Scuola Superiore Sant'Anna

Networks and Services

Reliable Flexible Optical Networks (Supervisor: A. Giorgetti, SSSUP)
This work will elaborate reliable routing algorithms for flexible optical networks. In particular, GMPLS control plane will be considered and compared with emerging SDN approaches based on OpenFlow protocol. This work will be mainly conducted using OPNET programming.

Flexible multi bit-rate wavelength switched optical networks (WSONs) *(Supervisor: Filippo Cugini, and Piero Castoldi, SSSUP)*
Due to network upgrades, in centralized wavelength switched optical networks path computation element (PCE) has to guarantee the coexistence of different bit-rates in the same WSON. Several new issues arise ranging from QoT guarantee to traffic engineering need to be addressed also using the recently established technique of flexible grid provisioning.

Energy efficient solutions for wireless networks based on LTE *(Supervisor: Isabella Cerutti, SSSUP)*
Due to the ever increasing power consumption of the wireless networks at the operator side, solutions for enabling energy efficiency and energy proportionality (i.e., a power consumption proportional to the utilization) are required. The thesis aims at studying energy efficient and energy proportional solutions to be implemented at the base station of Long Term Evolution (LTE) cellular networks.

Enhanced scheduler for optical interconnection networks *(Supervisor: Nicola Andriolli, SSSUP)*
A two-step scheduler (TSS) for optical interconnection networks has been recently proposed. TSS outperforms the existing schedulers in computational complexity and performance. The thesis aims at enhancing the current scheduler for the support of advanced features such as interconnection network energy-awareness, packet-mode operation, quality of service, and multicast.

Design and characterization of Photonic Integrated for optical interconnection networks *(Supervisor: Nicola Andriolli, Isabella Cerutti, SSSUP)*
The aim of the thesis is to design and characterize the behavior a photonic integrated circuit of a the whole or part of an optical interconnection network. Innovative solutions for integrating photonic and electronic design will also be explored.

Implementation of scheduler and switch controller with Field Programmable Gated Array (FPGA) *(Supervisor: Nicola Andriolli, Isabella Cerutti, SSSUP)*
The aim of the thesis is to extend the current implemented scheduler with FPGA and carry out the first experiments on the control of photonic integrated switches.

Energy efficient design of data center networks based on optical switches *(Supervisor: Isabella Cerutti, SSSUP)*
Today's data center networks are consuming up to 50% of the overall power drained by the data center. The replacement of the electrical Ethernet switches with optical switches has been proposed to reduce the energy consumption. The thesis aims at optimally designing the data center network with optical switches to minimize the overall power consumption, while ensuring the required connectivity and bandwidth.

De-fragmentation techniques in flex-grid optical networks *(Supervisor: Nicola Sambo, Piero Castoldi, SSSUP)*
In flex-grid optical networks, spectrum fragmentation may prevent lightpath setup. Effective techniques for de-fragmentation (i.e., re-optimization) are then required to limit the wasting of spectrum resources. The objective of this thesis is the study and the proposal of novel and effective de-fragmentation techniques and algorithms.

Support of multicast in dynamic GMPLS networks *(Supervisor: Nicola Sambo, Piero Castoldi, SSSUP)*
For supporting multicast services (such as IPTV, online gaming), GMPLS control plane needs to be properly extended. The thesis aims at developing GMPLS extension for supporting multicast in wavelength switched optical networks (WSONs). Dynamic performance of the proposed extension will be compared to the standardized GMPLS control plane.

Energy efficient design of wavelength switched optical networks (WSONs) with flexible multi-rate grid support *(Supervisor: Nicola Sambo, Piero Castoldi, SSSUP)*

The physical layer of the wavelength switched optical networks is being enhanced with the support of different transmission rates in flexible transmission grids. The study aims to optimize the design of a WSON with flexible multi-rate grid to enable support of the requested connections in an energy efficient way.

Energy efficiency in access networks (Supervisor: Luca Valcarenghi, SSSUP)
This thesis will focus on implementing an energy efficient Optical Network Unit (ONU) prototype. Energy efficient ONUs are optical customer premises equipments that implement schemes that automatically turn them off (i.e., put to sleep) the they are idle. This thesis will deal with the implementation of an ONU prototype implementing sleep modes into an FPGA.

Advanced smart management system for electric vehicles recharge (SMS-EV) (Supervisors: Luca Valcarenghi, SSSUP – Barbara Martini, CNIT)
This thesis will focus on simulating an advanced smart management system for electric vehicles recharge (SMS-EV). In particular both distributed and centralized algorithms for maximizing the system sustainability from the perspective of both the end users (i.e., EV drivers) and the service providers (i.e., electrical utility providers and micro producers of renewable energy resources) will be evaluated. The thesis will mainly involve programming an event-driven simulator to implement and evaluate the proposed algorithms.

Green Labeling Passive Optical Networks (Supervisor: Luca Valcarenghi, SSSUP in collaboration with Optical Systems group)
This thesis will focus on implementing a tool for evaluating the energy efficiency of (i.e., green labeling) passive optical networks, in particular of the optical network unit (ONU). The tool will need to generate several types of synthetic traffic. In addition the tool will need to measure not only the energy consumed by the ONU but also the quality of service (QoS) provided by the ONU to the end users in case it implements energy efficient schemes.

Advanced management solutions for Cloud Data Centers (Supervisor: Barbara Martini and Piero Castoldi, SSSUP)
Ever more popular cloud computing services are pushing towards convergent data center infrastructures acting as a unified pool of shared resources for many distributed services (e.g., cloud computing, high performance computing). In such a context the network interconnection among and within data centers become crucial. Key to the whole process is a management system able to jointly manage network, computing and data storage elements while enabling dynamic network reconfiguration, QoS-guaranteed data transfer and coordinated network control and management procedures also exploiting the novel Software-Defined Network (SDN) paradigm for controlling network data flows over heterogeneous systems.

Optical Communication Theory and Techniques (Supervisor Prof. E. Forestieri)

1) Electronic equalization in the presence of fiber nonlinearities.

2) Design of reduced complexity receivers for coherent optical systems.

Optical Communication Systems

Real-Time DMT decoder for Next-Generation Fiber-to-the-Home networks (Supervisor: E. Ciaramella, SSSUP)
Recently there has been a lot of interest in the implementation of multilevel adaptive modulation formats for optical communication systems, aided but the so-called "off-line" processing. Such modulation formats allow to increase greatly (e.g. a factor of 10) the capacity of existing optical links without changing the optical front-end. This is one of the more promising feature requested by major telecom operators and manufacturers. The aim of this thesis is the development of a FPGA board implementing in real-time a software already developed, but which is currently working "off-line". The thesis will be carried out in collaboration with engineers from Ericsson Ltd.

10Gb/s Bidirectional WDM Passive Optical Networks (Supervisor: E. Ciaramella, SSSUP)
There is continuously growing demand of high-capacity data-links in Passive Optical Networks (PON), which will realize the future Fiber-to-the-Home infrastructure. While the current standards, G-PON and XG-PON,

target 1Gb/s and 10Gb/s transmission, it is still a challenge to realize new generation 10Gb/s colorless transceivers for future WDM-Access networks. The thesis will focus on the extension of a scheme, recently demonstrated by the OpSys group, allowing for 10 Gb/s links by using colorless transceivers of 1 GHz E/O bandwidth. The thesis will be carried out within an ongoing research project in collaboration with Ericsson Ltd.

Development of low-cost coherent receiver for WDM Optical Access Networks (Supervisor: E. Ciaramella, SSSUP)
The thesis will be developed within the framework of an ongoing European project, COst-effective Coherent ultra-dense-WDM-PON for lambda-To-the-user access (COCONUT), whose challenge is to demonstrate an optical access network having WDM channels spaced at less than 5 Gb/s by using highly selective low-cost coherent receivers. The candidate will be responsible for the development (design, realization and characterization) of electrical PCBs that will be part of the aforementioned coherent receivers. The candidate will be in contact with researchers of Ericsson research centers of Pisa and Stockholm, as well as with other international partners, as British Telecom (BT) and other European Universities. Upon completion, the candidate will be considered for inclusion in the Pisa research team for the duration of the project.

Visible Light Communication systems connected to power line cables (Supervisor: E. Ciaramella, SSSUP)
Recently, Visible Light Communication realized by means of visible light LEDs (those used for illumination purposes) have been demonstrated to support Gb/s data rates. However, the delivery of information to the LEDs placed on roof is still an open challenge. This thesis will be carried out within a running research project aiming at interfacing power-line communication standard to visible-light communication systems, and vice-versa.

LED Based indoor localization system for Autonomous Mobile Systems (Supervisor: E. Ciaramella, SSSUP)
The perception of localization in mobile and autonomous robots is an important aid to navigation. To achieve perception of localization several methods have been proposed, e.g. based on apriori known maps, maps built by the robot itself, recognition of landmarks with pre-defined positioning and others. In this thesis a simple and low cost system for indoor environment based on visible led will be analyzed and implemented.
Implementation of an all-optical format converter QAM-OOK for photonic edge functionalities in high capacity multiformat networks

Far infrared Communication systems for automotive applications (Supervisor: E. Ciaramella, SSSUP)
Recently, Visible Light Communication realized by means of visible light LEDs (those used for illumination purposes) have been demonstrated to be useful also for automotive applications. However, the strong attenuation of the visible signal in case of fog is still an open challenge. During this thesis the candidate will explore the possibility to exploit the far infrared region in order to deliver signal between cars and infrastructures. The work will include the study of the problem, the preparation of the system specifications, the selection of sources and receivers and the realization of a lab experiments.

Visible Light Communication systems for underwater applications (Supervisor: E. Ciaramella, SSSUP)
Underwater communication have been realized with acoustic modem which present strong limitation in terms of data rate and latency of the signal. During this thesis the candidate will explore the possibility to exploit visible light communication for underwater interconnections.

Monitoring of Non-Linear Signal Distortion in High Speed Coherent Optical Systems (Supervisor: E. Ciaramella, SSSUP)
Optical performance monitoring is an indispensable feature for optical systems and networks. Prediction, monitoring, and control of nonlinear impairments are complicated by interactions between impairments. In particular the signal degradation from the fibre nonlinearity (mainly due to Kerr effect, such as cross-phase and self-phase modulation) accumulates during propagation along the optical transmission line and can only be fully characterized at the receiver end. The candidate will develop a model to separate linear distortions, additive noise and nonlinear distortions; simulations should be carried out for point-to-point links, where WDM channels are co-propagating along a common optical path.

Digital Photonics and all-optical processing (Supervisor: Dr. A. Bogoni)

1. Development of all-optical nonlinear processing based on nonlinear waveguides for phase modulated optical signals in new generation optical networks

2. Characterization and use of carbon nanotube-based devices for the photonic elaboration of ultra-fast optical signals

3. Optically tunable photonic delay line based on slow light for synchronization applications in network photonic node

4. Software development for data acquisition processing in a photonic-based fully digital radar system

5. Photonic generation of phase modulated RF signals with high phase stability

6. Testing of an optical sampling for RF signals

7. Design of an integrated photonic transmitter for RF signal generation (in collaboration with photonic technologies area)

8. Design of an integrated photonic receiver for RF signal generation (in collaboration with photonic technologies area)

9. Design of an integrated photonic logic gate for ultra-fast signal processing (in collaboration with photonic technologies area)

10. Modeling of a photonic edge node architecture and routing policy definition for high capacity multiformat optical networks (in collaboration with optical networks area)

Optical Amplification and Sensing

Improvement of distributed strain and temperature sensing performance using innovative algorithm for modulation

(Supervisors: *(F. Di Pasquale*, SSSUP)

Brillouin optical time-domain analysis (BOTDA) is the most effective scheme for distributed sensing of strain and temperature over long fiber ranges. One of the limitations in terms of monitored distance/resolution is related to the enhancement of pump modulation. Although a feedback system is used for modulation continuous monitoring and adjustment, the algorithm has not been optimized yet. This work will address the development of new algorithms for long terms modulation stabilization and optimization, which can remarkably improve BOTDA system performance. The developed algorithms will be tested in the actual BOTDA setup, in order to show enhanced performance and the overcoming of current BOTDA limitations in long range sensing applications

Modelling and optimization of tapers for hybrid III-V silicon technology

(Supervisors: P. Pintus, F. Di Pasquale, SSSUP)

This thesis work will deal with modelling and optimization of tapers for hybrid integration of III/V structures on SOI structures by means of wafer bonding. For integration of hybrid silicon devices, such as lasers, amplifiers, modulators and detectors, with passive SOI-based silicon devices, e. g. waveguides or multiplexers, low-loss mode conversion from the silicon waveguide mode to the hybrid mode and vice versa is essential. To achieve this, tapered structures can be used. In the thesis, the candidate will model the structure using electromagnetic commercial software. The results of the simulations will be compared with the experimental results provided by the University of California, Santa Barbara.

Design of optical filter/switch for fiber sensing applications

(Supervisors: C. Oton, S Faralli, F. Di Pasquale, SSSUP)

The work will involve of the design of passive/thermo-optic devices on silicon for applications in optical fiber sensing systems. It will include simulations of single components with Finite Difference Time Domain (FDTD) and system optimization calculations with robustness considerations.

All-Optical Technologies

All-Optical Technologies Thesis Proposals (supervisors: Claudio Porzi, Giampiero Contestabile, SSSUP):

1) All-optical amplitude regeneration of multichannel DPSK signals by means of a Semiconductor Optical Amplifier (experimental)

By exploiting the nonlinear gain characteristic of a semiconductor optical amplifier (SOA), amplitude noise of constant-envelope phase signals can be strongly compressed, enhancing the resilience of the phase-modulated data to transmission impairments. The inherently broad gain bandwidth of the SOA can be suitably exploited to perform such operation with more than one noisy data channel at the amplifier input. Experimental activity will be performed to assess the regenerative operation for two and more DPSK data channels.

2) Numerical simulation of Semiconductor Optical Amplifier for all-optical regeneration of phase-modulated signals (simulative)

Numerical models present in the literature can be suitably exploited and opportunely modified to describe the process of amplitude noise compression of constant envelope phase-modulated signals travelling in a semiconductor optical amplifiers (SOA) in presence of assist CW light. By developing an existing original code, written with Matlab simulation software, the coupled differential equations describing the nonlinear interaction of the different signals in the semiconductor amplifier will be solved. The results of the simulations will be used to provide the best choice of the amplifiers parameters for most effective regenerative operation. By using the parameters obtained from real devices, the numerical results will be also compared to data obtained from experimental measurements.

High capacity Optical Communications

1. **Pre-emphasis techniques in coherent optical communications for spectral efficiency increase**
   The activity will include theoretical investigation, modeling, and experimental validation over a real optical communication system. Expected background: telecommunications, optical communications, DSP, matlab/fortran/C++ programming, measurement techniques, electro/optical devices
2. **Novel devices for high capacity intra data center optical communications**
   The activity will include theoretical investigation, modeling, and experimental validation over a real optical communication system. Expected background: telecommunications, optical communications, measurement techniques, electro/optical devices
3. **Few-lambda generation, characterization, and stabilization for optical super-channels**
   The activity will include theoretical investigation, modeling, and experimental validation over a real optical communication system. Expected background: telecommunications, optical communications, measurement techniques, electro/optical devices
4. **Design and testing of 1Tb/s super-channel over a real infrastructure through commercial systems**

The activity will include theoretical investigation, modeling, and experimental validation over a real optical communication system. Expected background: telecommunications, optical communications, measurement techniques, electro/optical devices

5. **Space Division Multiplexing through few-core fibers with coherent systems**
   The activity will include theoretical investigation, modeling, and experimental characterization for enabling subsystems. Expected background: telecommunications, optical communications, measurement techniques, electro/optical devices
6. **Multiuser detection in Time-Frequency Packed coherent systems**
   The activity will include theoretical investigation, modeling, and experimental validation over a real optical communication system. Expected background: telecommunications, optical communications, measurement techniques, electro/optical devices