# Abstract

The exponential increase in traffic demands in broadband networks, driven by emerging applications such as smart cities, remote healthcare, and immersive media, requires access network solutions that are not only high capacity and scalable, but are also cost-efficient and resilient. Fiber-wireless (FiWi) access networks, which synergistically integrate the ultra-high throughput of passive optical networks (PONs) with the flexibility and ubiquity of wireless access technologies, have emerged as a promising hybrid architecture for next-generation broadband deployments. In recent times, fixed wireless access (FWA) technology has emerged as a highly attractive solution for providing last-mile broadband connectivity. Its rapid, flexible, and cost-effective deployment makes it a practical choice in regions where optical fiber installation is time-consuming, capital expenditure (CapEx)-intensive, or logistically complex. However, despite the advantages, FWA suffers from inherent limitations such as constrained radio spectrum, interference, and sensitivity to propagation conditions, especially in dense deployments or under environmental impairments, such as rain and foliage. These challenges restrict its ability to scale effectively while ensuring consistent quality of service (QoS) across all users. By enabling both fiber-to-the-home (FTTH) and FWA services over a common infrastructure, FiWi networks support dynamic service provisioning tailored to user requirements and real-time network conditions. The existing FiWi network planning frameworks remain fragmented, focusing on either optical or wireless segments in isolation, without comprehensively considering their joint deployment. Addressing these gaps, this thesis proposes comprehensive planning framework through three novel and unified studies.

This thesis proposes unified cost-efficient planning framework for next-generation FiWi access networks that jointly optimizes network topology (offering FTTH and FWA services over a common infrastructure), resource allocation, and resilience under realistic deployment constraints. The first contribution presents an iterative integer linear programming (ILP)-based framework integrating multi-stage time division multiplexing-PON (TDM-PON) and LTE-A-based FWA, enabling adaptive user service mode selection and resource allocation while minimizing CapEx. The second contribution extends the framework to incorporate 5G mmWave technologies, leveraging 3D beamforming and a 3D resource grid (beam and time-frequency resource block) for efficient spatial reuse and enhanced scalability in different 3GPP deployment scenarios. The final contribution introduces an environmentally resilient FiWi planning approach that integrates active reconfigurable intelligent surfaces (RIS) to overcome mmWave signal degradation due to rain and foliage. A convex hull-based RIS placement strategy combined with ILP-based optimization ensures robust user coverage with minimal fiber deployment.

The simulation results under various 3GPP deployment scenarios, viz., rural macro (RMa), urban macro (UMa), and urban micro (UMi-street canyon), demonstrate the effectiveness of the proposed framework in significantly reducing CapEx while satisfying user demand and QoS constraints. The thesis addresses multiple technical dimensions, including hybrid FiWi access network design, cross-domain resource optimization, 3D beamforming, 3D resource scheduling, environmental resilience, and RIS-assisted coverage extension. Collectively, the outcomes of this thesis offer a technically rigorous and practically viable roadmap for planning cost-efficient, scalable, and environmentally resilient FiWi access networks suitable for 5G and beyond.

Keywords: Fiber-wireless (FiWi), fixed wireless access (FWA), passive optical network (PON), LTE-A, fiber-to-the-home (FTTH), reconfigurable intelligent surface (RIS), 5G.