.

Experimental Evaluation of Phase Noise Impact on OFDM at D-Band with Common Phase Error Based Phase Recovery

Yalin Zhou and Izzat Darwazeh (University College London, United Kingdom (Great Britain))

Sub-terahertz and D-band(110-170GHz) wireless systems offer large bandwidths for ultra-high data rate transmission, but are severely challenged by oscillator phase noise enlarged by frequency-multiplication-based carrier signal generation. This work experimentally investigates the impact of 153 GHz carrier phase noise on Orthogonal Frequency Division Multiplexing (OFDM) signal transmission by

using three signal sources with different integrated root-mean-square(rms) jitter characteristics with frequency multiplied based generation. A tracking-based phase recovery scheme, with symbol-wise common phase error, is implemented and evaluated. Experimental results show that phase recovery improves the SNR by up to 4 dB and increases the achievable capacity by up to 3.7 Gbps with 1 GHz bandwidth OFDM signal for phase-noise-limited cases. The results highlight the critical role of phase recovery in practical D-band OFDM systems.

Geometry-Based Channel Quality Prediction Under Unknown RIS Configuration

Chisom Michael Onyekwelu, Yooncheol Choi and Dongweon Yoon (Hanyang University, Korea (South))

Reconfigurable intelligent surfaces (RISs) are typically studied under cooperative assumptions with known phase configurations and channel state information (CSI). In practice, however, RISs deployed on building façades may operate autonomously, rendering their configurations unknown to user equipment (UE). This paper considers a non-cooperative RIS-assisted vehicular scenario where a mobile receiver communicates with a fixed base station without access to RIS phase information or cascaded CSI. We develop a geometry-based signal model with random RIS phase configurations and show that, despite instantaneous randomness, the mean received signal strength indicator (RSSI) depends deterministically on the UE position. Leveraging this property, we formulate channel quality indicator (CQI) prediction as a nonlinear state estimation problem and propose an extended Kalman filter (EKF)-based framework that fuses noisy position and RSSI measurements. Simulation results demonstrate that the proposed framework achieves nearly a 57% reduction in CQI prediction RMSE as the RIS size increases from N = 16 to N = 1024, highlighting its effectiveness for RIS-assisted communication without RIS cooperation.

Thursday, July 16 11:30 - 12:30

SS05-02: Optical and Wireless Sensor Networks for 6G

Room: Pentland West

Real-Time PWM Recovery in Rolling Shutter OCC Using Header-Based Packet Detection: An Experimental Study

Atiya Fatima Usmani (University of Aveiro, Portugal); Raul Zamorano-Illanes and Qiang Wu (Northumbria University, United Kingdom (Great Britain)); Pedro Fonseca (University of Aveiro, Portugal & Instituto de Telecomunicações, Portugal); Stanislav Zvanovec (Czech Technical University in Prague, Czech Republic); Zabih Ghassemlooy (Northumbria University, United Kingdom (Great Britain)); Luis Nero Alves (DETI, Universidade of Aveiro, Portugal & Instituto de Telecomunicações, Portugal)

OCC (optical camera communication) using rolling shutter cameras enables low-cost optical wireless communication) with light-emitting diodes. PWM (pulse width modulation) is well suited for such systems due to its simplicity and compatibility with LED-based transmitters. In this paper, we experimentally demonstrate real-time PWM signal recovery in a rolling shutter OCC system using header-based packet detection and extraction. The rolling shutter effect converts temporal PWM variations into spatial intensity patterns, from which an intensity profile is extracted to detect packet headers and recover the transmitted PWM-modulated data in real time. Experimental results confirm reliable real-time packet detection and symbol recovery, validating the feasibility of the proposed approach.

A Robust Whispering-Gallery-Mode Resonator Platform for Refractive Index Sensing

Yiming Shen (Technological University Dublin, Ireland & Eblana Photonics, Ireland); Hongyan Xia, Haili Ma, Adeel Faruq and Yingchao Liu (Northumbria University, United Kingdom (Great Britain)); Zhe Wang (Technological University Dublin, Ireland); Zabih Ghassemlooy (Northumbria University, United Kingdom (Great Britain)); Bo Cai (Eblana Photonics, Ireland); Yuliya Semenova (Technological University Dublin, Ireland); Qiang Wu (Northumbria University, United Kingdom (Great Britain))

Whispering-gallery-mode (WGM) resonators offer superior optical confinement and higher resolution for bio-chemical sensing compared to conventional fiber interferometers. However, traditional functionalization often relies on thick polymer coatings that introduce structural instability and hinder direct light-matter interaction. In this work, we propose a robust, coating-free WGM resonator platform featuring a molecular-level surface functionalization strategy. A key innovation is the "closed-vessel" surface modification process, which protects the fragile sensing region from mechanical damage and contamination. For practical implementation, a specialized 3D-printed sensor holder is developed to enable liquid-phase measurements with minimal analyte volume. A wavelength shift of 0.15549 nm is observed when changing the liquid from deionized water to pH 0.44 hydrochloric acid. Experimental results using a bare-fiber resonator demonstrate excellent reversibility and structural integrity when cycling between deionized water and acid solutions. The proposed platform is easy to fabricate and offers a versatile template for various reliable sensing applications, ranging from environmental monitoring to real-time chemical detection.

Cellular Automaton-Based Modelling for Fire Monitoring over LoRa Links

Juan Yentzen (Universidad de Santiago de Chile, Chile); Ismael Soto (University of Santiago, Chile); Felipe Salgado (USACH, Chile); Enrique San Juan (University of Santiago de Chile, Chile); Cesar Azurdia (Universidad de Chile, Chile)

This paper presents the modelling and experimental validation of a 915 MHz LoRa (Long Range) wireless link as a resilient communication layer for a wildfire monitoring and simulation platform based on cellular automata. The work addresses the need for reliable environmental sensing under infrastructure-constrained conditions, where ground IoT nodes provide temperature, humidity, and wind observations used to initialise and update ignition and fire spread dynamics. LoRa is evaluated as a Low Power Wide Area Network (LPWAN) technology for environmental telemetry in such scenarios. The methodology combines link-budget analysis, an Additive White Gaussian Noise (AWGN) reference simulation for Bit Error Rate (BER), Symbol Error Rate (SER), and Packet Error Rate (PER), and an outdoor field campaign using Received Signal Strength Indicator (RSSI), Signal-to-Noise Ratio (SNR), and packet reception statistics. Results suggest that communication-layer performance may impact the availability and reliability of environmental data feed- ing the cellular automaton, thereby influencing the operational fidelity of wildfire monitoring and prediction systems.

Low-Complexity Line Coding for Baseline Wander Mitigation in OOK-Based Optical WBANs

Christos Giachoudis and Ali Khalighi (Ecole Centrale Méditerranée, France); Stanislav Zvanovec (Czech Technical University in Prague, Czech Republic)

Wireless Body Area Networks (WBANs) are gaining prominence for remotely monitoring the physiological signs of patients and elderly individuals. In this work, we consider the use of infrared signal transmission to transfer sensor-acquired medical data to an access point. Such WBAN links are characterized by a typically low-to-moderate data rate range, on the order of hundreds of bits-per-second (bps) to a few Mbps. We examine a key challenge inherent to the physical layer, i.e., the so-called baseline wander (BLW) effect, when using pulsed modulation schemes such as on-off-keying. To mitigate this effect, we investigate the use of simple Manchester and 8B/10B line coding techniques, and evaluate the link performance using both numerical simulations and experimental measurements. The results highlight the suitability of Manchester coding, which combines good performance with low implementation complexity, which is an important requirement in WBANs.

Embedded Pilot Asymmetrically Clipped Optical OFDM (EPACO-OFDM) for Enhanced Spectral Efficiency and PAPR Reduction in VLC

Marco Yacelga-Pinto (Universidad Carlos III de Madrid, Spain); Víctor P. Gil Jiménez (University Carlos III of Madrid, Spain); Riera Palou (University of the Balearic Islands (UIB), Spain); Guillem Femenias (University of the Balearic Islands, Spain)

In visible light communications (VLC), early standard modulations, such as direct current-biased optical OFDM (DCO-OFDM) and asymmetrically clipped optical OFDM (ACO-OFDM), have limited spectral efficiency (SE), high peak-to-average power ratio (PAPR), and constrained data transmission rates. This paper proposes an Embedded Pilot ACO-OFDM (EPACO-OFDM) to address these limitations using a two-layer structure. The first layer is exclusively for data transmission, while the second layer embeds pilot sequences. This architecture achieves a significant improvement in SE while simultaneously enabling channel estimation (CE) and reducing PAPR. Simulation results demonstrate that EPACO-OFDM with iterative interference cancellation doubles the effective throughput over classical ACO-OFDM while maintaining equivalent bit error rate (BER) performance at comparable energy per bit to noise power spectral density ratio ($Eb/N0$) levels. The proposed scheme offers a compelling trade-off between SE, estimation accuracy, and implementation complexity for high-speed VLC networks with a PAPR reduction of approximately 0.5-2.0 dB.

Thursday, July 16 2:00 - 2:50

Plenary talk 4: Prof. Nuno Borges Carvalho, "Energy sustainable IoT SWIPT and LEO satellite integration"

Room: Pentland

Thursday, July 16 2:50 - 4:00

Coll1-04: Advanced techniques for OWC

Room: Pentland East

Performance Analysis of Semantic-Aware Optical Wireless Communications

Milica Petkovic (University of Novi Sad, Faculty of Technical Sciences, Serbia); Dejan Vukobratović (University of Novi Sad, Serbia)

This paper analyzes the performance of semantic-aware optical wireless communication (OWC) systems, where uplink users transmit semantic feature representations instead of conventional symbols. A time-structured model with feature extraction and feature transmission phases is considered. Semantic accuracy is captured through a logistic similarity function dependent on the received signal-to-noise ratio. Closed-form expressions are derived for the average semantic rate and the semantic spectral efficiency, revealing how semantic encoding parameters and OWC channel conditions affect the achievable semantic performance.

Hybrid Optical Wireless/RF System for Indoor Health Monitoring of Elderly

Nermine Elmabrouk (Université de Limoges, France); Stéphanie Sahuguède (XLIM UMR CNRS 7252 - University of Limoges, France); Anne Julien-Vergonjanne (University of Limoges & XLIM CNRS 7252, France)

Hybrid Optical/RF systems offer a promising solution for indoor e-health monitoring by reducing RF exposure through the predominant use of optical links, while maintaining reliability via an RF backup in case of optical link interruption. However, their performance under realistic patient mobility remains

insufficiently explored. This paper investigates a hybrid uplink architecture in which a wrist-worn infrared transmitter communicates with a ceiling-mounted photodetector, while a low-power RF link to an access point in an adjacent room ensures connectivity during optical link blockage. Simulation results show that hybrid transmission significantly improves link availability compared with optical-only systems. A sliding-window-based approach is employed to capture the temporal evolution of the channel under mobility and to evaluate a threshold-based hard-switching mechanism. The results highlight a trade-off between handover frequency and optical link utilization, governed by the window size and RF lock duration, which must be optimized according to application requirements.

Novel Multiplier-Optimised Real-Time Radix-4 IFFT Architecture for High-Throughput, Low-Latency Optical OFDM Transceivers on FPGA

Michael Codd (Maynooth University, Ireland); Ciara McDonald (Maynooth University); John Dooley (National University of Ireland Maynooth, Ireland)

Hermitian symmetry constrained optical OFDM in IM/DD transmitters incurs higher computational costs per transmitted bit than conventional complex-valued-OFDM, as only a small subset of the IFFT subcarriers carry independent information. This work introduces a unified optimisation framework that combines juxtaposed IFFT architectures, arithmetic rearrangement for complex multiplication, and a novel deterministic radix-4 pruning strategy tailored for specific optical-OFDM modulation formats. The proposed approach achieves higher numerical precision than comparable radix-2 implementations, operates with up to a twofold reduction in clock cycles, and requires 25%-50% fewer multiplications relative to the current state of art. The architecture is validated on an RFSoC 4×2 platform using a fully parallel, unrolled N = 64 implementation. A maximum operating fabric clock of 153.6 MHz was achieved, corresponding to a throughput of 19.6608 GS/s and a latency of 19.5312 ns, while consuming only 7 200 FPGA LUTs and 168 DSP slices. These characteristics make the proposed architecture well suited to low-power, low-latency, and low-complexity optical transceivers.

Enhancing Security Performance of Optical Wireless Communication with Acoustic Waves in Fog Conditions

Alex Cameron (University of Northumbria, United Kingdom (Great Britain)); Carlos Guerra-Yánez (Czech Technical University, Czech Republic); Stanislav Zvanovec (Czech Technical University in Prague, Czech Republic); Xicong Li (University of Glasgow, United Kingdom (Great Britain)); Zabih Ghassemlooy and Richard Fu (Northumbria University, United Kingdom (Great Britain))

Optical wireless communication is an innovative and cost-effective family of communication systems which rely on modulated lights for high-speed and secure networks. However, sub-optimum atmospheric conditions, natural or man-made, can severely affect the performance of the optical link, because suspended small particles with a different refractive index scatter the light and which results in the loss of power and ultimately reduces the link availability. Furthermore, scattered light can allow third parties to intercept the line-of-sight and eavesdrop on the signals. To solve this crucial issue, we propose applying acoustic signals in the desired target area to enhance both the performance and security of the link. Results from the experimental test using a laboratory fog chamber and 1.2 m wireless optical link show using an acoustic wave strategy (AWS), the eavesdropper window can be reduced by up to 40% while simultaneously improving the main links' visibility, and therefore the related performance metrics.

Robust Wavelet-First Preprocessing for IM/DD-OOK Under Drift and Impulsive Transients

Isabel Silva (Universidad de Santiago de Chile, Chile); Ismael Soto (University of Santiago, Chile); Pablo Palacios Játiva (Universidad Diego Portales, Chile); Raul Zamorano-Illanes (Northumbria University, United Kingdom (Great Britain))

A wavelet-first preprocessing method is proposed for Optical Wireless Communication (OWC) links employing intensity modulation and direct detection with On-Off Keying (IM/DD-OOK) under

compound degradation. Attention is focused on the joint presence of slow baseline drift and intermittent impulsive contamination before threshold-based detection in open optical environments. The drift is estimated through the Stationary Wavelet Transform (SWT), whereas impulsive samples are treated on the residual by means of a segmented Hampel-type detector. An optional translation-invariant denoising stage based on cycle-spinning (CS) is then applied to reduce residual noise while limiting edge attenuation in short OOK-like events. Evaluation is carried out on photometric time series from the All-Sky Automated Survey for SuperNovae (ASAS-SN), used as realistic temporal proxies within a controlled semi-synthetic framework for proof-of-concept validation of receiver-side preprocessing under compound degradation. Event-preservation, drift-suppression, impulse-related, and communication-oriented metrics are reported. Improved drift removal and greater robustness to impulsive contamination are observed, while event contrast is preserved and communication performance remains close to the strongest robust baselines.

A Cascade ISAC Framework for RIS-Assisted Asymmetric RF/VLC Systems

Claudia Leoni (University of Roma Tre, Italy); Vasilis K. Papanikolaou (Friedrich-Alexander-University Erlangen-Nuremberg, Germany); Anna Maria Vegni (Roma TRE University, Italy); Robert Schober (Friedrich-Alexander University Erlangen-Nuremberg, Germany)

Integrated sensing and communications (ISAC) has emerged as a key paradigm for future wireless networks by enabling spectrum- and hardware-efficient coexistence of sensing and data transmission. In parallel, the high spatial confinement and unregulated bandwidth of visible light communication (VLC) make optical ISAC particularly attractive for indoor applications. In this paper, we investigate a system- and Medium Access Control (MAC)-layer cascade-ISAC (C-ISAC) framework, where sensing outcomes explicitly support communication decisions. The proposed C-ISAC framework is applied in an indoor asymmetric Radio Frequency (RF)/VLC system, where RF is used for uplink, while VLC for downlink. An optical Reconfigurable Intelligent Surface (RIS) device is also deployed to assist direct VLC links, which may suffer of link degradation. In C-ISAC framework, infrared (IR) signals are used for sensing, followed by VLC direct links for data transmission, while RIS-aided link are adopted in case of VLC direct link degradation. We analytically characterize the uplink echo throughput during the sensing phase by accounting for collisions, time-slot unavailability, and false detections. Our analysis reveals fundamental trade-offs between network load, sensing reliability, and scalability, and shows how sensing performance directly impacts link selection between direct line-of-sight (LoS) and RIS-assisted non-line-of-sight (NLoS) VLC transmissions.

Thursday, July 16 2:50 - 4:00

GT-05: IOT and Cyber Security

Room: Prestonfield

Physical Layer Security in Finite Blocklength Massive IoT with Randomly Located Eavesdropper

Tijana Devaja (Aalborg University, Denmark); Milica Petkovic (University of Novi Sad, Faculty of Technical Sciences, Serbia); Sokol Kosta (Aalborg University, Denmark); Dejan Vukobratović (University of Novi Sad, Serbia); Čedomir Stefanović (Aalborg University, Denmark)

This paper analyzes the physical layer security performance of massive uplink Internet of Things (IoT) networks operating under the finite blocklength (FBL) regime. IoT devices and base stations (BS) are modeled using a stochastic geometry approach, while single passive eavesdropper is placed at a random location around the transmitting device. This system model captures security risks common in dense IoT deployments. Analytical expressions for the secure success probability, secrecy outage probability and secrecy throughput are derived to characterize how stochastic interference, fading and

eavesdropper spatial uncertainty interact with FBL constraints in short packet uplink transmissions. Numerical results illustrate key system behavior under different network and channel conditions.

IoT as a Cyber Attack Platform: Lessons from Real-World and Proof-of-Concept Incidents

Vassilios G. Vassilakis and Thomas Girdler (University of York, United Kingdom (Great Britain))

The rapid proliferation of Internet of Things (IoT) devices has transformed everyday environments, connecting homes, enterprises, and industrial systems in unprecedented ways. While these devices offer significant convenience and functionality, their widespread deployment coupled with common weak security mechanisms, make them an attractive target for cyberattacks. In this paper, we examine IoT as a cyber attack platform, analysing both real-world incidents and proof-of-concept attacks to understand how compromised devices are leveraged to target other systems. We identify the IoT device vulnerabilities most frequently exploited, classified according to the OWASP Top 10 IoT vulnerabilities, and evaluate the resulting impact on the confidentiality, integrity, and availability (CIA) of targeted systems. Our review highlights the evolving strategies attackers use to harness IoT devices for distributed attacks, from botnets to lateral movement within networks. Based on these insights, we discuss the lessons learned and underscore the critical role of robust security mechanisms in enabling the next generation of secure IoT devices and services.

ZeroScatter-LoRa: Microcontrollers are RFIDs

Shayan Majumder (Heriot-Watt University, United Kingdom (Great Britain) & LibreCube, Germany); Matthew Reynolds (University of Washington, USA); Stylianos D. Asimonis (University of Patras, Greece); Sandeep Joshi (Birla Institute of Technology and Science (BITS) Pilani, India); George Goussetis and Spyridon Nektarios Daskalakis (Heriot-Watt University, United Kingdom (Great Britain))

ZeroScatter-LoRa is an all-digital and zero-added- component technique for Long Range (LoRa) backscatter communication using commodity Microcontroller Units (MCUs). Instead of using traditional Radio Frequency (RF) switches for impedance modulation, it utilizes existing digital peripheral pins of ultra-low-power MCUs, such as Inter-IC Sound (I 2 S), Serial Peripheral Interface (SPI), or Inter-Integrated Circuit (I 2 C), to produce LoRa chirp signals using logic-level changes. We show backward compatibility of ZeroScatter-LoRa with commercial LoRa Wide Area Network (LoRaWAN) gateways in multipath- rich indoor environments with an average power consumption of 9.8 µA. The results show that the monostatic configuration using Universal Software Radio Peripheral (USRP) in full duplex mode has an achievable range of 2.5 m, and the bistatic configuration using a single-tone generator at a distance of 2 m (transmitter- to-tag) has valid packet reception of more than 20 m (tag- to-receiver). The technique is applicable to billions of existing MCUs using high-speed digital interfaces. The long range that is achieved using MCU pins for backscatter communication also suggests that security risks may be present in existing digital systems if digital I/O lines are not electromagnetically shielded from outside signals.

Thursday, July 16 2:50 - 4:00

Invited talk 2

Room: Prestonfield

Thursday, July 16 2:50 - 4:00

SS06: Green and Intelligent RF and Optical Wireless Communication Systems

Room: Pentland West

Retroreflector-Based Channel Estimation for Robust Optical Wireless Communication

Jianhui Chen (University of Edinburgh, United Kingdom (Great Britain)); Egecan Guler (The University of Edinburgh, United Kingdom (Great Britain)); Wasiu O. Popoola (University of Edinburgh, United Kingdom (Great Britain))

This paper presents an optical retroreflector-based channel estimation architecture that addresses the fundamental challenge of maintaining reliable optical wireless communication (OWC) under adverse channel conditions. The proposed retroreflector-based system uses polarisation transformations to achieve autonomous transmitter-side channel state estimation, thereby bypassing the requirement for feedback channels. Experimental validation in turbulent underwater and free-space optics (FSO) OWC channels demonstrates that the adaptive system achieves 3.4 Gbps in underwater OWC channels and 3.52 Gbps in foggy FSO channels, representing 9% and 15% improvements respectively over fixed modulation schemes.

Multi-Region ROI Detection Algorithm for MISO-HSSK Optical Camera Communication Systems Using Hybrid Color Space Filtering

Jonas Elias Peñailillo and Cesar Azurdia (Universidad de Chile, Chile); Vicente Matus (IDeTIC-ULPGC, Spain); Pablo Palacios Játiva (Universidad Diego Portales, Chile); David Zabala-Blanco (Universidad Católica del Maule, Chile); Ismael Soto (University of Santiago, Chile)

Optical Camera Communication (OCC) enables pervasive Internet of Things (IoT) connectivity by leveraging widespread infrastructure; however, robust multi-source detection remains a bottleneck for low-power devices. While Deep Learning detectors like You Only Look Once (YOLO) achieve high accuracy, their computational footprint relies on deep convolutional backbones where computational cost grows superlinearly due to channel depth expansion. This paper presents a novel Multiple-Input Single-Output (MISO) Hue-Saturation Shift Keying (HSSK) system driven by a lightweight Multi-Region Region of Interest (ROI) detection algorithm. Unlike neural approaches, our method exploits the high spectral signature of Light Emitting Diodes (LEDs) within the Hue-Saturation-Value (HSV) color space, applying a hybrid filtering strategy defined by logical thresholding on chromaticity and saturation. By restricting operations to a fixed channel depth, the proposed algorithm ensures strict asymptotic linear complexity relative to the frame size. Experimental validation demonstrates that this heuristic approach effectively isolates multiple transmitters under severe optical interference-rejecting high-intensity achromatic noise like sunlight-while enabling real-time-feasible signal tracking on standard consumer-grade smartphones without the need for hardware acceleration.

A Hybrid VLC-IR Optical Wireless Architecture with Load Balancing for NLoS Tunnels

Nicolás Morales (Universidad de Santiago de Chile & CIMTT, Chile); Ismael Soto (University of Santiago, Chile); Raul Zamorano-Illanes (Northumbria University, United Kingdom (Great Britain)); David Zabala-Blanco (Universidad Católica del Maule, Chile)

This paper presents the evaluation for VLC/IR optical wireless architectures for NLoS-only underground tunnels scenarios, modeling the system as a bidirectional link with VLC uplink and IR downlink, evaluating its performance under a load-balancing approach that reallocates traffic according to link availability. Four configurations are considered, corresponding to levels of directional redundancy. The baseline 1-1 configuration is supported by a practical testbed, whereas the remaining cases are examined through system-level comparative extensions under the same traffic-allocation and link-availability, while the system-level performance is evaluated in relation with the load-balance, including throughput, unmet demand, per-link utilization, and fairness. In addition, an illustrative bit error rate (BER) analysis is used to relate physical-layer behavior with system-level robustness. The results show

that increasing directional redundancy improves service continuity by mitigating throughput degradation during link DOWN events through traffic reallocation. While configurations with single-link directions exhibit single points of failure, the 2-2 configuration achieves the highest aggregate throughput, the lowest unmet-demand ratios, and the most robust behavior under partial link failures. The BER trends further indicate that parallel link availability reduces sensitivity to individual channel degradation, reinforcing the benefits of balanced uplink and downlink redundancy in tunnel environments.

Enhancing the Performance of Free Space Optical Communication Using Wavelet-Based de-Noising

Fanuel Elias, Muhammad Ijaz and Zeyad Elsaraf (Manchester Metropolitan University, United Kingdom (Great Britain)); Sunday Cookey Ekpo (Manchester Metropolitan University & Akwa Ibom State University of Technology, United Kingdom (Great Britain)); Pablo Palacios Játiva (Universidad Diego Portales, Chile); Cesar Azurdia (Universidad de Chile, Chile)

This paper investigates the performance of OOK- NRZ based free space optics (FSO) communication link in the presence of turbulence by employing discrete wavelet transform (DWT) based denoising. The Bayesian wavelet utilising a Haar wavelet as the mother wavelet is evaluated using MATLAB simulations. Performance was primarily evaluated by comparing the Bit Error Rate (BER) before and after denoising. The simulation results demonstrate significant performance gains. The Q-factor improves from 2.056 to 4.030. The noise variance of the received bit "1" is reduced from 0.3262 to 0.1843, while that of logical bit "0" decreases from 0.1663 to 0.0586, resulting in improved signal power. The theoretical BER decreases from 2 × 10−2 to 2.7 × 10−5, and the simulated BER is reduced from 3.1 × 10−2 to 1 × 10−4. These results show a strong agreement between the theoretical and simulation results. The proposed approach provides an effective and simple solution to improve OOK-NRZ based FSO systems operating under turbulence conditions.

Edge-Native AI-Enabled Spatial Decision Region Formation for Optical Attocell-Based Indoor VLC

Rida Zia-ul-Mustafa (University of Bristol, United Kingdom (Great Britain)); Hoa Le Minh and Zabih Ghassemlooy (Northumbria University, United Kingdom (Great Britain)); Stanislav Zvanovec (Czech Technical University in Prague, Czech Republic)

This research study investigates the impact of machine learning (ML) hyperparameters and the training dataset on optical attocell formation in indoor 6G visible light communication (VLC) networks that leverage edge-native artificial intelligence (AI). The work employs a probabilistic neural network (PNN) to form the optical attocell given the user's location, i.e., classifying the VLC transmitter based on its proximity to the user. The numerical simulations show that the distribution and density of the training dataset directly influence the spatial resolution and convergence of classification boundaries, while the variance parameter of the PNN pattern layer, σ 2, governs the smoothness, stability, and generalization of the resulting decision regions. In the presence of a spatially ambiguous training sample, the higher value of σ 2 destabilizes the decision boundaries, resulting in the fusion of attocell regions; conversely, in the case of the limited dataset density with sparse spatial samples, the increase in σ 2 results in stabilized and smooth decision boundaries for attocell formation. The results indicate that the ML-driven optical attocell formation is not fixed by the VLC system's geometrical model, but dynamically adapts to the learning parameters and data availability, hence providing a novel design dimension in practical edge-native AI-based VLC deployments.

Thursday, July 16 4:30 - 5:30

GT-06: Command, Control, and Communication

Room: Prestonfield

A Wing-Borne NVIS Command System

Sergey Karamov (Novus Converged Aerospace Ltd., United Kingdom (Great Britain))

In this paper, Near-Vertical Incidence Skywave (NVIS) communication is analysed for use in tactical and strategic UAVs for command, control, and communication (C3). The developed methodology includes propagation prediction for elevation angle estimation, turnstile antenna polarisation control, and effective control of the take-off angle (TOA) of the antenna's main or local beam maximum. We specifically analyse and present solutions for ultra-low altitude aircraft and UAV flights (typically 50-150 meters). Crucially, we introduce a novel linear equation to determine the optimal transmit frequency configuration depending on the UAV flight altitude and the required radio communication range. We propose integrating the turnstile antenna into the wings and fuselage of the aircraft. Furthermore, the tolerance of the turnstile antenna's elevation directivity as a function of UAV pitch and roll is evaluated. The proposed method of receiving control commands beyond visual line of sight (BVLOS) is highly suitable for very low-flying aircraft utilizing terrain contour matching (TERCOM).

A Multi-Mode Surface Sensing Simulation Framework for UAS Integrating Radio-Frequency, Infrared and Optical Domains

Nikolay Lysenko and Sergey Karamov (Novus Converged Aerospace Ltd., United Kingdom (Great Britain))

This paper presents the Multi-Mode Surface Sensing Simulation Framework (MM3S) for Unmanned Aerial Systems a physics-based simulation framework that generates perfectly co-registered synthetic data across radio-frequency (RF), thermal infrared (IR), and visible spectral domains from a maneuvering Unmanned Aerial Vehicle (UAV). The pipeline supports arbitrary terrain maps, material-specific electromagnetic properties, full-3D antenna pattern synthesis for complex arrays, and accelerated ray-tracing with novel early-ray-culling and precomputed normals. Doppler velocity signatures are computed from platform motion and superimposed on RF returns. The system outputs quad-view video sequences (RF power, IR radiance, visible RGB, Doppler) suitable for training cross-modal perception algorithms. Validation on complex scenarios demonstrates a 2× speedup over baseline Möller-Trumbore implementations while preserving physical accuracy. MM3S addresses the scarcity of labeled multi-modal UAV datasets and enables reproducible evaluation of sensor fusion techniques in challenged environments.

Reliable Dual-Protocol Data Transfer Architecture for Real-Time Instrumentation Control

Faiza Abdul Salam, Mohammed Al-Obaidly, Giedre Astrauskaite, Shuja Ansari and Massimo Vassalli (University of Glasgow, United Kingdom (Great Britain))

Reliable and low-latency data transfer is critical for real-time instrumentation control and high-rate (≥ 10 kHz) experimental data acquisition, where data loss or excessive delay can invalidate results. To improve modularity and scalability, this work adopts a distributed publish/subscribe data acquisition architecture inspired by IoT systems and extends it to support high-rate experimental instrumentation workloads. However, commonly used publish/subscribe (pub/sub) protocols such as MQTT and ZeroMQ exhibit trade-offs between delivery reliability and latency, rendering it challenging to satisfy both requirements simultaneously. This paper presents and evaluates a dual-protocol communication architecture that integrates MQTT for reliable, ordered data delivery and ZeroMQ for low-latency real-time visualisation. Reliability is ensured through batching, sequence numbering, checksums, and buffered reconnection. The system is experimentally validated using signal-generator inputs to emulate high-frequency instrumentation data. Results demonstrate sustained ≥ 10 kHz sampling (240 kB/s) with end-to-end latency below 200 ms for MQTT and below 150 ms for ZeroMQ, and complete data recovery across multiple randomly induced network outages. Stress-test results highlight the impact of data rate on transmission integrity, providing insight into transport and interface bottlenecks in low-cost embedded systems.

A Layered SFU Architecture for Reproducible Multi-Party WebRTC Systems

Francisco Manuel García, David Vallejo, Santiago Schez-Sobrino, Sergio Martínez-Cid, Rubén Grande and Javier Albusac (University of Castilla-La Mancha, Spain)

This paper presents a layered Selective Forwarding Unit (SFU) architecture for reproducible multi-party WebRTC systems, implemented using mediasoup. The design enforces a clear separation between the control plane, responsible for signalling and room lifecycle management, and the media plane, responsible for selective forwarding of audio and video streams. The mapping between application-level concepts and mediasoup resources is made explicit, including workers, routers, transports, producers, and consumers. This architectural model aims to support operability, deployment clarity, and repeatable experimentation. The proposal is validated through an instrumented multi-party session under heterogeneous network conditions, combining wired Ethernet clients and a mixed reality device connected over 5G. Transport- and stream-level metrics collected at the SFU are analysed to characterise round-trip time, bitrate distribution, jitter, and packet loss. The proposed architecture provides a structured foundation for future extended deployments and controlled network evaluation campaigns.

Improving HydroCast Protocol Efficiency Using Spatial Temporal PIML in Underwater Communication

Amith Srivatsa (Vellore Institute of Technology, India); Neha Anna Lenchu, Sai Aarshia Radhakrishnan, Sheean Jolicoeur, Rani Chinnappa Naidu and Rajesh Kumar M (VIT Mauritius, Mauritius)

Underwater acoustic sensor networks are highly vulnerable to large-scale environmental disturbances which causes node failures and link instability. This work investigates the limitations of conventional HydroCast routing under such conditions and introduces a Spatial-Temporal Physics-Informed Machine Learning (ST-PIML) assisted framework to improve post-event performance. The proposed approach uses spatial density, acoustic link quality, landslide risk awareness, and temporal link memory to guide adaptive routing decisions. Simulation results demonstrate that ST-PIML significantly enhances packet delivery, path stability, network connectivity, and energy efficiency compared to HydroCast, enabling reliable underwater communication even under severe topology disruption.

Thursday, July 16 4:30 - 5:30

SS03-02: Teletraffic Models, Traffic Engineering and Network Optimization

Room: Pentland East

An Analytical Study of the Limited Availability Group Model for Multirate Poisson Traffic

Marinos Vlasakis (University of Peloponnese, Greece); Maria Kourtesi (Hellenic Open University, Greece); Iskanter-Alexandros Chousainov (University of Peloponnese, Greece); Eirini Keramidi (University of the Peloponnese, Greece); Dimitris Uzunidis (National Centre of Scientific Research Demokritos, Greece); Ioannis Moscholios (University of Peloponnese, Greece); Michael D. Logothetis (University of Patras, Greece)

Loss models for finite-capacity systems play a fundamental role in teletraffic theory, particularly for dimensioning multirate service-classes. Among them, the Limited Availability Group (LAG) model constitutes an important extension of the classical Erlang Multirate Loss Model (EMLM) for systems consisting of multiple separate resources that accommodate Poisson arriving calls. In this paper, after providing an overview of the EMLM, we present an analytical study of the LAG model with emphasis on clarifying the model's assumptions and the intermediate steps required for the call blocking probability

determination through analytical/numerical examples. Furthermore, the accuracy of the LAG model is evaluated against simulation results for low-capacity systems, demonstrating satisfactory performance.

On the Analysis and Validation of a Multiparameter Analytical Loss Model for an IaaS Cloud Physical Infrastructure

Maria Kourtesi (Hellenic Open University, Greece); Marinos Vlasakis, Iskanter-Alexandros Chousainov and Ioannis Moscholios (University of Peloponnese, Greece); Michael D. Logothetis (University of Patras, Greece)

Cloud computing (CC) infrastructures operating under the Infrastructure as a Service (IaaS) model require efficient capacity dimensioning to support dynamic workloads while meeting quality-of-service constraints. Analytical loss and queueing models are particularly attractive for this purpose due to their low computational complexity. This paper presents a detailed study of an analytical multirate loss model for estimating blocking probabilities in the physical infrastructure of a CC. The model integrates key multirate loss models, namely the Erlang Multirate Loss Model, the Limited Availability Group model, and the Reduced Load Approximation method. We provide a comprehensive review of these models, describe the intermediate computational steps required for blocking probability evaluation, and assess the accuracy of the proposed framework through simulation-based validation. Numerical results demonstrate the effectiveness of the model for IaaS capacity dimensioning.

Adaptive Offloading Control in 6G Cell-Free O-RAN Using Reinforcement Learning

Pouya Mehdizadeh (Universitat Politècnica de Catalunya, Spain & Iquadrat Informatica S.L, Spain); Golshan Famitafreshi (Iquadrat, Spain); John S Vardakas (Iquadrat Informatica, Spain); Christos Verikoukis (University of Patras, Greece)

Open Radio Access Networks (O-RAN) enable programmable radio access architectures in which learning-based intelligence at the RAN Intelligent Controller (RIC) supports adaptive resource management in future 6G systems. To address the dynamic and heterogeneous traffic conditions observed at the regional edge, we propose a Reinforcement Learning (RL)-driven offloading framework to adaptively offload wireless services between SDN-controlled network segments. Simulation results demonstrate that the proposed approach consistently outperforms a threshold-based heuristic baseline, achieving an average reduction of approximately 34% in overall blocking across different traffic loads. These results convey the effectiveness of learning-based offloading control for improving service performance in dynamic 6G network environments.

Priority-Aware CAC Method with PI Adjustment for Low-Priority VoIP Sessions in Emergencies

Sota Narikiyo and Sumiko Miyata (Institute of Science Tokyo, Japan); Ken-ichi Baba (Kogakuin University, Japan); Katsunori Yamaoka (Institute of Science Tokyo, Japan)

During emergencies such as earthquakes or terrorist attacks, surging voice traffic causes network congestion and degrades Quality of Service (QoS) for VoIP applications. While high-priority emergency calls take precedence, low-priority safety confirmations also play a vital role. However, conventional Call Admission Control (CAC) methods lack dynamic parameter adjustment, often resulting in call blocking. Specifically, despite the Packetization Interval (PI) directly affecting QoS, no research to date has explored priority-aware CAC with PI adjustment. This paper proposes a method that assigns the smallest bandwidth PI to low-priority sessions, thereby increasing admitted low-priority sessions while guaranteeing QoS and high-priority connectivity. The analytical model is validated through simulation.

LSTM-Based Traffic Forecasting for Dynamic P2MP Light-Tree Reconfiguration in Metro-Access Networks

Polyzois Soumplis (National Technical University of Athens, Greece); Konstantinos Christodoulopoulos (University of Athens, Greece); Konstantinos Yiannopoulos (University of

Peloponnese, Greece & Institute of Communication and Computer Systems, Greece); Emmanouel Varvarigos (National Technical University of Athens, Greece)

Point-to-multipoint (P2MP) coherent optical architectures that use digital subcarrier multiplexing support efficient aggregation in metro-access networks. Proactive provisioning of hub capacity requires accurate per-spoke demand forecasts. However, spoke nodes carry heterogeneous traffic profiles such as business, residential, and mixed, with distinct diurnal patterns and forecast difficulty. We examine whether a single multivariate Long Short-Term Memory (LSTM) network can capture these profile-specific dynamics without explicit labels, and quantify how the resulting per-profile forecast accuracy propagates to operational P2MP resource provisioning metrics. The forecasts feed a greedy reconfiguration-aware heuristic algorithm, which jointly decides light-tree assignment at each control epoch while accounting for rerouting, resizing, and point-to-point forwarding penalties. Evaluation on a 30-node TID-derived metro topology with 300 spokes with different OSNR budgets shows that the joint LSTM reduces per-profile mean absolute error by 13-22% over a seasonal baseline, with the largest gains on business spokes. LSTM-driven provisioning achieves 13-15% lower total operational cost than seasonal-driven provisioning and 29-30% savings over static peak allocation, while maintaining demand violations below 1.2%. The LSTM reduces reconfiguration churn by 12-26% per profile over seasonal and lagged baselines, largest on mixed spokes whose composite weekday/weekend pattern is hardest for seasonal forecasts to track.

Thursday, July 16 4:30 - 5:30

SS07-02:Camera-Based Optical Wireless Communication Systems

Room: Pentland West

Selective Detection of Black Rot in Grapevine Leaves Using Convolutional Neural Networks

Patrícia Sergueevna Moltchanova (Universidade de Aveiro, Portugal); Luis Nero Alves (DETI, Universidade of Aveiro, Portugal & Instituto de Telecomunicações, Portugal); Carla Sofia Santos Ferreira (Instituto Politécnico de Coimbra, Portugal)

Grapevine diseases represent a major threat to vineyard productivity, with Black Rot being among the most destructive due to its rapid spread and visual similarity to other diseases. These diseases are associated with a diversity of pathogenic agents, namely fungi, oomycetes, bacteria and pests. While prior work frequently reports high accuracy in controlled multi-class classification, practical deployments commonly require selective detection of a target disease against a contaminated negative class. In this work, Black Rot detection is formulated as a binary classification task, where the negative class includes healthy leaves and other visually similar diseases. This study employed ImageNet pretrained Convolutional Neural Network (CNN) backbones, MobileNetV2, DenseNet121, ResNet50 and VGG16, using a two-stage transfer learning protocol. The ability of the CNN models to accurately identify Black Rot cases was evaluated using standard classification metrics, namely accuracy, precision, recall and F1-score. The results show clear differences in detection behaviour across architectures. ResNet50 achieves the highest overall performance, obtaining 100.0% precision, with no false positives while maintaining a high recall 96.3% and a F1-score of 98.1%, with an accuracy of 98.9%. Overall, the achieved performance is competitive and exceeds values reported in the literature, while addressing a more realistic contaminated-negative scenario.

Optical Camera Communication as a Complementary Technology for Internet of Things: Architectures, Applications and Future Perspectives

Fábio Matias (Universidade de Aveiro, Portugal); Miguel Rêgo (University of Aveiro, Portugal & Instituto de Telecomunicações, Portugal); Atiya Fatima Usmani (University of Aveiro, Portugal); Monica Figueiredo (Polytechnic Institute of Leiria, Portugal); Luis Nero Alves (DETI, Universidade of Aveiro, Portugal & Instituto de Telecomunicações, Portugal)

Optical Camera Communication (OCC) has emerged as a promising branch of Optical Wireless Communications (OWC), leveraging the unlicensed optical spectrum and widespread camera-equipped devices to enable low-cost, secure, and interference-resilient communication. As Internet of Things (IoT) deployments grow, conventional radio-frequency (RF) technologies face challenges related to spectrum congestion and electromagnetic interference. OCC addresses these limitations by offering a complementary solution for IoT applications where moderate data rates can be traded for robustness, spatial selectivity, and seamless integration with existing infrastructure. This review provides a comprehensive overview of OCC technologies, examining both transmitter and receiver architectures. Furthermore, this work identifies technical challenges hindering large-scale adoption and outlines emerging research directions towards sixth-generation (6G) networks. Special emphasis is placed on Integrated Sensing and Communication (ISAC) paradigms, and on distributed intelligent OCC networks.

Energy-Autonomous Optical Camera Communication Node for Intra-Satellite Links

Vicente Matus (IDeTIC-ULPGC, Spain); Jaime Aranda Cubillo and Rafael Perez-Jimenez (Universidad de Las Palmas de Gran Canaria, Spain); Jose Rabadan (IDeTIC-ULPGC, Spain)

This paper presents the design and experimental validation of an energy-autonomous optical camera communication (OCC) transmitter node intended for intra-satellite links. The proposed prototype harvests optical energy using a photovoltaic cell and stores it in an ultracapacitor, enabling threshold-triggered burst transmissions without electrical connection to a power bus. A laboratory demonstrator is characterized in terms of charge-transmit operating cycles and energy budget metrics, showing repeatable autonomous behavior with a charging time of approximately 199 s, burst durations of approximately 21 s, payloads of 315 bits per burst, a duty cycle of 9.6%, and an effective throughput of 1.43 bps. The results highlight how energy availability governs the effective throughput and motivates energy-aware OCC design for modular spacecraft subsystems.

Real-Time Optical Camera Communication Based on Side-Emitting Fibers

Jakub Formánek (Czech Technical University of Prague, Czech Republic); Carlos Guerra-Yánez (Czech Technical University, Czech Republic); Stanislav Zvanovec and Matej Komanec (Czech Technical University in Prague, Czech Republic)

This paper presents a real-time Optical Camera Communication (OCC) system for sensor-data transmission using a side-emitting optical fiber as a distributed light transmitter and a rolling-shutter camera as the receiver. Sensor data are packetized and sequentially transmitted using On-Off Keying modulation with Manchester encoding, while all receiver-side processing is done in real time. Region of Interest (ROI) detection is achieved using a Minimal Spanning Tree (MST)-based approach, enabling reliable tracking of the side-emitting fiber under varying distances. Experimental evaluation demonstrates stable real-time operation at approximately 47.5 fps across all tested conditions. For transmitter-receiver distances up to about 150 cm, the system achieves a low Bit Error Rate (BER) and near-unity Success of Reception (SoR). The presented results confirm the feasibility of low-cost, real-time OCC links for short-range sensor-data transmission using side-emitting optical fibers and provide a solid foundation for future improvements.

Friday, July 17

Friday, July 17 9:10 - 10:00

Plenary talk 5: Dr Sébastien Bigo, "A Giant Laser Pointer: The New Way to Watch Movies on the Moon"

Room: Pentland

Friday, July 17 10:00 - 11:00

GT-07: Applications of ML/AI

Room: Pentland West

Energy-Aware AI Optimization for Scene-Adaptive Video Encoding in Edge Communication

David Elias Emmanuel, Nimesha Senanayake and Warnakulasuriya Fernando (University of Strathclyde, United Kingdom (Great Britain))

Edge communication systems operating under strict energy constraints increasingly depend on continuous video sensing, introducing a trade-off between compression quality and computational energy cost. This paper proposes a scene-adaptive video encoding framework that integrates spatio-temporal complexity estimation with an energy-aware training strategy. In contrast to approaches that rely solely on proxy-based energy estimates, the proposed method validates energy consumption through direct hardware measurements on a Raspberry Pi platform, where energy is computed from measured power and encoding duration. The training objective incorporates reconstruction loss, encoder effort, and scene complexity, enabling the model to adapt its encoding behaviour according to both content characteristics and resource limitations. Experimental evaluation on standard HEVC test sequences shows that the proposed approach reduces energy consumption by up to 28% compared to HEVC/x265 at similar visual quality, and by more than 40% relative to static encoding configurations, while maintaining competitive PSNR and SSIM. These results demonstrate that embedding energy-awareness within the learning objective provides an effective mechanism for improving efficiency in edge-based video encoding systems.

Label-Efficient Self-Supervised Acoustic Indoor Positioning Enabling Effortless Deployment

Daan Delabie, Liesbet Van der Perre and Lieven De Strycker (KU Leuven, Belgium)

Data-driven Indoor positioning systems (IPS) commonly require ground truth (GT) labels and are prone to changing environments. This makes deployment labour-intensive and difficult to scale. This work proposes a label-efficient and self-supervised ultrasonic IPS that removes these requirements by learning the spatial relationships of the environment directly from received channel observations. The method builds on channel charting (CC), using a triplet-based training objective and a graph neural network (GNN) to generate a latent chart that preserves geometric neighbourhood. An affine alignment step maps the learned chart to physical space using only a minimal number of reference points. The system is implemented and evaluated in an indoor testbed. Results demonstrate that the CC-based approach achieves positioning accuracy close to conventional supervised learning while requiring neither GT labels nor anchor coordinate knowledge, highlighting its potential for effortless and scalable deployment. Additional learning during operation mitigates the difficulties arising from a dynamically changing environment.

An Interpretable AI Architecture for System-Level Reasoning from Engineering Documentation

Amrutha Moorthy (Patenti Technology Solutions and University of Oxford, India & CEO, United Kingdom (Great Britain))

Engineering systems are increasingly characterized by large, heterogeneous collections of technical documentation, including specifications, interface descriptions, and contribution records. While artificial

intelligence techniques have been applied to document analysis, many existing approaches rely on opaque models that limit transparency and human trust. This paper presents a structured AI-based approach for deriving system-level understanding from engineering documentation by combining semantic abstraction, modular reasoning, confidence-aware outputs, and analyst validation. The approach emphasizes transparency and evidence-linked reasoning, enabling users to inspect intermediate representations and validate inferred relationships. A case study using a large-scale wireless systems documentation corpus and a focused Wi-Fi Aware worked example demonstrates how source-anchored reasoning can scale across extensive document sets while preserving human oversight.

Cuboid Extraction for Graphite Electrode Reuse Using an AI-Enhanced Optimization Framework

Jerusha Samuel Jayaraj (Universidade do Minho, Portugal); Monica Figueiredo and Luis Conde (Polytechnic Institute of Leiria, Portugal)

Intelligent reuse of worn industrial components is an important challenge in sustainable manufacturing systems. In Electrical Discharge Machining (EDM), graphite electrodes are typically discarded once they fail to meet dimensional accuracy and surface quality requirements, despite retaining usable internal material. This paper presents a novel geometric optimization framework for assessing electrode reuse by extracting the maximum manufacturable internal cuboid. Unlike prior data-driven or similarity-based approaches, the proposed method formulates reuse assessment as a constraint-driven volumetric optimization problem that explicitly incorporates manufacturability requirements. An Artificial Intelligence (AI) enhanced computational intelligence framework is developed by integrating Differential Evolution (DE) with Signed Distance Function (SDF) based geometric reasoning. The SDF provides a continuous spatial representation for robust containment verification under surface degradation, while DE enables global optimization in a non-convex search space without requiring gradient information or training data. Experimental results on scanned graphite electrodes demonstrate stable convergence, strong robustness to geometric damage, and recovery of up to 65% usable volume. The proposed framework provides an interpretable, data-independent, and scalable solution for automated electrode reuse assessment in Industry 4.0 manufacturing environments.

A Systematic Evaluation of Machine Learning Algorithms and Handcrafted Features Across Multiple Plant Disease Datasets

Abdulla Al Mahin Khan (Multimedia University, Malaysia); It Ee Lee (Multimedia University, Malaysia & Northumbria University, United Kingdom (Great Britain)); Teong Chee Chuah, Qamar WAli and Gwo Chin Chung (Multimedia University, Malaysia); Khanthanou Luangxaysana (Faculty of Engineering National University of Laos, Laos)

This paper systematically analyzes classical machine learning models with handcrafted features in the classification of plant diseases in varying structural complexities in datasets. An integrated experimental pipeline was used on three datasets that corresponded to a binary, imbalanced and multi-class setting through image preprocessing, Haralick and HOG feature extraction and classification by SVM, Random Forest (RF), and KNN. 5-fold stratified cross-validation was used to assess the model's performance, and metrics like accuracy, precision, F1-score, per-class recall, and the analysis of the confusion matrix were implemented. Findings demonstrate that classical models are very accurate when applied in controlled binary data, but it becomes much less accurate when imbalanced and multi-class datasets. The early performance saturation indicated by learning curve analysis presents the problem of limitations that are not caused by lack of data but instead caused by the feature representation. Per-class analysis demonstrated that it persistently misclassifies visually similar disease groups which are not reflected in overall accuracy. These results show that handcrafted feature-based models do not have the representational ability to support credible plant disease classification in real world situations.

Friday, July 17 10:00 - 11:00

SS05/SS06: Optical and RF Wireless for 6G

Room: Pentland East

Incremental Learning in Network Traffic Management: A Fixed-Representation Rehearsal Approach

Francisco Rau (MaxLinear, Spain & Universitat de Valencia, Spain); Petia Georgieva (University of Aveiro, DETI/IEETA & Institute of Electronics Engineering and Telematics of Aveiro (IEETA), Portugal); Carlos Herranz (Maxlinear & MXL, Spain); Iñaki Val (MaxLinear, Spain); Joaquin Perez (Universitat de Valencia, Spain)

Network traffic management systems must continuously evolve to new applications without degrading the performance of previously learned categories. This paper evaluates a class-incremental learning strategy that combines rehearsal-based replay with fixed feature representation. Starting from a Fully Connected Neural Network (FCNN) trained on six traffic classes using flow-level features, we freeze all feature-extraction layers and retrain only a newly initialized classification head. Incremental updates are performed using all samples from the incoming class(es) plus a compact, stratified rehearsal buffer containing 10% of the original training set. Experiments on 46,729 labeled flows assess two scenarios: adding one class and adding two classes, and compare against full retraining as an upper bound. The proposed approach reaches 87.90% and 87.72% test accuracy (weighted F1 of 0.877 and 0.875) with minimal forgetting (gaps up to 1.13%). Incremental updates reduce training time by 89-92% and decrease training-data storage requirements by up to 76.88%, supporting deployment in dynamic network environments.

Comprehension of Lower Band Terahertz Frequencies Beyond 6G: An Investigative Paradigm

Fawziya Al Wahaibi (Utas Muscat, Oman); Hamed Saffa Al-Raweshidy (University of Brunel, United Kingdom (Great Britain)); Dr.Maddikera Kalyan Chakravarthi (University of Technology and Applied Sciences, Muscat, Oman); D Srinivasa Rao (University of Technology and Applied Sciences, Oman); Pradeep Reddy Gogulamudi (Manipal Institute of Technology, India); Ch. Pradeep Reddy (CGC University, India)

The following paper suggests a technique of producing lower-band Terahertz (THz) frequencies within a 12x frequency-tupling process. An RFSSR of 30.01 dB is attained at 25 GHz with input of a 25 GHz RF local oscillator to a 0.3 THz signal at the photodetector. The created signal is tested in a hybrid fiber / free system with 20 Gb/s of 2 km with free space optics (FSO) and 80 km with optical fiber. The Q-factor is used to evaluate system performance at various transmission distances. To attain a 20 Gb/s connection with a range of 20km with 300GHz, the system would have a peak of 8.22 and a minimum of 1.97×10^{-28} BER. The 0.3THz FSO link is further analyzed under gamma-gamma and log-normal channel conditions at varying attenuation conditions with a stable and reliable link enabling it to operate to 2000 m. The suggested design proves to be efficient in the generation and transmission of millimeter waves which is a measure of its applicability in the modern wireless communication network. In addition to existing applications of 5G, the 300 GHz mmWave optical-FSO solution is to enable future 6G communications to overcome the mmWave propagation.

A SDN-Based Access Control Framework for Powerline Communications Networks

Luis Miguel Giraldo and Joaquin Perez (Universitat de Valencia, Spain); Raimundo Garcia (Department of Electronic Engineering - Higher Technical School of Engineering, Spain); Atiyeh Pouralizadeh and Volker Jungnickel (Fraunhofer Heinrich Hertz Institute & Technische Universität Berlin, Germany); Francisco Rau (MaxLinear, Spain & Universitat de Valencia, Spain); Carlos Herranz (Maxlinear & MXL, Spain)

The proliferation of Internet of Things (IoT) devices in smart grid environments has been intensified by the need for robust, granular security in Powerline Communication (PLC) networks. Although the G.hn

standard offers high-speed data rates over electrical wiring, it lacks a programmable and centralised security layer capable of dynamic access control. This paper proposes a Software-Defined Networking (SDN) architecture to enforce Media Access Control (MAC) based access control authentication at the MAC layer in a G.hn environment. By integrating the Ryu SDN controller with a simulated G.hn topology via a transparent bridging gateway, it is possible to demonstrate a Hardware-in-the-Loop (HiL) setup that enables filtering of unauthorised devices at the edge. Our proposed framework results indicate that it is effective in mitigating unauthorised access while maintaining the throughput characteristics required for high-bandwidth PLC applications.

Integrated 6G LiFi-NOMA Framework with Optical Sensing Under Poisson-Gaussian Channel Noise

Zeyad Elsaraf and Muhammad Ijaz (Manchester Metropolitan University, United Kingdom (Great Britain)); Pablo Palacios Játiva (Universidad Diego Portales, Chile); Cesar Azurdia (Universidad de Chile, Chile); Bamidele Adebisi (Manchester Metropolitan University, United Kingdom (Great Britain)); Salman Ghafoor (National University of Sciences and Technology, Pakistan); Ismael Soto (University of Santiago, Chile)

This paper proposes a 6G Light Fidelity (LiFi) communication framework integrating power-domain Non-Orthogonal Multiple Access (NOMA) and optical sensing for unified communication and environment awareness. A physically consistent Poisson-Gaussian noise model is developed to describe simultaneous photon shot and thermal effects encountered in light-based wireless systems. The framework employs a DC-biased BPSK (DB-BPSK) modulation compatible with intensity modulation/direct detection (IM/DD) transceivers. The system is analysed in terms of spectral efficiency, energy efficiency, Bit Error Rate (BER), and localization accuracy, with detailed comparisons to AWGN-based NOMA and Orthogonal Multiple Access (OMA) references. Simulations show 32% spectral and 18% energy improvements and centimetre-level localization accuracy, demonstrating the potential of LiFi-NOMA sensing as a key enabler of 6G indoor networks. The limitations of the simulation-only validation are acknowledged, as real indoor environments introduce multipath reflections, user-device tilting, ambient-light interference, and synchronization imperfections that may degrade performance. Sensitivity considerations and future experimental plans are discussed in this paper.

Event-Triggered Selective Channel Refinement for Energy-Constrained IoT Communications

Adewale Femi Ogabi and Geetika Aggarwal (Teesside University, United Kingdom (Great Britain)); Gobind Pillai (Teesside University & Member IET, Member IEEE, United Kingdom (Great Britain)); Michael Short (Teesside University, United Kingdom (Great Britain))

Energy-constrained IoT receivers must balance communication reliability with limited computational resources. This paper proposes an event-triggered selective channel refinement framework. The receiver activates refinement only when significant channel variation is detected. The approach combines a low-complexity baseline estimate with a lightweight refinement mapping governed by a noise-normalised innovation trigger. By adapting computation to channel dynamics, the proposed receiver reduces unnecessary processing while maintaining reliable detection performance. A compute-aware evaluation framework is developed to jointly quantify bit error rate (BER), trigger rate, and a multiply-accumulate (MAC) operation-based compute-cost proxy. Simulation results in time-varying first-order autoregressive (AR(1)) fading channels show that the proposed receiver closely tracks the BER performance of continuous refinement while achieving up to 68% reduction in average computational cost under low-mobility conditions. These results demonstrate that reliable wireless communication does not require continuous refinement and that event-triggered selective processing provides a practical pathway toward compute-efficient IoT and edge wireless systems.

Friday, July 17 11:30 - 12:30

Coll1-05: OWC system analysis, modelling and implementation

Room: Pentland East

Implementation of Visible Light Communication Carrier Synchronization for Internet of Things

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Visible Light Communication (VLC) is an alternative to radio-frequency (RF) systems for short-range and indoor Internet of Things (IoT) applications. This paper presents the design and implementation of an analog Costas-loop for carrier synchronization in hybrid multi-band carrierless amplitude and phase (m-CAP)/quadrature amplitude modulation (QAM) VLC systems. The developed circuit was modeled, simulated using SPICE modeling, and experimentally validated. Results show a lock time of 686 µs with a phase error below 2%, demonstrating that the proposed circuit enables analog carrier recovery for VLC-based IoT nodes.

Experimental Validation of the Benefits of OFDM-Based Waveforms for Optimizing Data Rates in OCC Receivers with Rolling-Shutter Cameras

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Optical Camera Communication (OCC) with rolling-shutter (RS) cameras offers a promising solution to implement a Visible Light Communication (VLC) receiver in commercially terminals. However, its achievable data rate is limited by the relatively slow row-sweep-rate and long exposure time integration of the RS, which induce severe inter symbol interference in reception. While existing OCC receivers rely on computationally demanding time-domain equalization and/or data-driven models to compensate this effect, this paper investigates the benefits of using Orthogonal Frequency-Division Multiplexing as the waveform to take advantage of the low-pass response of the RS camera. when the exposure time equals the row-sweep-rate, we derive a unified frequency domain formulation that analytically characterizes the subcarrier dependent attenuation caused by the lack of time synchronization between VLC transmitter and receiver. Furthermore, a frequency-domain Direct Current suppression technique is introduced, eliminating the need for traditional spatial-domain calibration. Experimental validation using a commercial RS camera confirms the accuracy of the theoretical subcarrier response model that was derived. Received signal constellation and Error Vector Magnitude demonstrate the successful recovery of QPSK and 16-QAM symbols, proving clear evidence of the effective mitigation of timing-induced distortions and the notable improvement of spectral efficiency in asynchronous low-cost OCC links.

Experimental Evaluation of Multi-User Multi-Point Transmission Schemes in Multi-Cell VLC Systems

Ramya Mummadi, Xinyu Zhang and Alexis Alfredo Dowhuszko (Aalto University, Finland); Konstantinos G. Rallis (Aristotle University of Thessaloniki, Greece); Risto Wichman and Jyri Hämäläinen (Aalto University, Finland)

This paper evaluates the performance of different multi-point transmission schemes in a software-defined multi-cell Visible Light Communication (VLC) system. Using a GNU Radio and Universal Software Radio Peripheral (USRP)-based testbed with phosphor-converted white LEDs and black silicon photodetectors, we assess the achievable data rates for Zero-Forcing (ZF) precoding and Joint Transmission (JT) scheme in a distributed Multiple-Input Multiple-Output (MIMO) VLC configuration. OFDM waveforms are utilized and co-channel interference is modeled as additive white Gaussian noise. Experimental results show that the data rate performance is mainly limited by the narrow electrical

modulation bandwidth of phosphor-converted LEDs, yielding a 150-160 cm single-cell coverage radius. In a two-cell scenario with an LED separation of 170 cm, ZF, JT, and Single-Input Single-Output (SISO) are the most convenient scheme for 46%, 32%, and 22% of the service area, respectively.

MU-MIMO for LiFi: Performance Analysis Based on IEEE Std 802.11

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Light Fidelity (LiFi) can provide robust and secure wireless connections with high data rates and low latency, making it suitable for demanding applications in industries, hospitals, and enterprises. The multi-user multiple-input multiple-output (MU-MIMO) scenario has already been investigated for LiFi. Meanwhile, IEEE Std 802.11bb has integrated LiFi into the 802.11 framework, demonstrating how existing Wi-Fi chipsets can be reused. However, 802.11 employs specific MU-MIMO algorithms and their performance for LiFi has not yet been explored. In this paper, we study the use of MIMO algorithms in 802.11 for LiFi in single- and multi-user scenarios by using distributed optical frontends in the infrastructure and angular diversity at mobile stations. We derive the bit error rate (BER) for zero-forcing (ZF) precoding and determine both the spatial transmission mode and the modulation and coding scheme (MCS) that maximize the achievable throughput. Simulation results demonstrate maximum user rates of nearly 2 Gbps comparable to state-of-the-art Wi-Fi access points. The results indicate that LiFi can be used to create "optical hotspots", increasing the spatial reuse beyond current RF capabilities. Overall, our findings show that conventional MU-MIMO schemes from Wi-Fi can be immediately reused for LiFi and, high performance is achievable by optimizing the deployment.

Indoor Visible Light Communications: Modeling and Channel Bandwidth Aspects of a Real Indoor Office Room

Pranav Sharda (University of Oxford, United Kingdom (Great Britain))

A realistic indoor office in Oxford is modeled to examine channel propagation based on visible light communications (VLC), employing light-emitting diodes as optical luminaires. A design tool for optical systems, called Zemax, is used to model the indoor office room. Moreover, ray tracing in Zemax is accounted for two comparative VLC propagation scenarios. Further, channel impulse response and channel frequency response metrics are emphasized. Building upon these propagation metrics, ultimately, the 3 dB channel bandwidth versus receiver position results are investigated for an indoor office room, accounting for the considered comparative propagation scenarios. Concerning the key findings of scenario 1, 50 MHz and 150 MHz 3 dB channel bandwidths are obtained at the center and at the corners, respectively. Likewise, for scenario 2, 40 MHz and 50 MHz 3 dB channel bandwidths are obtained at the center and at the corners, respectively.

Air-Sea Surface Modeling and Operating Link Range Evaluation for AUV-to-UAV Optical Wireless Communication Links

Ikenna Chinazaekpere Ijeh (FUNAI, Nigeria); Ali Khalighi (Ecole Centrale Méditerranée, France); Wasiu O. Popoola (University of Edinburgh, United Kingdom (Great Britain))

Air-sea surface interactions play a critical role in underwater-to-air optical wireless communication (OWC) links, particularly in vertical autonomous underwater vehicle (AUV) to unmanned aerial vehicle (UAV) scenarios, where the stochastic nature of the sea surface introduces optical distortions that impair link reliability. This work investigates the impact of air-sea surface roughness on AUV-to-UAV OWC systems using two experimentally validated models: the classical Cox-Munk and the Elfouhaily-Chapron-Katsaros-Vandemark (ECKV). A tractable analytical representation of the ECKV model is derived and validated against measured sea-state data. Using both analytical and Monte Carlo

approaches, the link ergodic capacity is evaluated with particular emphasis on operating range, pointing errors, receiver field-of-view, and solar noise level, providing practical system design insights.

Friday, July 17 11:30 - 12:30

GT-08: DSP for Communications

Room: Pentland West

Iterative Local Rényi Entropy with Time-Frequency Filtering for Crossing Components in Compressive Sensing-Based Reconstruction

Vedran Jurdana (University of Rijeka, Croatia)

Accurate estimation of the local number of components is critical in time-frequency (TF) signal analysis, as it underpins reliable detection and preservation of auto-terms. Existing local Rényi entropy (LRE) methods have notable limitations: the non-iterative approach is robust but may miss weak components, whereas the iterative approach may erroneously remove multiple components within a single iteration when components are closely spaced or intersect in the TF domain. This paper presents a TF-filtered iterative LRE framework that isolates components one by one across iterations. The proposed method is integrated into a compressive sensing-based TF reconstruction framework, where local component estimation is used to guide the shrinkage process. Experiments on synthetic signals and real-world electroencephalogram (EEG) seizure data demonstrate that the proposed approach outperforms existing LRE methods in component estimation accuracy and reconstruction quality, while also reducing computational time compared with the conventional iterative LRE. These results highlight the effectiveness of the proposed framework for non-stationary signals exhibiting intersecting TF components.

Open-Set Multi-Label Automatic Modulation Classification for Overlapping Radio Frequency Digital Communications

Iain C High (University of Edinburgh, United Kingdom (Great Britain)); David J Sadler (Roke Manor Research Ltd., United Kingdom (Great Britain)); Yoann Altmann (Heriot-Watt University, United Kingdom (Great Britain)); Wasiu O. Popoola (University of Edinburgh, United Kingdom (Great Britain))

Automatic modulation classification is a key technology for modern adaptive communication receivers. Practical deployments must operate in crowded radio frequency spectrum conditions. In these settings, transmissions can overlap, and previously unseen modulation schemes may be present. These conditions reduce the efficacy of current modulation classification algorithms. This paper addresses overlapping signal automatic modulation classification under open-set conditions by formulating the task as multi-label classification with explicit unknown rejection. A synthetic co-channel dataset was generated, comprising four known modulation schemes for training and four additional unknown schemes for evaluation. A compact one-dimensional residual convolutional network was trained using class-weighted binary cross-entropy together with a triplet loss to structure the penultimate feature space. Open-set recognition was then performed by fitting diagonal Gaussian models to known modulation superclasses. During inference, a received frame is only assigned to the known superclass if its Mahalanobis distance lies within a calibrated quantile threshold. Results demonstrate that this formulation enables strong classification accuracy of overlapping transmissions and reliable rejection of transmissions containing previously unseen modulation schemes.

Blind Symbol Rate Estimation via Wavelet-Based Deep Learning for Noncoherent FSK Signals

Hanseung Cho, Ganghyuk Jeon, Chisom Michael Onyekwelu and Dongweon Yoon (Hanyang University, Korea (South))

In non-cooperative contexts, accurate symbol rate estimation is essential for demodulation and information recovery. This paper proposes a deep learning-based algorithm for the blind estimation of the symbol rate in noncoherent frequency-shift keying signals. In the proposed approach, the received signals are first subjected to wavelet transform-based preprocessing with frequency normalization, from which discriminative features are extracted. The extracted features are subsequently utilized to train a deep learning model for symbol rate estimation. Simulation results demonstrate that the proposed algorithm outperforms a conventional wavelet transform-based algorithm and provides reliable estimation performance under various signal-to-noise ratios, unseen symbol rates, and frequency-shift conditions.

A Fully-Parallel and Flexible Baseband Processor Using Processing-in-Memory for Wireless Systems

Mojtaba Mahdavi (Ericsson, Sweden)

This paper presents a novel architecture for realizing a fully parallel and flexible digital baseband processor for massive MIMO systems using processing-in-memory (PIM). The proposed approach leverages memristor-based crossbar arrays to implement key functional blocks within the baseband processing chain, thereby alleviating the data-movement bottleneck inherent in conventional von Neumann architectures. To enable efficient hardware mapping, the signal processing algorithms and corresponding computations are reformulated into a unified matrix-based framework. The resulting matrix operations are then mapped onto multiple crossbar arrays, exploiting their intrinsic analog computing capabilities. The proposed PIM-based baseband processor achieves fully parallel operation and significantly reduces processing latency, making it well suited to the stringent performance requirements of next-generation wireless systems. The presented architecture demonstrates the potential of PIM technology as an effective solution for future high-performance and energy-efficient baseband processing platforms.

Analysis of Crosstalk Drift in SLM-Based Mode-Multiplexing Systems for Free-Space and Multimode Fibre Transmission

Zun Htay, Fabio A Barbosa and Filipe M. Ferreira (University College London, United Kingdom (Great Britain))

Long-term stability is a critical requirement for space-division multiplexing systems, where time-varying crosstalk can degrade modal orthogonality and system performance. However, the behavior of crosstalk and the corresponding singular values of the channel matrix, which quantify the strength and number of independent transmission channels, remains insufficiently characterized under realistic environmental conditions. We investigate the crosstalk drift and singular values in space division multiplexing with phase holograms in a Fourier telescopic architecture. System stability is analyzed over a 30-hour period for 0.5 m and 20 m OM4 multimode fibres and a free-space link, with simultaneous temperature monitoring and statistical characterization of crosstalk drift.