Degree Course: Computer Science and Networking

Faculty: INFORMATICA
Objectives: The Master's Degree in Computer Science and Networking (Computer Science and Networking) was designed to respond to the growing demand of a professional figure requiring graduates that are
• able to master, in an integrated way, both the information technology and the networking in the design
• able to effectively intervene in the implementation of distributed and innovative hardware-software infrastructures,
• able to analyze the requirements and proceed, by providing high added value solutions, to the design and implementation of applications based on distributed services in different sectors of industry, commerce, research, social and citizen services as well as of public administration.
This professional figure is a figure recognized as necessary both nationally and internationally. The recent technological innovations, which provide increasingly high-performance computing and transmission devices, and enabled ae pervasive presence of technologies that combine information technology and telecommunications, make this figure even more necessary in a large set of application areas including research, industry and services, such as Industry 4.0, cyber-physical systems, smart cities, emergency and disaster management , management of energy sources and many more.
For this purpose, graduates will possess comprehensive computer and communications knowledge concerning:
• distributed systems, enabling platforms, services architectures, high performance systems, pervasive and mobile computing;
• access networks on various levels of geographic scale, transmission and wireless and optical technologies;
• models and tools for programming and developing applications, analysis, design and evaluation of systems and applications.
This master degree program has an international characterization and organization, based on courses taught in English, in order to attract students from various parts of the world. Students will have the opportunity to access advanced architecture, programming and communication laboratories in complex centralized, parallel and distributed configurations.

Activities

Digital Communications

Description: The course is organized in two parts FUNDAMENTALS OF SIGNALS AND SYSTEMS and FUNDAMENTALS OF DIGITAL COMMUNICATIONS wich are described as follows:

FUNDAMENTALS OF SIGNALS AND SYSTEMS
Description
This course contains the basic notions about signals and systems, namely signal representations, both continuous time and discrete time, in the time domain and in the frequency domain, the Fourier, and Z transforms, their properties, elements of filtering and elements of stability. This course introduces also the students to probability theory, random variables and random signals (or stochastic processes), and concludes with an introduction to Gaussian processes. The course combines lectures, and practical exercises/demonstrations in MATLAB.
Prerequisite
Basic notions of linear algebra and analysis.
Syllabus
-Basic concepts for continuous-time signals
-Fourier transform
-Sampling and discrete signals
-Discrete Fourier transform and Z Transform
-Filtering and filter design
-Random variables and probability theory
-Stochastic processes
-Gaussian processes

FUNDAMENTALS OF DIGITAL COMMUNICATIONS
Description The course introduces the main principles of digital communications considering various aspects, such as the how to model the wireless propagation channel, digital modulation and demodulation of the information, forward error coding and decoding and the most important multiple access techniques. Where possible, the topics addressed in this course will be presented highlighting how they are declined in modern communication systems, both fixed and mobile, such as WiFi, LTE and their possible implementation in 5G.
Syllabus
-Basic principles of data modulation and demodulation.
-Digital transmitter architecture. Digital modulation formats: PSK, QAM.
-Digital receiver architecture. Main performance indicators.
-Basic principles of error correction coding and decoding. Shannon theorem.
-Wireless channel propagation models. Modulation techniques for the multipath channel: OFDM and spread spectrum modulations.
-Multiple access techniques: FDMA, TDMA, CDMA and OFDMA.
CFU: 12
Official language: English

Wireless networks

Description: The course provides to the students a critique survey of the evolution of the architecture of cellular networks, focusing mainly on the characterizing aspects of the LTE and 5G systems. In addition, the teaching is aimed at analyzing the most widespread technologies for wireless LAN networks, both in the RF band and in mmWave, and the introduction of the various architectural and protocol aspects of the Wireless Mesh Networks (WMN) networks. Finally, the course aims to provide guidelines for the design of these systems.

Syllabus

Wireless LAN (WLAN) networks
• The evolution of the IEEE 802.11 family
• Certification of Wi-Fi products
• Architecture of IEEE 802.11 networks
• Differentiation of the transport service: 802.11e

• Management, authentication and security management procedures
• Design aspects of WLAN networks,

Wireless Mesh Networks (WMN)
• WMN architecture and scenarios
• WMN project aspects
• Project principles of routing protocols in WMNs
• Classification of routing protocols
• Basic concepts on the development of routing metrics for WMN
• Examples of routing protocols and metrics for WMN: OLSR, AODV, BATMAN, HWMP, ETX, ETT, ALM
• The IEEE 802.11s standard.
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Cellular networks
• General structure of a cellular system
• Evolution of the network and functions of GSM, GPRS and UMTS systems
• The LTE system: the elements of the core network and E-UTRAN
• QoS in LTE systems
• Mobility management and handover
• LTE evolution towards LTE-Advanced
• Active Antennas Systems
• Services architecture and the IMS platform
• Examples of QoE evaluation for VILTE services and reporting for VOLTE services
• 5G systems
• RAN 5G network scenarios
• Flexible RAN 5G architecture
• Virtualization concepts of network functions
• Software Defined Networking
• Network Functions Virtualization
• Scenarios Verticals 5G.

CFU: 9
Official language: English

Progetto di sistemi di trasmissione

Description:
CFU: 6
Official language: English

Reliability

Description: Objectives
The course aims at introducing the concepts of reliability, availability, mean time to failure, mean time to repair and to apply them to the communications networks. In addition the course provides the methods for network availability analysis both in stationary and transient regime.

Syllabus
1. Availability, realiability, mean time to failure, mean time between failure, mean time to repair defintions.
2. Mathematical background: probability theory, Markov chains.
3. Combinatorial analysis applied to reliability theory.
4. System availability. Two-terminal, k-terminal, all-terminal reliability. Methods for reliability computation based on graphs and graph reducitions.
5. Probabilistic methods for availability analysis in stationary regime .
6. Probabilistic methods for availability analysis in transient regime.

Course structure
6 credits consisting in teaching and exercises. The final exam will be a written exam.

CFU: 6
Official language: English

Optical communication theory and techniques

Description: The course will introduce the students to the fundamental principles of communication theory and data transmission, with emphasis on spectral characteristics of signals and performance and complexity of optical systems. The most common transmission impairments that must be taken into account when designing modern high capacity optical systems are reviewed, and the fundamentals of optical modulation and demodulation are presented on an introductory level. The structures of highperformance optical transmitters and receivers and their noise properties are also outlined.
Syllabus
1. Digital transmission theory
a) Data transmission over Gaussian channels

b) System design for band-limited channels
c) Channel and line coding
d) Adaptive equalization
2. Fundamentals of optical communications
a) Optical transmitters and modulation formats
b) Impact of fiber linear and nonlinear transmission impairments
c) Optical receivers and noise

CFU: 9
Official language: English

Principles for software composition

Description: This course introduces concepts and techniques in the study of advanced programming languages, as well as their formal logical underpinnings. The central theme is the view of individual programs and whole languages as mathematical entities about which precise claims may be made and proved. The course will cover the basic techniques for assigning meaning to programs with higher-order, concurrent and probabilistic features (e.g., domain theory, logical systems, well-founded induction, structural recursion, labelled transition systems, Markov chains, probabilistic reactive systems) and for proving their fundamental properties, such as termination, normalisation, determinacy, behavioural equivalence and logical equivalence. In particular, some emphasis will be posed on modularity and compositionality, in the sense of guaranteeing some property of the whole by proving simpler properties of its parts. Emphasis will be placed on the experimentation of the introduced concepts with state-of-the-art tools.

• Introduction and background [1 CFU]
• Induction and recursion, partial orders, fixed points, lambda-notation [1 CFU]
• Functional programming with Haskell and analysis of higher-order functional languages [1 CFU theory and 1 CFU exercises and experimentation]
• Concurrent programming with Google Go and Erlang and analysis of concurrent and non-deterministic systems [2 CFU theory and 1 CFU exercises and experimentation]
• Code orchestration with Orc and analysis of coordination languages [1 CFU theory and experimentation]
• Models and analysis of probabilistic and stochastic systems [1 CFU theory and experimentation]

CFU: 9
Official language: English

Applied optics and propagation

Description: Aims

This course will provide the fundamentals of electromagnetic fields, and present in detail the applications of optics. The course will provide concepts and basic notions on light waves, their nature, their description and their physical characteristics, and also outline the main areas of optics application. The course provides the fundamentals of geometrical optics (refraction and reflection, lenses, microscopes etc.), of wave optics (interference, diffraction, polarization) and quantum optics (concept of photon emission properties / absorption of light, lasers) .

Program

Basics of electro-magnetic fields. The geometrical optics and optics of light rays: reflection, refraction, lenses, complex systems of optical elements- Optical Matrix - Maxwell's equations - The phenomenon of polarization (Jones and Stokes description) - Interference and Diffraction: principles, Young experiment, Bragg condition, Fraunhofer and Fresnel diffraction, gaussian beams - Quantum Optics: light emission and absorption, optical spectral properties of materials, population inversion - Lasers basics and laser applications

CFU: 6
Official language: English

Networks and technologies for telecommunications

Description: The course is divided in three modules.
The first module, Network Management Systems (NMS), introduces the fundamentals of network management techniques.
The second module Laboratory of Network Software (LabNS), introduces the utilization of a commercial software (OPNET Modeler) enabling communication network simulation. In this module the students will have the opportunity of simulating the network architectures, the protocols, and the management techniques learned in the previous module.
The third module FPGA for Communications Network Prototyping (FCN) introduces FPGA programming basics and shows how FPGAs can be used for prototyping communications network protocols. In this module students will have the opportunity of implementing basic protocols in FPGAs.

PROGRAM
-Network Management Systems (NMS)
+Management framework and systems
+Information and Data Model
+Protocols and standards
+IP-based management framework
+Sub-IP (optical) management framework
+Emerging network management paradigms
*Software-Defined Networks
*In-network Magagement

*Probabilistic Network Management
*Data Center Management

-Laboratory of Network Software (LabNS)
+Network modeling and simulation: introduction to OPNET Modeler
+Process modeling with OPNET Modeler and exercise
+Variables, statistics, attributes, packets and exercise
+Manual debugging, OPNET Modeler debugger
+Link models and pipeline stage and exercise
+Dynamic processes and exercise
+OPNET practice

-FPGA for Communications Network Prototyping (FCN)
+Introduction to FPGAs
+Introduction to Quartus Prime
+In and Out
+Clocks and Registers
+State Machines
+Modular Design
+Memories
+Managing Clocks
+I/O Flavors
+Laboratory exercises

CFU: 9
Official language: English

Parallel and distributed applications

Description: Course Objective
The course illustrates the issues of parallel and distributed applications, by discussing approaches and solutions for different computing architectures and programming paradigms. For each of the topics covered, real-world applications and case studies will be presented.

Syllabus
1) Classes of applications
a) cpu-, network-, I/O-bound applications
b) decomposition techniques
c) common patterns in parallel applications
2) Parallel applications for:
a) chip multiprocessing (CMP) architectures
b) streaming computing
3) Distributed applications for
a) small to medium scale environments
b) large scale and geographically distributed environments

Oral exam and discussion of a laboratory project to be developed during the course.

CFU: 9
Official language: English

Free-choice exam

Description: The student is free to choose a 9-CFU course in any SSD, provided that it must be approved by the Consiglio di Corso di Studi. A group of courses, suitable for this Master Degree, is indicated by the Consiglio.
Under approval of the Consiglio di Corso di Studi, the free choice exam can consist of a 6-CFU exam and the Survey in Preparation of the Final Proof (3 CFUs).

CFU: 9
Official language: English

Security methods and verification

Description: The course is meant to provide a broad overview of security in networking systems and software applications. With the students, we will explore the theoretical foundations of security, and the formal methodologies used to design, analyse and verify secure systems and applications. Experimental aspects are addressed, too.
Lectures cover the following topics and are also based on a series of research papers.
- Language based security
- Design principles for security protocols
- Information flow security
- Java security, Stack inspection and access control
- Web-application security

At the end, students should have acquired a security-aware way of thinking to systems; they should understand which are the main issues and which are the ways to increase systems security, by co-designing it with the systems, from the very beginning. The course will introduce some notions and problems that concern the security of net applications and will present some formalisms and techniques to address them.

CFU: 6
Official language: English

Advanced software engineering

Description: The overall objective of the course is to introduce some of the main aspects in the design, analysis, evelopment and deployment of modern software systems. Service-based software engineering is introduced by presenting core interoperability standards, service descriptions, and service compositions techniques. Techniques for modelling and analysing business processes are then illustrated. Finally, cloud-based software engineering and DevOps practices are discussed. The course includes a weekly "hands-on" lab where students experiment the design, analysis, development and deployment techniques introduced.
Syllabus
• Service-based software engineering
• Business process modelling and analysis
• Cloud-based software engineering
• DevOps practices
• Hands-on laboratory
CFU: 9
Official language: English

Software verification methods

Description: Objectives
Model checking concerns the use of algorithmic methods for the assurance of software and hardware systems. As our daily lives depend increasingly on digital systems, the reliability of these systems becomes a concern of overwhelming importance, and their reliability can no longer be sufficiently controlled by the traditional approaches of testing and simulation.

Syllabus
Verification algorithms: linear and branching temporal logics, omega automata, equivalences.
State explosion: symbolic data structures, automatic abstraction, compositional reasoning.
Case studies

Course structure
6 CFUs. Exam consists in an oral test and possibly of a small project.
CFU: 6
Official language: English

Web security

Description: Objectives
The course subject is to address the main problems related to a secure usage of web applications, and coutermeasures for fight the possible attacks that attackers may perform.
After a short introduction to the general issues related to security, and to those related to the use of world wide web, the main attacks web users are subject to, like cross site scripting, or phishing, are presented, as well as the software that typically is used in such attacks. Such an example software is taken from real attacks performed in the past, and for which working patches exist and are widespread, but it is similar to that presently used by hackers. Besides, the actions, software tools and web applications that can be used for such attacks are presented. Finally, countermeasures typically adopted to counterfight the above attacks, or to alert about them, are given.
The attacks considered are not only those performed by technically skilled attackers: also attacks based on human weaknesses, like those known as social engineering, are part of the course.

Syllabus
1. Introduction and intelligence gathering
2. cross site scripting
3. cross site request forgery
4. internet application level vulnerabilities
5. blended attacks
6. vulnerabilities of the applications for cloud computing
7. attacks to mobile devices
8. phishing
9. social engineering through the web
10. attacks to the executives
11. case studies

Course structure
6 CFUs. Exam consists in an oral examination.
CFU: 6
Official language: English

Embedded systems

Description: Objectives
This course covers the main stages in the development of embedded systems, with emphasis on model-based development and formal methods for the analysis of system properties. We review problems and approaches related to all the stages of development including requirements analysis, system-level design, component oriented modelling, behavioural modelling, verification of properties, architecture selection and design, code generation and testing.

Syllabus
1) Model-based development of embedded Systems

a. Embedded systems and impact on modern day industrial electronics
b. Stages in the development flow, model based design.
c. Computation models for Embedded Systems: finite state machines, hierarchical FSM, timed automata, dataflows.
d. User requirements analysis, system-level testing, requirements tracking, architecture selection and analysis, component modelling, design of components, implementation of models into concurrent code, semantics preservation issues. Tools, standards and methods for system modelling.
e. Introduction to verification techniques, functional and timing analysis.
f. Automatic code generation for abstract models.
g. Testing techniques, conformance testing, concept of coverage, MC/DC coverage.
2) Embedded Systems Programming: Operating systems and wireless communication: technologies and examples-

Course structure
6 credits consisting of front lectures, exercise, laboratory and project. Exam consists in a colloquium concerning course concepts and the discussion of the project assigned to the student.
CFU: 6
Official language: English

Teletraffic engineering

Description: The course gives the fundamentals concepts related to Teletraffic Theory and its application to network engineering. The aim of the course is to give the students the capacity of building up and analyse their own abstraction of basic functions related to telecommunication networks or discrete state stochastic systems in general. Transient and Steady-state analysis of Discrete and Continuous Time Markov processes are introduced. Fundamentals concept related to Queueing theory and their application to circuit and packet switching networks are presented. The analysis of fundamental performance indexes is carried out, when necessary, by means of the transforms theory (e.g. Laplace, Zeta). The fundamental theorems related to the tractability of open and closed Queueing Networks are also presented. The classroom and laboratory (matlab) exercise are aimed to give the student the ability to carry out the solution of basic cases by proper analytical or numerical methods.

1) Discrete state Markov processes
a. Discrete State, Discrete Time Markov Processes (Markov chains)
b. Discrete State, Continuous Time Markov Processes
2) Point Processes
a. Pure Birth and Pure Death processes
b. Discrete time and continuous time Bernoulli processes
c. Poisson process
3) Birth and Death Processes
a. Ergodic conditions
b. First and second order momentum
4) Basics on teletraffic analysis
a. Stochastic models
b. Deterministic models
c. Non stationary behavior. TCBH, ADPH definitions
5) Markovian queues
a. Kendall notation; Geo/Geo/1, M/M/Ns, M/M/Ns/0, M/M/1/Nw;
b. Erlang B Formula, Erlang C Formula, Engset formula.
c. Problems and solutions related to the evaluation of Erlang B e Erlang C formulas. MATLAB functions for the evaluation of loss probability in M/M/1/Ns and M/M/Ns/Nw queues. MATLAB solutions for M/Cox2/1/Nw, M/H2/1/Nw and M/E2/1/Nw queues.
d. Matrix-Geometric approach for the solution of Markov chains described by block Hessenberg matrices.
e. Matrix-Geometric approach for the analysis of the M/Cox2/1 queue.
6) Non Markovian queues:
a. A simple non markovian queue: the M/G/1 queue;
b. The embedded Markov chain; steady state analysis of the M/G/1 queue.
c. Multiple user classes and priorities in M/G/1 queues

7) Queueing networks:
a. Open and Closed Markovian Queueing Networks.
b. Burke Theorem. Jackson Theorem.
c. Gordon-Newell Theorem.
d. Convolution Algorithm and Mean Value Analysis for the solution of the Gordon-Newell queueing networks.
e. BCMP queueing networks. Performance indexes in markovian open and closed queueing networks and BCMP.
8) Numerical tools for the solution of Markov Chains
a. Matlab Matfun e Stats Libraries. Erlang k, iperexponential, ipoexponential and Coxn generators
b. Quantile-quantile plots. Eigenvalues decomposition for the transient analysis of Markov chains.
c. Direct methods for the evaluations of the steady state in ergodic Markov Chains.

Written test, laboratory test on MATLAB, and Oral Exam.
CFU: 9
Official language: English

Network management and configuration

Description: Objectives
This course aims at providing students with a guided and critical overview of the communications network protocol evolution. The course will mainly focus on the TCP/IP architecture of the current Internet and on the Ethernet protcol. Finally the most recently introduced standards will be presented. Protocols (e.g., MPLS) and algorithms for traffic engineering and resilience will be introduced. Elements of event driven simulation will be provided. The concept presented in class will become topic of lab experiments.

Syllabus
1) Communications Networks
• Data Transmission fundamentals (4 hours)
o Digital vs Analog Transmission
o Analog to Digital Conversion
o Physical Media
o Connection-oriented vs connectionless communications
o Packet switching
• Review of ISO/OSI and TCP/IP protocol architecture (2 hours)
• MAC and Logical Link Control (4 hours)
o Automatic Repeat reQuest (ARQ)
o Pipelining
• Ethernet (6 hours)
o CSMA/CD
o Repeaters, Bridges, Switches
o Switched Ethernet
 1GbE, 10GbE, beyond 10GbE
o VLAN
• IP Protcols (4 hours)
o Classes
o Subnetting
o Supernetting
o Routing basics
 OSPF
o Quality of service
 IntServ
 DiffServ
• MPLS protocols (4 hours)
o OSPF-TE
o RSVP-TE
• Optical Networks (4 hours)
o SONET/SDH
o Wavelength Division Multiplexing (WDM)
• Network resilience and availability (6 hours)
o Resilience in IP, MPLS and Optical Networks
o Introduction to availability theory
• Introduction to event driver simulation (6 hours)
2) Lab of Traffic Engineering
a. Methods for designing communications networks
b. Lab hands-on session

Course structure
9 credits consisting of front lectures and laboratory exercise. Exam consists in written test concerning course concepts and a possible discussion of a project assigned to the student.

CFU: 9
Official language: English

Fundamentals of signals, systems and networks

Description: Objectives
This course introduces the fundamentals of signal theory, of stochastic processes, the fundamentals of queueing theory, some basic elements of electromagnetism and some calulus. The course will also cover the main network architectures for access, metropolitan and core segments.

Syllabus
1) Signal Theory, basic calculus
a. Finite energy and finite power discrete and continuous signals
b. Periodic signals
c. Time invariant linear systems
d. Description of signals and systems in the frequency domain
e. Advanced calculus
2) Processi stocastici e teoria delle code
a. General concepts
b. Probability and random variables
c. Stochastic processes
d. Markov chain and process
e. Elements of queuing theory
3) Design of networks
a. Network hierarchy
b. Access segment
c. Metropolitan segment
d. Core segment
e. Future architectures

Course structure
12 credits consisting of front lectures and exercise. Exam consists in a written test concerning course concepts and a possible discussion of a project assigned to the student.

CFU: 12
Official language: English

Survey for the final thesis

Description: Activity in support of the student for the thesis preparation.
CFU: 3
Official language: English

Information and transmission theory

Description: Objectives
The course covers the fundaments of Information Theory introducing the concepts of Entropy, Coding, Compression, Error Correction. It is intended as a for subsequent studies dealing generation, coding and transmission of Information.
Syllabus
General concepts of Information Theory. Entropy function. Asymptotic equipartition property.
Discrete Information Sources. Noiseless Coding: instantaneous and uniquely decipherable codes, the noiseless coding theorem. Optimal code generation. Huffman codes, arithmetic coding.
The discrete memoryless channel. Channel capacity, decoding schemes and error probability. Channel coding, The fundamental Theorem.
Error correcting codes, block coding, linear codes, decoding algorithms. Cyclic codes, BCH codes, Reed Solomon Codes and their applications.
The continuous channel, introduction to the Transmission Theory.
Course structure
9 credits (6 on Information Theory, 3 on Transmission Theory). Exam consists in a written test and a colloquium.
CFU: 9
Official language: English

Distributed operating systems

Description: Objectives
The course provides concepts and techniques needed to extend the definition of Operating System, known for single machines from previous courses, up to include inherently parallel and distributed computing platforms.
In this course we compare different middleware and DOS technologies, we analyze the system abstractions they provide, the issues they imply, the implementation choices made and the functionalities obtained. A fundamental component of the course is the presentation from a technological viewpoint of a Distributed Operating System (DOS).

Syllabus
Basic notions
Models of Distributed Operating Systems, basic techniques
Middleware systems, Quality of Service
Single-sistem-image DOSes (SSI)
Cooperating kernel instances, implementation, applicability;
Geographical and wide-area DOSes
Virtual Organizations; security, communication and cooperation mechanisms;
Large-scale distributed file systems;
Execution mechanisms
Resource Heterogeneity in DOSes
Classes of resources and operating system constraints
Consequences on system abstractions and implementation
Complements and links
DOSes and hierarchical multilevel computing architectures
Virtualization and DOSes : system-level interpretation, containers, virtualization, paravirtualization
Future Internet and DOSes

Course structure
6 CFU, 4 of them concerning SSI and wide-area DOSes. The teaching needs that a laboratory is available to the students for experimenting. The final exam is a discussion about course material and a student project, related to one of the DOSes that are presented during the course.
CFU: 6
Official language: English

Routing Architectures and Protocols Lab

Description: Aims
The course is aimed to provide the fundamental knowledge to understand the key concepts and the functional components necessary to design and implement inter-domain routing. Basic concepts concerning the configuration, management and monitoring of Juniper Networks router are recalled. Moreover, the course deals with theoretical and practical topics, such as the design and deployment of networks with EGP (BGP) routing protocols or the implementation of advanced services and functionalities (Stateful firewall, NAT/PAT, IPSec VPNs, QoS). Traditional lectures are coupled with laboratory experiments which provides students with the possibility to work with Juniper Networks routers.
The course includes the topics for the Juniper Networks Certified Internet Specialist (JNCIS-ER) exam.

Contents
JUNOS Policy. Policy language and policy evaluation process overview. Routing policy. Firewall policy.
(L:4)

BGP routing protocol. BGP overview. IBGP implementation. EBGP implementation. BGP-IGP interaction.
(L:4)

Enterprise routing policies. Design and deployment of BGP in an enterprise network. Case Study: primary/secondary routing policy.
(L:4; Lab:8)

Transitioning between IGP routing protocols. Transition methodologies overview. Overlay transition. Route redistribution transition. Integrated transition.
(L:2; Lab:2)

JUNOS services. Introduction to JUNOS services. Layer 2 services configuration. Layer 3 services configuration. Stateful firewall and NAT. applications. Configuring stateful firewall rules. Configuring NAT rules. Implementing and monitoring stateful firewall and NAT. IPSec VPN overview. IPSec VPN configuration, implementation and monitoring.
(L:4; Lab:8)

Quality of Service in IP networks. Class of Service overview. Design of a network with QoS support at IP level. Differentiated Services architecture overview. DSCP marker. Traffic classification. Traffic queuing. Traffic scheduling. Troubleshooting.
(L:4; Lab:4)

Examinations. Form of assessment:
Oral Examination with lab test.

CFU: 6
Official language: English

Data mining

Description: Objectives

Recent tremendous technical advances in processing power, storage capacity, and interconnectivity are creating unprecedented quantities of digital data. Data mining, the science of extracting useful knowledge from such huge data repositories, has emerged as an interdisciplinary field in computer science. Data mining techniques have been widely applied to problems in industry, science, engineering and government, and it is believed that data mining will have profound impact on our society. The objective of this course is to provide:
1. an introduction to the basic concepts of data mining and the knowledge discovery process, and associated analytical models and algorithms;
2. an account of advanced techniques for analysis and mining of novel forms of data;
3. an account of main application areas and prototypical case studies.

Syllabus
- Concepts of data mining and the knowledge discovery process
- Data preprocessing and exploratory data analysis
- Frequent patterns and associations rules
- Classification: decision trees and Bayesian methods
- Cluster analysis: partition-based, hierarchical and density-based clustering
- Experiments with data mining toolkits
- Mining time-series and spatio-temporal data
- Mining sequential data, mining large graphs and networks
- Data mining languages, standards and system architectures
- Social impact of data mining
- Privacy-preserving data mining
- Applications (hints):
- Retail industry, Marketing, CRM
- Telecommunication industry,
- Financial data analysis, risk analysis
- Fraud detection
- Public administration and health
- Mobility and transportation

Course Structure
9 credits (6 on foundations and 3 on advanced topics and applications.) The course is taught in English. The exam consists in a written test, a data mining project and an oral examination.

CFU: 9
Official language: English

Advanced programming

Description: Objectives

The objectives of this course are:
a. to provide the students with a deep understanding of how high level programming concepts and metaphors map into executable systems and which are their costs and limitations
b. to acquaint the students with modern principles, techniques, and best practices of sophisticated software construction
c. to introduce the students to techniques of programming at higher abstraction levels, in particular generative programming, component programming and web computing
d. to present state-of-the-art frameworks incorporating these techniques.
This course focuses on the quality issues pertaining to detailed design and coding, such as reliability, performance, adaptability and integrability into larger systems.
Syllabus
1. Programming Language Pragmatics
2. Run Time Support and Execution Environments
3. Generic Programming

4. Class Libraries and Frameworks
5. Generative Programming
6. Language Interoperability
7. Component Based Programming
8. Web Services
9. Web and Application Frameworks
10. Scripting Languages

The exam consists in a homework or laboratory test, and and oral test.
CFU: 9
Official language: English

Algorithm engineering

Description: Study, design and analyze advanced algorithms and data structures for the efficient solution of combinatorial problems involving all basic data types, such as integer sequences, strings, (geometric) points, trees and graphs. The design and analysis will involve several models of computation — such as RAM, 2-level memory, cache-oblivious, streaming — in order to take into account the architectural features of modern PCs and the availability of Big Data upon which algorithms could work on. We will add to such theoretical analysis several engineering considerations spurring from the implementation of the proposed algorithms and from experiments published in the literature
· Design of algorithms for massive datasets: disk aware or cache oblivious
· Design of advanced data structures in hierarchical memories for atomic or string data
· Data compression for structured and unstructured data
· Algorithms for large graphs
· Engineering considerations about the implementation of algorithms and data structures
CFU: 9
Official language: English

Peer to Peer Systems and Blockchains

Description: Introduction of the basic technologies for the development of highly distributed systems and some real scenarios exploiting them. Presentation of the disruptive technology of blockchains, and of its numerous applications to different fields.
Syllabus
• P2P Topologies (2 + 1/2 credits)
o Peer to Peer (P2P) systems: general concepts
o Unstructured Overlays: Flooding, Random Walks, Epidemic Diffusion
o Structured Overlays: Distributed Hash Tables (DHT), Routing on a DHT
o Case Studies: Bittorrent as a Content Distribution Network: KAD implementation of the Kademlia DHT, game-based cooperation
• Complex Network for the analysis of P2P systems (1/2 credits)
o Network models
o Random Graphs and Small Worlds
o Small World navigability: Watts Strogatz and Kleinberg.
o Complex networks navigability
• Cryptocurrencies and Blockchains (3 credits)
o Basic concepts:
o review of basic cryptographic tools (digital signatures, cryptographic hash, Merkle trees.,..), blockchains: definitions, distributed consensus: definitions,
o The Bitcoin blockchains
o Nakamoto consensus
o Bitcoin mining mechanism, fraudolent mining.
o pseudoanonymity: traceability and mixing
o The Bitcoin P2P Network
o Bitcoin ecosystem
o scalability issues
o applications and security
o Bitcoin Extensions/alternatives: altcoins, sidechains, the
o StellarConsensus Protocol
o Applications of blockchains
o Ethereum: programming smart contracts
o Blockchain 1.0: cryptocurrencies
o Blockchain 2.0: finantial instruments built on cryptocurrencies
o Blockchain 3.0: applications beyond cryptocurrencies (DNS, lotteries, voting, IoT...)
CFU: 6
Official language: English

Concurrent programming

Description: Objectives
The course deals with methodologies and techniques for concurrent and distributed systems programming. The classical local-environment and global-environment are developed in depth, and applied to existing technologies (communication and shared memory libraries) and concurrent languages, as well as to higher level models, e.g. structured parallel programming and distributed framework, experimented in several case studies.

Syllabus
1. Concurrent programming models
2. Application to communication libraries

3. Application to shared memory libraries
4. Concurrent languages
5. Environments and tools for structured parallel programming and distributed frameworks
6. Case studies.

Course structure
6 CFUs. Exam consists in a written and an oral part.
CFU: 6
Official language: English

Pervasive computing

Description: Objectives
The course deals with methodologies and techniques for design and application of pervasive/ubiquitous computing paradigms: ambient intelligence, context-awareness, human-centered computing, sentient computing, and others. Technologies, systems and frameworks for distributed support of these paradigms are studied and related to general models for parallel abd distributed computing. Several case studies are presented.

Syllabus
1. models for pervasive/ubiquitous computing
2. ambient intelligence,
3. context-awareness,
4. human-centered computing,
5. sentient computing,
6. analysis and evalutation of technologies, systems and frameworks,
7. case studies.

Course structure
6 CFUs. Exam consists in a written and an oral part.
CFU: 6
Official language: English

Distributed enabling platforms

Description: Course Objective
This course develops the issues of fundamental course on distributed computing platforms in depth, such as Grids and Clouds. This aim is also achieved through the study of state-of-the-art solutions, the detailed analysis of their technologies and of the best practices regarding last-generation distributed enabling platforms,

Syllabus
Introduction to distributed middleware
Development of concepts and techniques for Grid computing in depth
Grid computing components and solutions
Resource virtualization
Virtualization technologies
Introduction to cloud computing
Development of concepts and techniques for Cloud computing in depth
Applications tools for grid and cloud Computing

Grading
The examination procedure consists in a colloquium on course topics and on a project assigned to the student.
CFU: 6
Official language: English

ICT risk assessment

Description: At the end of this course, the student should be able to discover and analyze the weaknesses and the vulnerabilities of a system to evaluate in a quantitative and formal way the risk it poses. The student should be able to select and deploy a cost-effective set of countermeasures at the various implementation levels to improve the overall ability of the system to withstand its attackers. Focus of the course is on a predictive approach where risk assessment and management is a step in the system design. The student should also be able to know the various tools that can support the assessment and simplify both the assessment and the selection of countermeasures. In this framework, the focus on cloud computing makes it possible to cover the most complex assessment.
• Risk Assessment and Management of ICT Systems 3 CFU
o Vulnerabilities/Attacks 1 CFU
o Countermeasures 1 CFU
o Tools for Automating Assessment & Management 1 CFU
• Security of Cloud Computing 6 CFU
o Economic Reasons/Deployment Models/ Service Models 1 CFU
o Virtualization and TCM 1 CFU
o New Vulnerabilities 1 CFU
o New Attacks 1 CFU
o New Countermeasures 1 CFU
o Certification of Cloud Provider 1 CFU
CFU: 9
Official language: English

Description: The goal is to introduce the theoretical foundations and algorithmic-engineering tools for the design, analysis and implementation f IR systems. We will study several algorithmic techniques which are nowadays deployed to design IR applications, like: algorithms for data streaming, data compression, data indexing, data sketching and data searching. This algorithmic machinery will be used to study the design and analysis of the main components of a modern search engine, and to investigate their computational limitations. Together with the theoretical study of the previous, the course will consist also of a practical activity (3 CFU) in which the students will pratice with the open-source tools nowadays available for the implementation of a search engine and of other IR applications.
CFU: 6
Official language: English

Photonic switching

Description: Objectives
The curse introduces the fundamentals of photonic technologies by considering the photonic devices on a structural, functional and manufacturing point of view. Moreover it will be given the basis of the photonic switching techniques by means of nonlinear photonic devices based on semiconductor and fibres. The curse includes practical in the laboratory.

Syllabus
1) Semiconductors for Photonics
a. Optical Proprieties of Semiconductors.
b. LEDs.
c. Optical guiding and cavities, losses and threshold condition.
d. DBR lasers, DFB lasers, VCSELs, quantum-cascaded lasers, microcavity lasers.
e. Key design parameters and degradation mechanisms in semiconductor lasers.
f. Semiconductor optical amplifiers.
g. PIN and avalanche receivers.
2) Photonic Passive and Functional Integrated Devices
a. Integrated guided optics.
b. Passive integrated devices.
c. Functional integrated devices.
d. Nonlinear devices.
3) Deposition and Compound Semiconductors Growth Techniques
a. Oxidation, sputtering, evaporation.
b. “Plasma enhanced” and “low-pressure” CVD.
c. Liquid-phase (LPE/) and vapour-phase (VPE/MOCVD) epitaxy.
d. Molecular beam epitaxy (MBE).
4) Processing/Manufacturing Devices
a. Lithography (electron-beam lithography, laser-beam lithography, optical lithography) and metallization.
b. "wet“ e “dry” etching techniques.
c. Ion implantation techniques, diffusion, annealing.
d. Device packaging.
5) Material/Device Testing and Characterization
a. Characterization equipment for materials (x-ray diffraction, photo-luminescence, Hall measurements, spectroscopy and microscopy techniques).
b. Characterization equipment for devices, examples of test setup.
6) Photonic Crystals Devices
a. Basic principles.
b. One-, two-, and three-dimensional PCD: typology, fabrication and characterization techniques.
7) Optical Fiber Technologies
a. Step- and graded-index fiber technology.
b. Micro-structured Fibers.
c. Fibre devices.
d. Optical fiber amplifiers.
e. Opical fiber sensors.
f. Fiber-guide coupling.
8) Glass-on-Silicon Technology.
9) Polarisation switching in a highly nonlinear fibre.
10) Signal inversion through XGM in a SOA.
11) Mode locked pulse characterization.
12) NOLM characterization through optical pulses.
13) AND photonic logic gate in a HNLF.
14) RZ packet generation.

Course structure
9 credits consisting of front lectures and exercise. Exam consists in a colloquium concerning course concepts and it could include the evaluation of reports on the experimental activities.
CFU: 9
Official language: English

Packet switching and processing architectures

Description: Objectives
The course presents the main network switching architectures, with particular focus on packet switching architectures. After a brief introduction to the notions of circuit and packet switching, the course will focus on the main schemes of packet switching together with their performance and possible issues. Then, the course will deal with packet lookup and classification by presenting main algorithms currently in use. Finally, the course addresses the topic of traffic measurements and monitoring by introducing the main probabilistic techniques (mainly Bloom filters and their variations) to improve performance on high-speed links.
Syllabus
1) Basics on switching paradigms (circuit/packet switching)

2) Switching fabrics
a. Basic properties of Interconnection Networks
b. Multistage Networks
c. Clos Networks
i. Strictly and Rearrangeably non blocking networks
ii. Recursive construction of Clos networks
d. Self-routing (Banyan) Networks
3) Packet switching architectures
a. Output Queued Switches (OQ)
i. Average delay and maximum throughput
b. Input Queued Switches (IQ)
i. Head Of the Line blocking (HOL)
ii. Virtual Output Queueing
iii. Scheduling (MWM, MSM, etc.)
c. Combined Input-Output queueing (CIOQ) and OQ emulation
4) Packet Lookup and Classification
a. Exact/Prefix match lookup algorithms
i. Unibit and MultibitTrie
ii. Lulea-Compressed Tries
iii. Tree bitmap
b. Mono/Multi dimensional packet classification
5) •Traffic Measurements/Monitoring
a. Packet capturing
b. On-the-wire packet processing
c. Probabilistic techniques for high performance monitoring applications

Exam consists of an oral colloquium including the discussion on a simple project that will be assigned during class time.
CFU: 6
Official language: English

Cost models and run time design

Description: Objectives
The course deals with methodologies and techniques for the design of run-time supports for programming and application paradigms in distributed systems, according to approaches based on abstract architectures and cost models for computation and communication. General methodologies and techniques are presented in the general case, as well as relevant case studies which can be defined and modified in distinct years.

Syllabus
1. Abstract architectures and cost models for distributed systems
2. Methodologies and techniques for static analysis of distributed applications
3. Methodologies and techniques for run-time analysis of distributed applications
4. Design of run-time supports and optimizations
5. Configuration, inizialization, and execution tools
6. Case studies.

Course structure
6 CFUs. Exam consists in a written and an oral part.
CFU: 6
Official language: English

Network optimization

Description: Objectives
Aim of the course is to present the main modelling techniques and the main algorithmic methodologies for managing communication networks both at a design and at an operational level.
We shall introduce relevant design and operational problems for communication networks, such as QoS routing problems, location problems, resiliency and robustness problems, and equilibrium problems in traffic networks. Then, we shall describe modelling techniques and algorithmic approaches for both basic probelms and NP-Hard problems.

Syllabus
1) Basic network optimization problems: models and algorithms
a. Maximum flow
b. Minimum cost flow
c. Multicommodity flows
2) NP-Hard network optimization problems: models and algorithms
a. Routing models
b. Network design models
c. Main heuristic techniques
d. Exact approaches
3) Applications
a. QoS routing
b. Location problems
c. Resiliency problems
d. Robustness in communication networks
e. Equilibrium in traffic networks

The exam consists of an oral examination.
CFU: 6
Official language: English

Programming tools for parallel and distributed systems

Description: Objectives
The course deals with design, evaluation and utilization of programming tools and environments for parallel and distributed applications. The programming paradigms, and related cost models, concern high-performance stream- and data-parallel computations, distributed shared memory, adaptive and context-aware programming, high-performance event-based programming, real-time programming, programming of fault-tolerance strategies, and others. For these paradigms, static and dynamic tools are defined and their performances are evaluated through case studies in experimental and laboratory activites.
Syllabus
1. high-performance stream- and data-parallel computations,
2. distributed shared memory,
3. adaptive and context-aware programming,
4. high-performance event-based programming,
5. real-time programming,
6. programming of fault-tolerance strategies,
7. tools and environments
8. run-time supports
9. case studies

Exam consists in a written and an oral part.
CFU: 6
Official language: English

Virtual network environments

Description: Objectives
This course will provide a general introduction to Virtual Environments, including an analysis of the common forms of network communication used in real-life applications. The course will also expose the practical aspects of Virtual Environments development, and practical lab sessions will provide the opportunity to conduct tests on some simple test applications.

Syllabus
1) Virtual Environments theory
a. General concepts
b. Introduction to Virtual Environments
c. Real-Time computer graphics for VEs
d. OpenGL fixed pipeline & Shaders
e. Real-time physics
f. Motion Tracking
g. User Interaction
h. Haptic feedback
i. Communication architectures in Networked VEs
j. Data traffic, payloads, latencies
k. Events arbitration
l. Gemetric data compression

2) Development & exercises
a. Virtual Environments software architectures
b. Introduction to a VE Integrated Development Environment
c. Authoring 3D content
d. VR equipment for Immersive visualisation, motion tracking and force feedback
e. System Integration, profiling and debugging
f. Testing network communication in collaborative VEs

Course structure
6 credits consisting of front lectures and exercise. Exam consists in a colloquium concerning course concepts and discussion of a simple project assigned to the student.
CFU: 6
Official language: English

Distributed software design lab

Description: Objectives
The aim of the course is the development of distributed software systems that satisfy given requirements and time and cost constraints. The development process presented and followed during the course consists of both technical activities (domain analysis, requirement specification, design in UML, implementation in Java, documentation) and management activities (customer meetings, inspections, acceptance test).

Syllabus
1. Domain analysis
2. Requirement specification
3. Design in UML by using an integrated design environment
4. Coding in Java (or in another object-oriented programming language) by using an integrated development environment
5. Verification and validation

The exam consists in a colloquium concerning course matter plus a discussion on a project realized during the course.
CFU: 6
Official language: English

System virtualization

Description: Objectives

This course deals with virtualization techniques at various system levels. The course is focused on two main issues, 1) virtualization techniques, 2) main application of virtualized systems. Virtualization methodologies will be studied for different system components, integrated by design experiences and applications.

Syllabus
1) Virtualization approaches
a. Levels of applications, operating system, physical machine
b. Virtualization methodologies: simulation, binary code translation, para-virtualization
c. Virtualization costa and benchmarking
d. Virtualization of single machines and of cluster of machines
2) Utilization and application of virtualization
a. Excess parallelism and consolidation
b. Dynamic management of physical resources
c. Virtualized resource management
3) Virtualization methodologies of system components
a. Processor
b. Memory
c. I/o devices
4) Case studies
a. Full virtualization solutions: installing and configuration. Life cycle management, migration.
b. Virtualization exercizes (trap-and-emulate, interposition at OS level, …)
5) Interrerations between virtualization and security.

Course structures
6 CFUs, with laboratory experiences. Exam consists of an orarl test with discussion of a simple project.

CFU: 6
Official language: English

Networking architectures, components and services

Description: Objectives

The aim of the course is to present the architecture and protocols of modern packet-switching networks, focusing on the underlying problems and the different solutions proposed to solve them. In particular, issues related to IPv6, user mobility, multicast communications, Quality of Service requirements and peer-to-peer networks will be analysed. The theoretical part of the course will be followed by a lab module, devoted to the simulation of IP networks, the study of TCP (Linux TCP) and the implementation of rules for packet filtering and NATting in the Linux OS.
Syllabus
1. IPv6 and MIP
a. General features of IPv6 and header format
b. ICNPv6 and procedures of Neighbour Discovery
c. Transition IPv4-IPv6
d. Host mobility: MIPv4 e MIPv6
2. Multicast
a. Multicast addresses
b. IGMP
c. Multicast Routing Protocols (DVMRP, PIM-SM, PIM-DM)
3. Transport Layer
a. Overview on transport layer protocols (UDP, TCP, DCCP)
b. Flow and Congestion Control mechanisms in TCP and DCCP
c. RTT estimations
d. Congestion Avoidance techniques (DECbit, RED, CHOKe, TCP Vegas)
4. Quality of Service
a. Queueing and scheduling disciplines (FIFO, priority queueing, GPS, WFQ, WF2Q)
b. Token bucket traffic characterization
c. Intserv architecture
d. DiffServ architecture
5. P2P
a. General features
b. Classification of P2P architectures and examples

6. Lab
a. Simulation of IP networks
b. Simulation analysis of TCP connections
c. TCP linux in Linux OS
d. IPtables: packet filtering and NATting

CFU: 9
Official language: English

Performance and design issues of wireless networks

Description: Objectives

The objectives of the course are the presentation of the cellular network evolution, of the most popular technologies for Wireless LAN and MAN, and of the different solutions available for the Wireless Mesh Networks (WMN). Furthermore, the course aims at providing the tools necessary for the design of these networks and at highlighting their performance problems.

Syllabus
1) Cellular Networks
a. General structure of a cellular network
b. GSM network Architetture

c. UMTS network Architetture
d. Mobility and session management in cellular networks
2) Wireless LAN
a. The standard IEEE 802.11
b. Operative modes of IEEE 802.11 networks
c. Distributed Coordination Function and Point Coordination Function
d. IEEE 802.11 systems evolution
e. Security threats and solutions in IEEE 802.11 networks
3) WiMAX Networks
a. WiMAX network architecture
b. The standard IEEE 802.16
4) Wireless Mesh Networks (WMN)
a. MAC protocols
b. Capacity
c. Routing protocols
d. Transport protocols
e. Fairness issues
f. QoS, Security and Management issues
g. The working group IEEE 802.11s
5) Lab activity
a. Design issues of cellular networks
b. Performance and design issues of IEEE 802.11 networks
c. Performance and design issues of WiMAX networks
d. Techniques for improving performance of WMN

Oral exam.
CFU: 6
Official language: English

Real-time systems

Description: Objectives
The course introduces kernel mechanisms and analysis techniques for increasing the predictability of computer controlled systems.

Syllabus
1. Basic concepts on real-time computing
Application domains. Typical system requirements. Limits of traditional approaches. Task models. Typical timing constraints. Task Scheduling. Metrics for performance evaluation.
2. Real-Time scheduling algorithms
Algorithm tassonomy. Scheduling with precedence constraints. Scheduling periodic tasks. Utilization-based analysis. Response-time analysis. Aperiodic task handling. Fixed-priority servers. Dynamic priority servers.
3. Protocols for accessing shared resources
The priority inversion phenomenon. Non-preemptive protocol. Priority Inheritance Protocol. Priority Ceiling Protocol. Stack Resource Policy. Computing blocking times. Schedulability analysis.
4. Overload management
Definition of computational load. Methods for overload handling. Admission Control. Robust Scheduling. Imprecise Computation. Job Skipping. Elastic scheduling. Handling overruns. Resource reservation mechanisms. Resource reclaiming techniques.
5. Implementation issues
Kernel mechanisms for real-time support. Required data structures. Time representation. Taking overhead into account. Basic kernel primitives. Process states and state transitions. Synchronous and asynchronous

Course structure
6 credits consisting of front lectures, exercise, laboratory and project. Exam consists in a colloquium concerning course concepts.
CFU: 6
Official language: English

Wireless networks of embedded systems

Description: Objectives
The course aims at presenting the fundamental principles of Wireless Sensor Networks, with a specific focus on micro-kernels, IP programming, and Service Oriented Architectures. The approach of the Internet of Things will be followed. Technological add-up’s related to real-time programming will be also discussed.
Syllabus:
• Introduction to WSN technology and applications
• Device architectures and components
• Low-level coding and Operating Systems
• Wireless Communication Techniques at PHY and MAC layer
• Characterization of IP-level communication protocols
• Basic programming for embedded systems
• Networking sample applications
• Sensor network abstraction (db-like)
• Case studies: Embedded Vision, Multinode Data Aggregation
• Real-world applications, notably Intelligent Transportation"
Oral exam, plus an optional student project.
CFU: 6
Official language: English

High Performance Computing

Description: Objectives

This course deals with two interrelated issues in high-performance computing:
1. fundamental concepts and techniques in parallel computation structuring and design, including parallelization methodologies and paradigms, parallel programming models, their implementation, and related cost models;
2. architectures of high-performance computing systems, including shared memory multiprocessors, distributed memory multicomputers, clusters, distributed enabling platforms, and others.

Both issues are studied in terms of structural model, static and dynamic support to computation and programming models, performance evaluation, capability for building complex and heterogeneous applications and/or enabling platforms, also through examples of application cases. Technological features and trends are studied, in particular multi-/many-core technology and high-performance networks.
An initial part of the course is dedicated to review basic concepts and techniques in structured computer architecture, in order to render the different backgrounds of students as uniform as possible.

Syllabus
0. Computing architecture primer
1. Methodology for structuring and programming high-performance parallel applications, basic cost models: metrics, elements of queueing theory and queueing networks, load balancing, static and dynamic optimizations
2. Parallel paradigms: stream-parallel (pipeline, data-flow, farm, divide and conquer, functional partitioning), data-parallel (map, fixed and variable stencils, reduce, prefix), and their compositions
3. Cooperation mechanisms: dedicated and collective communications, shared objects, compiling tools, run-time supports and their optimization
4. Shared memory multiprocessors: SMP and NUMA, cost models; interconnection networks and their evaluation: indirect and multistage networks, direct and cube networks, fat tree, on-chip networks
5. Distributed memory architectures: multicomputers, clusters, distributed heterogeneous platforms, high-performance communication networks
6. Advanced research and/or technological issues: multi-/many-core, multithreading simd/vectorization/gpu, pervasive high-performance computing.

CFU: 9
Official language: English

Optical amplification and sensing

Description: Objectives

This course, which is composed of two parts, after providing the necessary fundamentals on optical components, will overview the most commonly used optical amplification and optical fiber sensor technologies. The course will also provide a hands-on laboratory module, where students will learn how to work and carry out experiments with optical amplifiers and components
Optical amplification has been one of the most important enabling technologies in communications during last years, which has allowed for the extraordinary increase in capacity and transmission distance underlying the present worldwide development of Internet and network-based services.
In the last few years a new sector is emerging, which is related to fiber-optic sensors, where optical and fiber-optic components are used for sensing of several physical, chemical and environmental parameters, finding manifold applications over a wide range of domains, from electric, electronic and nuclear engineering, to civil engineering and to energy-related sectors.

Syllabus

Optical amplification and fiber-optics sensing
- Fundamentals on light sources for optical communications: rate equations in semiconductors and the light emitting diode, LED, optical feedback, the LASER, multi-mode and single-mode lasers
- Photodiodes: pin and avalanche photodiodes
- Passive components: optic al fiber, coupler/splitter, Mach-Zehnder interferometer, optical filter technologies, tuneable filters, multiplexer/ de-multiplexer
- Non-reciprocal devices: isolator and the circulator
- Optical amplifier basics: stimulated emission and optical amplification, basic amplifier features, gain, noise figure, saturation power
- Overview of distributed and discrete amplifiers: Raman and Erbium-doped fiber amplifiers, semiconductor optical amplifier (SOA), parametric processes and parametric amplification
- Optical fiber sensors: introduction to fiber-optics sensing, distributed Raman and Brillouin sensors, fiber-Bragg grating sensors

Laboratory of photonic amplification and components

- Using a power meter, using a pin photodiode and an avalanche photodiode
- Measurements of wavelength-independent parameters in optical passive components
- Using the optical spectrum analyser in optical component measurements
- Characterising a laser
- Measurements of amplifier gain and saturation
- The amplifier optical noise figure: measurement basics
- Characterizing an EDFA
- Component linewidth characterisation: optical homodyne and heterodyne measurements
- Dynamic measurement with an oscilloscope and electric spectrum measurements

Course structure
9 credits consisting in teaching and exercises. The final exam will be a written exam.

CFU: 9
Official language: English

Business process modeling

Description: The course presents techniques for Business Analytics according to the process-driven view of Business Process Modeling. It presents the main concepts and problematic issues related to the process management, where processes are understood as workflow over some basic activities, and to show some of the languages, conceptual models and tools that can help to handle the main problems in a proper way. During the course, the students will become acquainted with the technical terminology
of the area, with several rigorous models that can be used to structure and compose processes, with the logical properties that such processes can be required to satisfy and with specific analysis and verification techniques. Moreover they will be given the possibility to experiment with some advanced tools for the design and analysis of business processes.

Syllabus

- Introduction to key issues in business process management.
- Terminology (business process, business process management, business process management system, business process model, process orchestration, business process lifecycle, workflow) and classification (orchestration vs choreography, automation, structuring).
- Hints on the evolution of business process architectures.
- Process modeling.
- Conceptual models and levels of abstraction.
- Functional decomposition and modularity.
- Process orchestration.
- Process properties.
- Orchestration patterns (sequencing, parallel split, exclusive split, and-join, exclusive join) and structured workflow.
- Rigorous workflow models: Petri nets and workflow nets.
- Tool-supported workflow design and analysis experimentation with state-of-the-art integrated tools for business process design, analysis and verification.

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CFU: 6

Official language: English

Distributed and parallel data bases

Description: Objectives
The course presents the principles of database technology both in a distributed and in a parallel environment. The course covers the classical topics concerning Database Management Systems (DBMS) both in a distributed and in a parallel environment: architecture, design, query processing, transaction management.

Syllabus
1) Distributed DBMS architecture
2) Distributed database design
a. Fragmentation design
b. Allocation design
3) Distributed query processing
a. Query decomposition
b. Optimization of access strategies
4) Distributed transaction management
a. Atomicity
b. Concurrency control
c. Reliability
5) Parallel database systems
a. Shared nothing architecure and data partitioning
b. Parallel agorithms for relational operations
c. Parallel query optimization

The examination consists of an oral exam

CFU: 6

Official language: English

Fault tolerance in distributed systems

Description: Objectives
The course introduces main issues and techniques in fault tolerance computing for distributed systems. Several techniques are discussed: software replication, atomic actions, checkpointing strategies and rollback recovery protocols. Each technique is introduced in its original context and in the context of parallel and distributed systems. Critical implementation details and optimizations will be also described, such as stable storage. Moreover the course introduces the models to evaluate the overheads provided by fault tolerance techniques over application performance. A part of the course is dedicated to the experimentation of existing techniques and their implementation by means of laboratory sessions.

Syllabus
1) Fault tolerance techniques for distributed systems
a. Software replication
b. Atomic actions
c. Checkpointing and Rollback Recovery
d. Cost models for fault tolerance supports
2) Supports
a. Group communication primitives
b. Stable storage
c. Message Logging
d. Garbage collection of checkpoints
3) Laboratory
a. Implementation of existing checkpointing and rollback recovery protocols:

b. Implementation of message logging for communication channels
c. Fault tolerance for parallel programming paradigms.

Course structure
6 credits (3 on techniques (1) and supports (2), 3 on lab activities). Exam consists in a study of a part of the course by means of a project, not necessarily including programming activities. The project is discussed in an final colloquia.
CFU: 6
Official language: English

Distributed components

Description: Objectives
The course deals with methodologies and techniques for the definition, design and utilization of distributed programming paradigms according to the component model. Issues to be studied include: distributed components models, high-performance components, cost models and support design, portability in heterogeneous systems, reliability and security. Relevant case studies are presented, related to current and foreseen technologies.

Syllabus
1. distributed components models,
2. high-performance components,
3. cost models and support design,
4. portability in heterogeneous systems,
5. reliability and security,
6. case studies.

Course structure
6 CFUs. Exam consists in a written and an oral part.
CFU: 6
Official language: English

Parallel and distributed algorithms

Description: The course introduces the main algorithmic techniques related to parallel and distributed computational models. In particular, we will define the most common complexity concepts useful to analyze these models and their computational limits, and we will introduce the necessary tools to deal with the design and analysis of distributed and parallel algorithms.

Syllabus
1) Computational models:
a. The PRAM model
b. The BSP model
c. The distributed model
2) Basic techniques for the design and analysis of parallel algorithms:
a. Prefix sums, List ranking, Euler tour.
b. Other techniques, and problems hard to parallelize
3) Basic techniques for the design and analysis of distributed algorithms:
a. Communication complexity
b. Control algorithms
c. Fault tolerant algorithms
d. Distributed data
4) Classic problems:
a. Coordination and control
b. Broadcast and Spanning Tree
c. Computation on trees: Saturations and functions' evaluation
d. Election on the ring and in arbitrary networks
e. Routing
CFU: 6
Official language: English

Multimedia network performance

Description: Objectives
The aims of the course are to evaluate the performance of Telecommunication Networks and to investigate how the performance may have an impact on the architecture and the design of these systems. The analysis will involve classical stochastic approaches (including source traffic modelling and modelling of TCP connections) as well as worst-case techniques, widely used in the characterization of IntServ and DiffServ architectures.

Syllabus
1) Network Calculus
a. Basic concepts: arrival and service curves, bounds on backlog and delay
b. Token bucket traffic characterization
c. Application to the Internet: IntServ and DiffServ architectures.
d. Traffic models based on packet arrival and departure times: GR and PSRG nodes.
2) Traffic modelling
a. SRD traffic models
b. LRD traffic models
c. Models of TCP connections
3) Rare Event Simulation
a. Large Deviation Theory

b. Effective Bandwidth
c. Restart
d. Importance Sampling

Course structure
6 credits. The exam will consist of an oral examination.
CFU: 6
Official language: English

Parallel scientific computing

Description: This course introduces high performance computing algorithms which an emphasis on using distributed memory systems for scientific computing. The topics include:

--Iterative methods for linear systems.

--Synchronous and asynchronous iterative methods for linear systems.

--Iterative methods for non linear systems.

--Synchronous and asynchronous iterative methods for non linear systems.

-- Applications: linear systems, graph theory and network analysis.
CFU: 6
Official language: English

Parallel and distributed systems: paradigms and models

Description: Aim
The course aims at providing a mix of foundations and advanced knowledge in the field of parallel computing specifically targeting data intensive applications. A first part of the course will provide the necessary background related to the parallel hardware, from multicore to accelerators up to distributed systems such as clusters and cloud. Then the principles of parallel computing will be addressed, including measures characterizing parallel computations, mechanisms and policies supporting parallel computing and typical data intensive patterns. Eventually a survey of existing programming frameworks will be included, aimed at preparing the students to use and exploit the more modern and advanced framework currently used in both research and production institutions. As a result, the student attending the course will be given a general perspective of the parallel computing area as well as a comprehensive survey of the currently available frameworks for data intensive computing. The whole set of arguments will be complemented with practical exercises, in class—according to the bring your own device principle—or as homework assignments. The correct and timely production of assignment solutions will constitute the final written essay needed to access the oral part of the exams. The student may choose to prepare a more consistent final project as substitute of the assignment exercises. The different programming frameworks used in the course will be introduced detailing the main features and usage patterns, leaving to the student the task of learning the low level syntactic details (under the supervision of the professors) as part of the homework assignments.
Contents
Evolution of computing devices from sequential to parallel (1.5 ETCS): introduction to multicore, general purpose many core, accelerators, clusters and cloud architectures.
Principles of parallel computing (4.5 ETCS): measures of interest (time and power), horizontal and vertical scalability, communication/sharing and synchronization mechanisms, concurrent activities (processes, threads, kernels) , vectorization, typical patterns for data intensive parallel computing. Lab exercise and assignments using OpenMP, TBB, FastFlow, MPI.
Advanced parallel & distributed computing frameworks for data intensive applications (3 ETCS): GPU, data stream processing and data intensive programming frameworks. Lab exercise and assignments using CUDA/OpenCL, Hadoop, Spark, Storm.
CFU: 9
Official language: English

Design and architecture of complex platforms

Description: Objectives
This course deals with models, design methodologies and case studies of complex, distributed and heterogeneous architectures, with special emphasis on general and dedicated systems based on large integration scale, like multiprocessor on chip, graphic processing units, fpga, networks on chip, and their compositions. Along with architectural models, the course studies programming model and application development tools having features of communication pattern optimization, memory hierarchies, heterogeneity, dynamic adaptivity and context-awareness, mobility, static and dynamic deployment, with respect to cost models for QoS, performance, real-time response, throughput, enegy saving. Case studies are discussed with reference to adavanced technologies through experimental and laboratory activites.
Syllabus
1. Architectural paradigms
a. Multiprocessors on chip
b. Graphic processing units
c. Networks on chip
d. Distributed systems based on large integration components
e. Communication strategies
f. Memory hierarchies
g. Redundancy management
2. Programmming models
a. Adaptivity and context-awareness
b. Dynamic deployment for heterogeneous systems
c. Energy reliability

d. Cost models and QoS for applications
3. Case studies

Exam consists in a project and an oral part.
CFU: 12
Official language: English

Numerical techniques and applications

Description: Objectives

In the course numerical methods are proposed for solving various applicative problems.
Major emphasis is given to the techniques of numerical linear algebra mostly used in applications.

Syllabus
1. Basic notions in linear algebra: similar reduction to diagonal and other canonical forms, positive definite matrices, singular value decomposition, norms, condition number
2. Direct methods for linear systems: elementary matrices, LU, LLh, QR, factorizations, Givens rotations, Cholesky and Householder methods
3. Iterative methods for linear systems: classic methods, overrelaxation, conjugate gradient method
4. Iterative methods for nonlinear systems: Newton and quasi-Newton methods
5. Iterative methods for eigenvalues: conditioning of the problem, power method, LR and QR methods, reduction to tridiagonal form of a symmetric matrix
6. Linear least squares problem: normal equations and SVD
7. Methods for tridiagonal matrices: cyclic reduction, Sturm sequences, divide-and-conquer techniques
8. Non-negative matrices: Perron-Frobenius results, stochastic matrices
9. Discrete Fourier Transform: some applications

Oral examination.
CFU: 6
Official language: English

Lab of Photonic Systems

Description: Aims

The course objectives are to provide the basic elements of the design of an optical transmission system and learn about the operation of the devices and equipment used for the realization and testing of optical systems.
The first part of the course provides a detailed theoretical analysis of transmission problems that must be considered in the design of today optical systems, such as fiber propagation effects (both linear and nonlinear).
The second part, which has a strong experimental flavour, introduces the student to the practical knowledge and use of key components and experimental techniques in the field of photonic systems. The course will also illustrate the principles of operation of the main equipment for analysis and measurement (including oscilloscopes, sampling oscilloscopes, spectrum analyzers etc.).

Program

High speed optical systems: applications, perspectives and design problems. power budget, amplification and optical noise chromatic dispersion: the effect and its impact on system performance. Compensation of chromatic dispersion: devices and techniques. Effect of polarization mode dispersion (PMD). Nonlinear optical effects: stimulated scattering effects and effects related to the Kerr nonlinearity.

Laser sources and modulators: DFB Laser and Laser Diodes, Fabry-Perot lasers, Laser Mode-Locking, Modulation of the lasers: direct and External.
Devices used in photonic systems: polarizers and polarization controllers, isolators, circulators and couplers, optical filters , detectors. OTDR , elements of optical amplification , fiber-air coupling solutions.
Equipment: electrical sampling oscilloscopes, Real-time oscilloscopes , Optical Spectrum Analyzers (OSA), polarimeters. temperature controllers , data acquisition tools and automation of measurement processes.
CFU: 6
Official language: English

Final Thesis

Description: The curriculum in Computer Science and Communications is concluded with the presentation and discussion of a Master Thesis, evaluated by a commission of the Faculty. The Thesis must be characterized by originality. Every Thesis has an academic supervisor of the Faculty, and possibly an external tutor for Thesis performed as a stage in an enterprise or public institution. The evaluation will be based upon the quality of the Thesis and upon the candidate’s autonomy, synthesis and communication capabilities.
CFU: 15
Official language: English