

EIT Digital Master School

# Cloud and Network Infrastructures

What can I study at the entry and exit points?



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## Entry - 1st year, common courses

### Aalto University (Aalto), Finland

[Visit University website.](#)

Programme Contact: **Jukka Manner**; [jukka.manner@aalto.fi](mailto:jukka.manner@aalto.fi)

#### Common Core (10 ECTS)

- ELEC-7320 Internet Protocols (5 ECTS)
- CS-E4100 Mobile Cloud Computing (5 ECTS)

#### Compulsory courses (6 ECTS)

- LC-xxxx Language course: Compulsory degree requirement, both oral and written requirements (3 ECTS)
- ELEC-E0110 Academic skills in master's studies (3 ECTS)

#### Electives (20 ECTS)

- ELEC-E712 Wireless Systems (5 ECTS)
- ELEC-E7130 Internet Traffic Measurements and Analysis (5 ECTS)
- ELEC-E7310 Routing and SDN (5 ECTS)
- ELEC-E7330 Laboratory Course in Internet Technologies (5 ECTS)
- ELEC-E7210 Communication Theory (5 ECTS)
- ELEC-E7470 Cybersecurity (5 ECTS)
- ELEC-A7901 Internet Forum (5 ECTS)
- ELEC-E7260 Machine Learning for Mobile and Pervasive Systems (5 ECTS)
- ELEC-E7230 Mobile Communication Systems (5 ECTS)
- ELEC-E7460 Modelling and Simulation (5 ECTS)
- ELEC-E7420 Network Service Provisioning (5 ECTS)
- ELEC-E7820 Operator Business (5 ECTS)
- ELEC-E7810 Patterns in Communications Ecosystems (5 ECTS)
- ELEC-E7450 Performance Analysis (5 ECTS)
- CS-C3130 Information Security (5 ECTS)

- CS-3140 Operating Systems (5 ECTS)
- CS-C3170 Web Software Development (5 ECTS)
- CS-E3210 Machine Learning: Basic Principles (5 ECTS)
- CS-E4110 Concurrent Programming (5 ECTS)
- CS-E4140 Applications and Services in Internet (5 ECTS)
- CS-E4260 Multimedia Services in Internet (5 ECTS)
- CS-E4300 Network Security (5 ECTS)
- CS-E4310 Mobile Systems Security (5 ECTS)
- CS-E4400 Design of WWW Services (5 ECTS)
- CS-E4460 WWW Applications (5 ECTS)
- CS-E4600 Algorithmic Methods of Data Mining (5 ECTS)
- CS-E4640 Big Data Platforms (5 ECTS)
- CS-E4800 Artificial Intelligence (5 ECTS)
- CS-E4840 Information Visualization (5 ECTS)
- CS-E5220 User Interface Construction (5 ECTS)
- CS-E5620 Social Media (5 ECTS)

## University of Rennes 1 (UR1), France

[Visit University website.](#)

Programme Contact: **Cédric Tedeschi**; cedric.tedeschi@irisa.fr

### Common Core (10 ECTS)

- Networks from Services to Protocols (5 ECTS)
- Big Data Storage and Processing Infrastructures (5 ECTS)

### Compulsory Courses (20 ECTS)

- Operating Systems (5 ECTS)
- Distributed Systems (5 ECTS)
- Service Technologies (5 ECTS)
- Object-oriented Software Design (5 ECTS)

### Elective Courses (10 ECTS):

- Modeling for Performance Evaluation and Safety Analysis (5 ECTS)
- Parallel Programming (5 ECTS)
- Operating Systems - Kernel Implementation (5 ECTS)
- Combinatorial Optimization and Related Algorithms (5 ECTS)

## Sorbonne University (SU), France

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### Semester 1

#### Common core (6 ECTS)

- **Internet Protocols & Algorithms ([MU4INX05](#)) 6 ECTS:** This course focuses on core network applications asked by users and services needed at the network level. The TCP/IP architecture and all the main associated protocols are detailed with particular emphasis on the end-to-end control mechanisms, classless addressing and routing hierarchy. Finally, the two main media technologies (Ethernet and Point-to-point) are studied before concluding with a presentation of residential access technologies.

#### Elective courses (12 ECTS)

- **Digital Communications ([MU4INX06](#)) 6 ECTS:** The course Signal and Communication has the objective of providing the tools that are necessary for analyzing, modeling and designing digital transmission systems. The first part of the course focuses on the necessary bases in deterministic and random signal processing. The rest of the course shows their application to the physical layer of communications systems: architecture of a digital transmission chain, models and performance evaluation.
- **Advanced Routing in Large Networks ([MU4INX20](#)) 6 ECTS:** This course will cover fundamental principles related to routing of computer networks. The goal is to teach networking fundamentals and techniques as it will provide students with a deep understanding of how the Internet works today, and where it is going in the near future.

#### I&E minor (12 ECTS)

- **I&E Basics ([MU4INX09](#)) 6 ECTS:** This course offers introductory lectures on technology-based entrepreneurship, marketing and markets, organization and project management, new product and process development, entrepreneurial finance, human resource development.

- **Business Development Lab 1 ([MU4INX08](#)) 6 ECTS:** This course is mainly concentrated on project work throughout the main phases of business modeling and development. It builds upon the Basic Course and will enable the student to conduct a fully-fledged business development project. Invited entrepreneurs and practitioners hand over relevant applicable experience and knowledge in parallel to academic lectures.

## Semester 2

### Common core (6 ECTS)

- **Cloud Computing ([MU4INX30](#)) 6 ECTS:** Introduction to cloud computing principal, IaaS (Infrastructure as a Service), PaaS (Platform as a Service), and SaaS (Software as a Service), cloud computing architectures, cloud providers, etc. Classical Distributed Algorithms applied to Clouds: Logical Time in distributed systems (logical clocks); Resource allocation and mutual exclusion; Broadcast protocols, membership, and synchronous view. Failures and fault tolerance: Unreliable Failure Detectors; Checkpoint and global state in distributed systems. Introduction to MPI and implementation of the above distributed algorithms in MPI. Courses with practical experiments: Virtualisation (Virtual machines and containers); Amazon Cloud (Concepts and deployment); Open Stack free open source (Deployment of Cloud Computing Service Infrastructure); Map Reduce (Programming model and an associated implementation).

### Elective courses (12 ECTS)

- **Wireless and Mobile Computing ([MU4INX19](#)) 6 ECTS:** The main objective of this course is to present how user mobility and wireless transmissions affect computer communications. The course first gives a basic understanding of the physical layer mechanisms. It presents the impact of wireless signal propagation, link budget, digital communications with an illustration based on spread spectrum technologies. It then presents a survey on existing wireless technologies with a strong emphasis on the Wi-Fi standard. Finally, this course details the impact of mobility on IP protocols, the benefits and limitations of the main proposals, as well as the constraints of data losses on existing transport protocols.



- **Network Design and Modeling ([MU4INX21](#)) 6 ECTS:** The objective of this course is to introduce students to the problem of modeling and performance evaluation of systems. It aims at answering the following questions: Why models are important? When do we need to evaluate the performance of a system? How? What kinds of models and techniques are useful?

#### I&E minor (12 ECTS)

- **Business Electives ([MU4INX22](#)) 6 ECTS:** This course covers advanced topics on any of the following: business development, business finance, marketing, innovation management, intellectual property and market research.
- **Business Development Lab 2 ([MU4INX23](#)) 3 ECTS:** Second part of Business Development Lab course (see below for description).
- **ICT Innovation Summer School ([MU4INX24](#)) 3 ECTS:** This Summer School brings you together for two weeks to work in groups on business modeling and planning project in the context of a societally relevant thematic area. Summer Schools take place at different locations throughout Europe and bring together students and business partners. Summer Schools support study programs with a multidisciplinary and international dimension, and create a clear EIT Digital flavor to education.



## KTH Royal Institute of Technology (KTH), Sweden

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Programme Contact: **Viktoria Fodor**; vjfodor@kth.se

### Common Core (15 ECTS)

- Advanced Internetworking (7.5 ECTS)
- Data-Intensive Computing (7.5 ECTS)

### Compulsory Course (7.5 ECTS)

- Research Methodology and Scientific Writing (7.5 ECTS)

### Elective courses (15 ECTS)

- Queuing Theory and Teletraffic systems (7.5 ECTS)
- Distributed Systems, Advance Course (7.5 ECTS)
- Wireless Networks (7.5 ECTS)
- Data mining, Basic Course (7.5 ECTS)

## University of Trento (UNITN), Italy

Link to the university: [www.unitn.it/en](http://www.unitn.it/en)

Programme Contact: Fabrizio Granelli; [fabrizio.granelli@unitn.it](mailto:fabrizio.granelli@unitn.it)

### Common Core (12 ECTS)

- Next Generation Networks (6 ECTS)
- Fog and Cloud Computing (6 ECTS)

### Compulsory Courses (18 ECTS)

- Network Modeling and Design (9 ECTS)
- Softwarized and Virtualized Mobile Networks (9 ECTS)

### Elective Courses (6 ECTS)

- Free Choice (6 ECTS)

## Exit - 2nd year, specialisation

### Aalto University (Aalto), Finland

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Programme Contact: **Jukka Manner**; [jukka.manner@aalto.fi](mailto:jukka.manner@aalto.fi)

#### Specialisation: Mobile Networking and Cloud Services

The courses cover the theoretical and practical aspects of designing and analyzing mobile networks and cloud services. In the Master's thesis project, the students can focus on problems arising from the thematic research projects in the Helsinki node of EIT Digital.

#### Compulsory courses (15 ECTS)

- ELEC-E0210 Master's Thesis Process (2 ECTS)
- LC-xxxx Language course: Compulsory degree requirement, both oral and written requirements (3 ECTS)
- Select at least 10 ECTS from below
- ELEC-E7130 Internet Traffic Measurements and Analysis (5 ECTS)
- ELEC-E7310 Routing and SDN (5 ECTS)
- CS-C3170 Web Software Development (5 ECTS)
- CS-E4640 Big Data Platforms (5 ECTS)

#### Electives (10 ECTS)

- ELEC-E712 Wireless Systems (5 ECTS)
- ELEC-E7130 Internet Traffic Measurements and Analysis (5 ECTS)
- ELEC-E7310 Routing and SDN (5 ECTS)
- ELEC-E7330 Laboratory Course in Internet Technologies (5 ECTS)
- ELEC-E7210 Communication Theory (5 ECTS)
- ELEC-E7470 Cybersecurity (5 ECTS)
- ELEC-A7901 Internet Forum (5 ECTS)
- ELEC-E7260 Machine Learning for Mobile and Pervasive Systems (5 ECTS)

- ELEC-E7230 Mobile Communication Systems (5 ECTS)
- ELEC-E7460 Modelling and Simulation (5 ECTS)
- ELEC-E7420 Network Service Provisioning (5 ECTS)
- ELEC-E7820 Operator Business (5 ECTS)
- ELEC-E7810 Patterns in Communications Ecosystems (5 ECTS)
- ELEC-E7450 Performance Analysis (5 ECTS)
- CS-C3130 Information Security (5 ECTS)
- CS-3140 Operating Systems (5 ECTS)
- CS-C3170 Web Software Development (5 ECTS)
- CS-E3210 Machine Learning: Basic Principles (5 ECTS)
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- CS-E4840 Information Visualization (5 ECTS)
- CS-E5220 User Interface Construction (5 ECTS)
- CS-E5620 Social Media (5 ECTS)

**Jukka Manner** received his MSc. (1999) and PhD. (2004) degrees in computer science from the University of Helsinki. He has been a full professor (tenured) of networking technology at Aalto University, Department of Communications and Networking (Comnet) since 2008. His research and teaching focuses on networking, software and distributed systems, with a strong focus on wireless and mobile networks, transport protocols, energy efficient ICT and cyber security. He has contributed to standardization of Internet technologies in the IETF since 1999.

## University of Rennes 1 (UR1), France

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Programme Contact: **Cédric Tedeschi**; [cedric.tedeschi@inria.fr](mailto:cedric.tedeschi@inria.fr)

### Specialisation: Smart City Services

Cloud/Fog computing and 5G networking technology convergence enables the design of innovative services and applications which aim to improve operational efficiency and urban citizen's quality of life. This specialisation focuses on enabling technologies to build, operate and manage massively distributed heterogeneous resources in the broad domain of smart city services and applications. Students will also learn about the fundamental properties of autonomic systems and how to adapt applications according to dynamic changes in data and system load.

This specialisation is given in close connection with the INRIA/IRISA research lab (the largest IT research lab in France) which hosts several internationally reputed research teams (ACES, ASAP, KERDATA, MYRIADS, STACK) representing about 60 researchers focusing their work on various aspects of cloud computing, fog computing, networking infrastructures and smart city services.

### Compulsory courses (16 ECTS):

- Smart City Services: From infrastructure to applications (4 ECTS)
- Advanced Cloud Infrastructures (4 ECTS)
- Scalable Network Infrastructures for Optimized Service Delivery (4 ECTS)
- Personal Project on Cloud and Network Infrastructure (4 ECTS)

### Elective courses (8 ECTS):

- Multimedia Networks (4 ECTS)
- Advanced Wireless Networks: 5G and Beyond (4 ECTS)
- Data Mining and Visualization (4 ECTS)

**Cedric Tedeschi** is the local coordinator of the CNI Master program at the University of Rennes 1. He holds a PhD from the University of Lyon, and has spent one year as a post-doctoral fellow at Inria (Sophia-Antipolis Méditerranée), before joining the University of Rennes. He is a member of the IRISA computing lab. His research interests revolve around distributed computing. Recently, he has contributed to decentralizing Cloud infrastructures and Stream processing.

## Sorbonne University (SU), France

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### Semester 1

#### Elective courses (30 ECTS)

- **Autonomic Networks (MU5IN063 ) 6 ECTS:** Main scientific and technological issues of autonomous and ubiquitous networks. Principles, techniques, and examples related to the design of such networks are introduced, sometimes through similarities and differences with classical networks. Various aspects of self-\* attributes are discussed, such as self-stabilization, self-configuration, self-organization, self-management, self-optimization, self-adaptiveness, etc. Passive mobility and proactive mobility are addressed and applied to sensor networks, swarms of robots, MANET, and VANET.
- **Cellular Networks (MU5IN050 ) 6 ECTS:** This course presents network architecture and protocols of 2G-GSM, 3G-UMTS, 4G-LTE networks and the upcoming 5G technologies such as C-RAN, Mobile Edge Computing, SDN-NFV and network slicing. The course explains problems in both access network and core network of a mobile network operator and provides basic techniques for performance analysis, resource allocation, network dimensioning and optimization.
- **Internet Governance (MU5IN052 ) 6 ECTS:** The objective of this EU is to acquire the basic knowledge as well as the analytical and methodological keys related to the technical, economic, legal, ethical and political issues that surround the governance and the use of the networks, as well as to the diversity stakeholders and public and private interests at stake. The French, European and international legislative contexts will be presented and analyzed.
- **Methodology for research in networking (MU5IN64 ) 6 ECTS:** The objective of this course is to help students improve fundamental skills when conducting research in computer networking: critical reading, writing scientific papers, data analysis, and oral presentation.



- **Network analysis and mining ([MU5IN062](#)) 6 ECTS:** Network Analysis and Mining is a course at the crossroad between data mining and graph algorithmic. We present concepts and tools for the analysis of real networks represented as graphs, such as online social networks, communication networks, the web, etc. Among the topics addressed in this course : measurement and dynamics of the Internet, community detection in social networks, research and filtering of information on the web.
- **Network data analysis ([MU5IN076](#)) 6 ECTS:** Introduction to probability and statistics. Bayes's law. Data collection, parameter estimation and regression methods. Statistical fitting. Hypothesis testing and applications to identification of changes that influence the network operation. Clustering and classification. Time-series analysis.
- **Internet Measurement ([MU5IN066](#)) 6 ECTS** This course presents the measures that can be performed in local networks, access networks and transit networks. It discusses which measures can be performed in the network, transport and application layers, or MAC. The student will learn to perform measurements using active measurement tools and passive measures, with practical exercises deployed on large experimental platforms.
- **Network Evolution with Virtualization and Automation ([MU5IN056](#)) 6 ECTS:** The goal of this course is to present new technologies designed for advanced operations of IP networks in the last twenty years. The course starts with the evolution of IP switching and routing architectures, with a particular focus in traffic engineering and quality-of-service architectures. Then, the evolution of the Ethernet architecture and layer-2 protocols in general is presented, showing the extensions applied to let layer-2 protocols scale going from the local area to metropolitan and data-center network segments. The course shows how IP and Ethernet evolution recently converged on novels softwarized network environments, making use of data-plane programmability, network virtualization, cloud-native systems and automation frameworks.

## Semester 2

### I&E minor (6 ECTS)

- **[MU5INX99](#)** - I&E Study - 6 ECTS. *This course is supervised business analysis work. It focuses on applying prior I&E knowledge and competences in a real business context. This*

*course will allow students to tackle a business challenge with a robust explorative business analysis methodology*

**5-6 month internship (24 ECTS)**

## KTH Royal Institute of Technology (KTH), Sweden

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Programme Contact: **Viktoria Fodor**; [vjfodor@kth.se](mailto:vjfodor@kth.se)

### Specialisation: Networked intelligence

KTH offers courses in the area of data intensive distributed computing, covering both the design of network infrastructures that can support these emerging applications, and the design of the distributed computing applications itself, focusing on scalable machine learning and on distributed artificial intelligence.

#### Compulsory courses (7.5 ECTS)

- Research Methodology and Scientific Writing (7.5 ECTS)

#### Elective courses (16.5 ECTS):

- Modern Methods in Software Engineering (7.5 ECTS)
- Distributed AI and Intelligent Agents (7.5 ECTS)
- Stream Processing and Data Mining (7.5 ECTS)
- Scalable Machine Learning and Deep Learning (7.5 ECTS)
- Network Analytics (7.5 ECTS)
- Network Programming with Java (7.5 ECTS)
- Networked Systems Security (7.5 ECTS)
- Programming Web Services (7.5 ECTS)
- Seminars in Information and Network Engineering 3.0 ECTS

**Viktoria Fodor** received her MSc and PhD degrees in computer engineering from the Budapest University of Technology and Economics. In 1999 she joined KTH, Royal Institute of Technology, where she now acts as assistant professor in the Laboratory for Communication Networks and coordinator of the local EIT Digital Master School programme ITA. Over the years she supervised several master thesis projects and 2 PhD theses. She participated in several European and Swedish research projects. Her current research interests include

multimedia and peer-to-peer communication, sensor network and cognitive radio network protocol design and performance analysis.

## University of Trento (UNITN), Italy

[Visit University website.](#)

Programme Contact: **Fabrizio Granelli**; [fabrizio.granelli@unitn.it](mailto:fabrizio.granelli@unitn.it)

### Specialisation: Beyond 5G

UNITN will offer a specialisation in 5G and beyond 5G. Indeed, 5G is expected to bring unprecedented improvements and advances to the cellular networks that we use today. Moreover, they will offer the infrastructure for the deployment of several novel emerging applications and services, including Internet of Things, Vehicular Communications, Tactile Internet, machine-to-machine communications, smart grid. The student attending this specialisation will be exposed to the most recent advances in communication protocols and devices, network virtualization and control, softwarization and service provisioning.

### Compulsory courses (18 ECTS)

- Research Project (12 ECTS)
- Project course on Beyond 5G (6 ECTS)

### Elective courses (6 ECTS)

- Next Generation Networks (6 ECTS)
- Networking II (6 ECTS)
- High Performance Computing for Data Science (6 ECTS)
- Simulation and Performance Evaluation (6 ECTS)
- Network Security (6 ECTS)

**Fabrizio Granelli** is an associate professor at the Dept. of Information Engineering and Computer Science (DISI) of the University of Trento (Italy) and Director of Online Content at IEEE Communications Society. He was IEEE ComSoc distinguished lecturer in 2012-15 and Delegate for Education of DISI in 2015-17. His main research activities are in the field of networking, with particular reference to wireless networks (performance optimization, ad-hoc networks modeling), cognitive networks/radios, cross-layer design and green

networking. He is the author of more than 200 papers, guest-editor in relevant international journals (ACM/Kluwer Mobile Networks and Applications Journal, ACM TOMACS, JSAC, IEEE Communications Magazine) and visiting professor at the State University of Campinas and at The University of Tokyo. He is the former Chair of the IEEE Communication Systems Integration and Modeling Technical Committee and he was chair or co-chair of several top-level international events, like IEEE Globecom Symposium TPC Co-Chair on "Performance Modeling, QoS and Reliability" from 2007 to 2009 and in 2012.





## EIT Digital

We believe in making and shaping a competitive digital Europe that is inclusive, fair and sustainable and aim at global impact through European innovation fueled by entrepreneurial talent and digital technology.

We embody the future of innovation by mobilizing a pan-European multi-stakeholder open-innovation ecosystem of top European corporations, SMEs, startups, universities and research institutes, where students, researchers, engineers, business developers and investors address the technology, talent, skills, business and capital needs of digital entrepreneurship.

We build the next generation of digital ventures, digital products and services, and breed digital entrepreneurial talent, helping business We build the next generation of digital ventures, digital products and services, and breed digital entrepreneurial talent, helping business and entrepreneurs to be at the frontier of digital innovation by providing them with technology, talent, and growth support:

For more information, visit [www.eitdigital.eu](http://www.eitdigital.eu). Follow us on Twitter: @EIT\_Digital



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