This thesis discusses the topic of physical layer aware open optical networking.

Modern optical communications involve transparent networks where the optical signals travel through intermediate nodes without being received and re-transmitted, i.e. without being regenerated. In this context, the physical layer cannot be approached as a simple set of point-to-point optical connections but a holistic approach that considers the entire network is necessary.
In this framework, the telecom operators target the reduction of the costs while maximizing the network capacity. For this reason, they are pushing the market towards open and disaggregated solutions where the equipment is compatible with open and standard APIs. For the same reason, promising solutions such as multi-band transmission are under investigations as they enable a capacity upgrade without deploying new fiber cables. Additionally, online and offline network analysis tools able to provide the meaningful performance metrics are fundamental to effectively tackle the network design. Finally, the automation of the network operations is an essential aspect of the network management as it allows a reliable and scalable management of the infrastructure.

The second chapter provides the theoretical background over which the rest of the thesis is structured. In detail, the physical modelling of the network elements is provided and the methodology for evaluating the generalized signal-to-noise ratio (GSNR) is described. Moreover, the impairment-aware network abstraction is introduced to represent the physical layer of a network. Finally, the basics of routing and wavelength assignment (RWA) are summarized.

Based on this, GNPy, an open-source quality-of-transmission estimator (QoT-E), is introduced and described. Then, the most significant experimental validation campaigns have been reported: the validation over a commercial line system hosted in the Microsoft labs and the subsequent validation over a segment of the Microsoft core network.

In the following chapter, the multi-band transmission has been investigated and analyzed. Such a technology raises the interest of the operators as it targets the increase of the capacity by extending number of channels transmitted along the same fiber without requiring the deployment of new fibers and, therefore, reducing the costs of a capacity upgrade. In this thesis, a simple but effective power optimization strategy aiming at improving the QoT has been proposed. Then, the capacity of a fully loaded multi-band communication considering several applications (DCI, metro and regional networks) has been assessed. The outcomes show how multi-band transmission can potentially accommodate 7 to 10 times more traffic than a state-of-the-art single-band C-band line system.

Subsequently, two network design tools have been introduced: an offline physical layer assessment (OPLA) tool and a statistical network assessment process (SNAP). In detail, the OPLA tool has been adopted to address some infrastructural upgrades to effectively increase the network capacity and to reduce the regenerators deployed in the network and therefore the costs. Then, SNAP has been used to compare the network benefit of several SDM solutions and multi-band transmission.

Lastly, a QoT-E has been integrated into the ProNET network orchestrator in order to enable a physical layer aware automation while the orchestrator operates the network. This integration has been experimentally validated as well.