

Curriculum “ICT Solutions Architect”

Objectives/visions – *The objective of this curriculum is to form the next generation of ICT solutions architects, capable of mastering the complexity of integrating heterogeneous and distributed software systems as well as of assessing non-functional properties of the obtained solutions.*

Modern ICT solutions are built by composing heterogeneous software services and infrastructures. Security, wireless network, web and cloud services and peer-to-peer technology set the scene for this track to create a specialist that can design innovative ICT solutions, by integrating software and hardware modules at distinct layers of the implementation stack. It is fundamental that the graduate can not only design and implement a complex ICT infrastructure but also evaluate whether such infrastructure can satisfy severe requirements in terms of performances, data security and privacy.

The curriculum covers traditional computer science topics, such as algorithm and programming, but it aims to focus these topics in a unifying framework. IT solutions architects must be able to design and assess innovative solutions:

- *from the software viewpoint these architects should master the design of complex systems, to exploit and assess existing service- and cloud-based solutions, and to employ DevOps principles,*
- *from the infrastructure viewpoint these Architects should understand and assess the exploitability of available IT (physical and/or virtualized) infrastructures,*
- *a critical know how for these Architects will be the ability of assessing and certifying non-functional properties – from performance to security- of IT solutions.*

The overall objective of this curriculum is to form the next generation of ICT solutions architects, possessing the above mentioned capabilities.

The plan of studies is composed by two courses on the infrastructure layers (“ICT infrastructures” and “Mobile and cyber-physical systems”), three courses on the software layers (“Advanced software engineering”, “Advanced programming” and “Distributed algorithms”), and two courses on security aspects (“ICT risk assessment” and “Peer to peer systems and blockchains”).

Studies plan

	Course name	CFU
	57 CFU OF:	
1	ICT infrastructures	6
2	Mobile and cyber-physical systems	9
3	Advanced programming (con WTW)	9
4	Advanced software engineering (con WTW)	9
5	ICT risk assessment (con WTW)	9
6	Algorithm engineering (con KD e WTW)	9
7	Peer to peer systems and blockchains (con WTW)	6
8-11	30 CFU (2 da 9 e 2 da 6) OF:	
	Distributed systems: paradigms and models (WTW)	9
	Information retrieval (KD)	6
	Software validation and verification (SW)	9
	Scientific and large data visualization (CNR)	6
	Data mining (KD)	9
	Machine learning (AI)	9
	Intelligent systems for pattern recognition	6
	Security methods and verification (WTW)	6
	33 CFU OF:	
12	Free choice	9
	Thesis	24

Syllabus

ICT infrastructures [6 CFU]

The goal of the course is to introduce students to the computing infrastructures powering cloud services. At the end of the course a student should be able to understand the general organization of a datacenter and the logical infrastructure that power virtualization and containers. The course starts from physical infrastructures such as power and datacenter organization. The network fabric is introduced, with particular focus on SDN techniques used to balance East-West and North-South traffic. Storage and compute are then introduced with special attention to hyperconverged systems.

- Physical infrastructures (datacenters, energy and PUE, SCADAs) (1 CFU)
- Networking (SDN and overlay, fabrics (RDMA, OPA, InfiniBand), monitoring techniques) (2 CFU)
- Storage (SDS) (1 CFU)
- Computing (hypervisor) (2 CFU)

Mobile and cyber-physical systems [9 CFU]

The course covers mobile and cyber-physical systems by providing an overview of issues, solutions, architectures, technologies and standards. It offers to the students an overall, coherent view of the organization of internet of things (IoT) systems, from the networking and sensing levels to the applications. Specifically, it shows how mobile, heterogeneous elements (from low-end sensors to high-end devices) form pervasive networks integrated in the internet and how they interact among themselves and with the surrounding physical world. The course is organized in three parts. The first part (3 CFU) introduces the principles of wireless communications and network architectures for mobility management. The second part (4 CFU) presents the foundations of signal processing and sensing and discusses the applications of sensor networks. The third part (2 CFU) provides an overview of the main standards and platforms of the IoT.

- Foundations of wireless technologies and mobility management (3 CFU)
 - 5G mobile, ad hoc networks, mobile social networks, IEEE 802.x standards
- Cyber-physical systems (4 CFU)
 - Foundations of signal processing, wireless sensor networks, energy harvesting, localization, elements of embedded programming
- Internet of Things (2 CFU)
 - ZigBee, Bluetooth, sensor network gateways, IoT platforms & standards (OneM2M, FIWARE, COAP, MQTT)

Advanced software engineering [9 CFU]

The objective of the course is to introduce some the main aspects in the design, analysis, development and deployment of modern software systems. Service-based and cloud-based systems are taken as references to present design, analysis and deployment techniques. DevOps practices are discussed, and in particular containerization is introduced. The course includes a "hands-on" lab where students will experiment weekly the design, analysis, development and deployment techniques introduced.

- Service-based software engineering (3 CFU)
 - core interoperability standards
 - software design by service composition, microservice architecture, examples of design patterns
 - business process modelling and analysis
 - service descriptions and service level agreements
- DevOps practices (1.5 CFU)
 - DevOps toolchain, continuous delivery
 - Docker and containerization
- Cloud-based software engineering (1.5 CFU)
 - service and deployment models
 - cross-cloud deployment and management of applications
- Hands-on laboratory (3 CFU)

ICT risk assessment [9 CFU]

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
 - Vulnerabilities/Attacks 1 CFU
 - Countermeasures 1 CFU
 - Tools for Automating Assessment & Management 1 CFU
- Security of Cloud Computing 6 CFU
 - Economic Reasons/Deployment Models/ Service Models 1 CFU
 - Virtualization and TCM 1 CFU
 - New Vulnerabilities 1 CFU
 - New Attacks 1 CFU
 - New Countermeasures 1 CFU
 - Certification of Cloud Provider 1 CFU

Peer to peer systems and blockchains (6 CFU)

Introduction of the basic technologies for the development of highly distributed systems and of some real scenarios exploiting them. Presentation of the disruptive technology of blockchains, and its numerous applications to different fields.

P2P Topologies (2 CFU)

- Peer to Peer (P2P) systems: general concepts (1/2 CFU)
- Unstructured Overlays: Flooding, Random Walks, Epidemic Diffusion (1/2 CFU)
- Structured Overlays: Distributed Hash Tables (DHT), Routing on a DHT (1/2 CFU)
- Case Studies: Bittorrent as a Content Distribution Network: KAD implementation of the Kademia DHT, game-based cooperation (1/2 CFU)

Complex Network for the analysis of P2P systems (2 CFU)

- Network models (1 CFU)
- Case Studies: Darknet Freenet (1 CFU)

Cryptocurrencies and Blockchains (5 CFU)

- basic concepts: (1 CFU)
- the Bitcoin protocol (2 CFU)

Bitcoin Extensions/alternatives (1/2 CFU)

- overview of altcoins
- sidechains
- the Stellar Consensus Protocol

Further applications of blockchains (1 CFU)

- Ethereum: programming smart contracts
- Blockchain 1.0: cryptocurrencies
- Blockchain 2.0: financial instruments built on cryptocurrencies
- Blockchain 3.0: applications beyond cryptocurrencies (DNS, lotteries, voting, IoT...)

Legal aspects of cryptocurrencies (1/2 CFU)

Advanced programming [9 CFU] (vedi WTW)

Algorithm engineering [9 CFU] (vedi KD)

Scientific and large data visualization [6 CFU]

The goal of this course is to provide an introduction to main topic of 3D computer graphics both in theory and practice. A significant part of the course will involve the realization of a project involving mostly surface modeling and processing and interactive rendering.

Topics covered will include:

- Modeling: Data structures for representing surfaces with simplicial complexes
- Modeling: Data structure for spatial indexing
- Modeling: High level frameworks for the representation of structured scene and environments

- *Rendering: The basic projective rendering pipeline. Hardware architectures for Rendering*
- *Rendering: Algorithms for Global Illumination and photorealistic rendering.*
- *Rendering: Shading Languages and advanced interactive rendering technique*