Ph.D. in Information Technology
Thesis Defense

June 24th, 2026
At 2:30 p.m.
Aula BIO 1 - Building 21

Filippo MORANDI – XXXVII Cycle

MODELS AND METHODS FOR FUTURE GENERATION FREE SPACE OPTICS ASSISTED BY OPTICAL SIGNAL PROCESSING
Supervisor: Prof. Umberto Spagnolini

Abstract:

The transition to 6G networks demands transport technologies capable of supporting ultra-high throughput and pervasive coverage, placing significant pressure on both backhaul and fronthaul segments. While E-band microwave technology currently addresses backhaul needs, its data rate limitations necessitate new solutions for future fronthaul, particularly in cell-free Radio Access Network (RAN) architectures. Free-Space Optics (FSO), leveraging a vast optical spectrum and advancements in photonic integrated circuits, has re-emerged as a promising candidate. However, its performance is impaired by atmospheric turbulence and weather conditions. Legacy FSO systems, based on single-input single-output (SISO) architectures and direct detection, are well-understood. In contrast, novel photonic-assisted FSO systems, which incorporate optical signal processing (OSP) before electrical conversion, require new modeling and design tools to capture the complex interplay between atmospheric propagation, optical coupling, and system parameters. This work addresses this need by developing comprehensive frameworks and models for photonic-assisted FSO. We present a general numerical simulation framework for efficient modeling of complex FSO channel matrices. Furthermore, we derive a novel statistical channel model for fiber-coupled FSO links under turbulence, accurately capturing the variability introduced by waveguide coupling. This model is used to evaluate the performance of a single-input multiple-output (SIMO) FSO system assisted by a photonic coherent combiner. We also investigate optical antenna array design for turbulence mitigation, proposing evaluation metrics and demonstrating two integrated silicon photonic arrays. A co-design approach for the array and its control mesh is disclosed to simultaneously mitigate fading and acquire pointing information. Finally, we explore the application of over-the-air OSP to realize multiple-input multiple-output (MIMO) multiplexing across a turbulent FSO link. We generalize a known power algorithm for singular value decomposition (SVD) computation and analyze its convergence over a long-haul link using realistic channel data, yielding critical insights for optical front-end design and its impact on channel gain and estimation. Collectively, this research provides foundational models and design insights aimed at enabling high-performance, photonic-assisted FSO systems to meet the stringent transport requirements of future 6G networks

PhD Committee

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