ΤΜΗΜΑ ΜΗΧΑΝΙΚΩΝ Η/Υ & ΠΛΗΡΟΦΟΡΙΚΗΣ • ΠΑΝΕΠΙΣΤΗΜΙΟ ΙΩΑΝΝΙΝΩΝ
DEPARTMENT OF COMPUTER SCIENCE & ENGINEERING • UNIVERSITY OF IOANNINA

ΠΑΡΟΥΣΙΑΣΗ
ΔΙΔΑΚΤΟΡΙΚΗΣ ΔΙΑΤΡΙΒΗΣ

ΗΜΕΡΟΜΗΝΙΑ: Πέμπτη, 28 Μαΐου 2026

ΩΡΑ: 11:30 – 13:00

ΑΙΘΟΥΣΑ: Αίθουσα Σεμιναρίων ΤΜΗΥΠ

ΟΜΙΛΗΤΗΣ: Αλέξανδρος Παπαδόπουλος

Θ έ μ α

«Resource Management in Networks with Intelligent Metasurfaces»

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Π ε ρ ί λ η ψ η:

Reconfigurable Intelligent Surfaces (RISs) are a promising physical-layer technology for Beyond-5G/6G, enabling Programmable Wireless Environments (PWEs) in which the propagation medium becomes software controlled. However, translating RIS potential

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into deployable network infrastructure requires solving three tightly coupled resource-management challenges: (i) how to compile RIS configuration codebooks with sufficient electromagnetic (EM) fidelity at acceptable cost, (ii) how to share a single RIS among concurrent users under operator policies with millisecond-level control latency, and (iii) how to coordinate multiple RIS units at the network level while maintaining tiered fairness under congestion. This thesis advances RIS operational maturity by developing a coherent, lifecycle-consistent framework that connects manufacturing-time computation of physics-consistent configurations to operating-time selection, sharing, and orchestration.

At the manufacturing (offline) phase, the thesis adopts a codebook paradigm: for each supported macroscopic function, configurations are computed via EM-aware optimization and stored for fast retrieval during operation. A central contribution is a sequence of physics-informed compilation tools that progressively raise fidelity and practicality, explicitly accounting for near-field operation, mutual coupling, reflections, and energy redistribution beyond the focal region. The resulting pipeline demonstrates that extracting and exploiting physical structure (e.g., correlated element responses and staged refinement) can reduce optimization cost by orders of magnitude without compromising EM consistency. The thesis further addresses scalability beyond the "optimize-per-location" paradigm by introducing a sparse 3D sampling and compression strategy: physics-consistent configurations are generated at representative spatial samples, then compressed and organized into a compact, searchable representation that supports bounded, predictable online inference complexity while maintaining near-optimal signal-to-noise ratio (SNR).

At the operating (online) phase, the thesis formalizes an RIS as a shareable network resource hosted by macroscopic EM functions, and introduces a resource-slice notion that links multi-user efficiency to the deviation between the shared configuration and each user's single-user optimum. Building on this abstraction, it develops a practical sharing mechanism based on multiplexing precompiled codebook entries rather than repeated channel estimation and iterative online optimization. This approach enables concurrent multi-user service with low latency, while supporting operator-defined differentiation (e.g., pricing tiers) and predictable performance trade-offs. The thesis validates the deviation–performance link analytically in both far-field steering and near-field focusing, and corroborates it with emulations and real testbed measurements, showing that multiplexing can match or outperform established sharing approaches (e.g., segmentation and time division) in both efficiency and fairness, while remaining computationally lightweight.

To scale from single-surface control to multi-RIS PWEs, the thesis introduces a system-level framework that combines node-level sharing with priority-aware, congestion-pricing routing on an RIS network graph. This enables end-to-end fairness enforcement across cascaded RIS links, ensuring that tier differentiation remains stable when multiple RIS units and congested paths interact. The framework includes a fairness mechanism that enforces an operator-defined efficiency floor while maintaining proportionality to user priority weights. The resulting network behavior remains robust under increasing user densities and varying RIS counts, with practical runtime and modest memory footprint.

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Finally, the thesis shows that codebook multiplexing supports PWE-native services beyond LoS restoration, focusing on proactive covert communications. It introduces an RF-fencing service that partitions the angular or spatial domain into friendly delivery zones and hostile suppression zones, and develops a controller that synthesizes the required response by combining manufacturing-time EM-consistent codebook entries with lightweight online refinement. Comprehensive evaluations across THz and mmWave far-field scenarios demonstrate strong suppression in hostile sectors while preserving near-baseline performance in intended service sectors, and near-field studies demonstrate the creation of highly localized "quiet zones" in indoor and outdoor environments. These results highlight that while densification can often approximate coverage restoration, intentional exposure control—covertness, quiet zones, and proactive suppression—benefits directly from coordinated multi-RIS programmability.

Overall, this thesis establishes a unified perspective on RIS resource management across compilation, sharing, and network orchestration. By grounding control in EM consistency while enforcing policy-driven fairness with bounded online complexity, it provides an architecture-consistent path toward practical PWEs for B5G/6G networks.

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