A Curriculum on the Internet of Things

iot-open.eu RELOADED

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Preface

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- Strategic Partnerships in the Field of Education, Training, and Youth – Higher Education, 2016, IOT-OPEN.EU – Innovative Open Education on IoT: Improving Higher Education for European Digital Global Competitiveness, project number: 2016-1-PL01-KA203-026471,
- Cooperation Partnerships in higher education, 2022, IOT-OPEN.EU Reloaded: Education-based strengthening of the European universities, companies and labour force in the global IoT market, project number: 2022-1-PL01-KA220-HED-000085090,
- Horizon 2020 Research Innovation and Staff Exchange Programme (RISE) under the Marie Skłodowska-Curie Action, Programme H2020-EU.1.3.3. - Stimulating innovation by means of cross-fertilisation of knowledge, Grant Agreement No 871163: Reactive Too - Reliable Electronics for Tomorrow's Active Systems.
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1. Introduction

The document offers a sample curricula for Bachelor and Master level studies (see figure below) in the rapidly evolving field of the Internet of Things (IoT). These examples serve as a foundational framework that educational institutions worldwide can adapt and expand upon to design their unique study modules/courses.

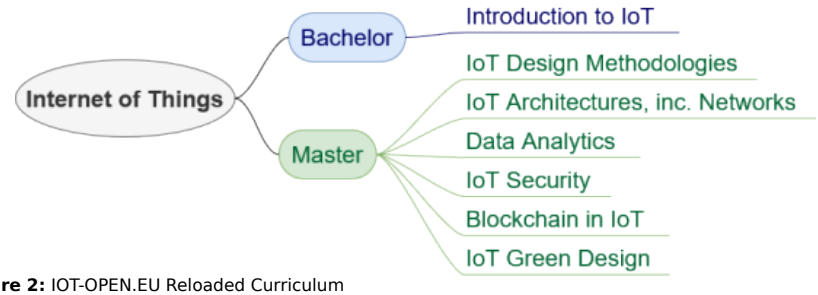

Figure 2: IOT-OPEN.EU Reloaded Curriculum

The Bachelor study offers an introductive module titled “Introduction to IoT,” which is segmented into four primary topics. This structure ensures a focused and in-depth exploration of each topic area within the realm of Internet of Things, providing students with a robust foundation in this innovative field. The topics are:

- IoT Overview (1 ECTS)
- IoT Programming and Frameworks (2 ECTS)
- IoT Hardware (2 ECTS)
- IoT Communicationa and Networking (1 ECTS)

The structure offers the flexibility to tailor the module according to needs of educational institutions. Schools and universities can choose to cover all of the topics for a total of 6 ECTS (European Credit Transfer and Accumulation System) credits or opt for a focused topic as “IoT Overview,” which awards 1 ECTS credit. This adaptable approach ensures that each educational institution can provide a learning experience that aligns with its educational objectives and the goals of its students.

The Master level study is structured into six distinct modules, each designed to provide a comprehensive understanding of the subject matter. This modular approach ensures a robust and focused educational experience, tailored to foster expertise and specialization in key areas of interest.

1. IoT Design Methodologies
2. IoT Architectures, inc. Networks
3. Data Analytics
4. IoT Security
5. Blockchain in IoT
6. IoT Green Design

1. Introduction

Each Master level study module is designed to award 3 ECTS credits. For added flexibility, there is also the option to amalgamate certain modules to better suit individual academic requirements or interests.

The following section delineates the architecture of the curriculum module in detail.

- Study level - provides the study level, to which the module is designed for
- ECTS credits - how many points can be obtained for completing the module
- Study form - explains where the module can take place: class, online, or hybrid
- Module aims - gives the overall goal(s) or purpose(s) of the module
- Pre-requirements - outlines pre-requirements for the current module, which the student must meet
- Learning outcomes - lists what students are expected to know, understand, and be able to do after completing the module
- Topics - listed subjects taught in the module. They are based on the books, which are made in the project IoT.Open.EU Reloaded
- Type of assessment - a general description of how assessment is carried out in the module
- Blended learning - the module's overall framework and student tasks are described
- References to literature - list of books, online books, articles, etc are given, which helps to improve knowledge in the module
- Lab equipment - list of equipments, softwares, etc. used in the module to do laboratory work(s) locally
- Virtual lab - link(s) to a virtual lab(s), which is/are used in the module to do laboratory work(s) remotely
- MOOC course - provides a link to a massive open online course made in the project IoT.Open.Eu Reloaded. Students over the world can attend it

2. IOT-OPEN.EU Reloaded Overview

IOT-OPEN.EU Reloaded project delivers comprehensive Internet of Things (IoT) learning and teaching materials for various stakeholders and use cases. IoT contents have been organised into modules and are available in various forms:

- classical stationery for in-person meetings and presentations,
- remote for self-study in mass scale (MOOCs),
- remote for tutored study, also in blended learning model,
- and practical, in particular with the use of the remote access laboratory.

IoT modules cover a wide range of IoT-related topics, and thus, they are logically organised for bachelors (beginners) and masters (advanced study). Modules can be used as a full course or selected, as each comprises a closed set of lectures and topics (cross-module references, however, are needed for understanding the basic concepts of IoT).

Project results are composed of 4 main pillars (intellectual results, see figure below):

- A flexible IoT curriculum, presenting course-level organisation and individual module syllabi, is available as a PDF booklet and interactive website.
- Classical materials for in-person meetings with students, composed of:
  - coursebook for bachelors level (hardcopy, PDF), so-called “The Blue Book”, also available online in an interactive model,
  - coursebook for masters level (hardcopy, PDF), so-called “The Green Book”, also available online in an interactive model,
  - a set of PDF and textual materials for in-class DLP presentations.
- On-line materials for self-study and blended learning models:
  - online platform available to enrol students for self-study,
  - online raw materials (access to video recordings, learning curve documents and other materials, i.e. higher resolution images) to let anyone compose tutored courses based on these contents, tailored directly to their needs.
- VREL NextGen - a remote access lab (selected hardware nodes available for public use) to perform real hardware experiments on a low or conceptual level.

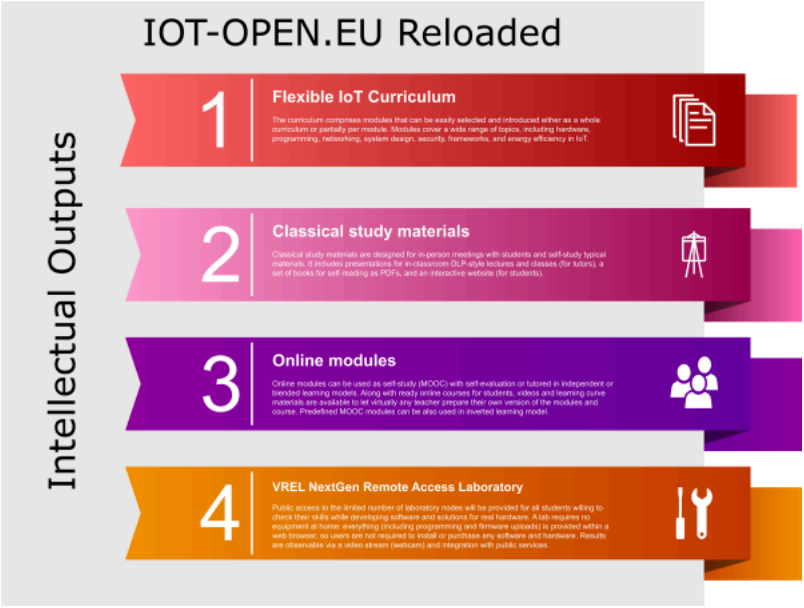

Figure 3: IOT-OPEN.EU Reloaded Projects Intellectual Outputs

3. Module: Introduction to IoT

Study level	Bachelor
ECTS credits	3-6
Study forms	Hybrid or fully online
Module aims	To give an introductory overview of IoT to students, where and how IoT solutions can be implemented, and what type of benefits implementing an IoT solution might offer. The module aims to give practical hands-on experience in creating simple IoT systems
Pre-requirements	Motivation to study IoT, recommended to have basics on programming, electronics and mechatronics
Learning outcomes	After completing this module, the student: - knows IoT concept and application fields - knows IoT technologies - understands the functionality of IoT components and their purpose in the system - can assemble and implement a simple IoT system
Topics	Topic 1 - IoT Overview (1 ECTS) Definition of IoT Enabling Technologies Mobility – New Paradigm for IoT Systems Data Management Aspects in IoT IoT Application Domains Topic 2 - IoT Programming and Frameworks (2 ECTS)) Introduction to the IoT Microcontrollers Introduction to Embedded Programming IoT and Embedded Systems Programming Models Introduction to the Programming Frameworks Software Development Tools and Platforms C/C++ Language Embedded Programming Fundamentals Programming with the Use of Scripts Python Fundamentals for IoT Windows IoT and C# Fundamentals Topic 3 - IoT Hardware (2 ECTS) Embedded Communication IoT Hardware Overview Most Noticeable Platforms Sensors and Sensing Actuators and Output Devices Powering of the IoT Devices Topic 4 - IoT Communication and Networking (1 ECTS) Introduction to the IoT Communication and Networking Communication Stack Communication Models Media Layers - Wired Network Protocols Media Layers - Wireless Network Protocols Application Protocols Programming for IoT Networking IoT Frameworks and Firmware
Type of assessment	The prerequisite of a positive grade is a positive evaluation of module topics and presentation of practical work results with required documentation
Blended learning	The practice is divided into two distinct parts. In the first part, students work independently to acquaint themselves with existing IoT devices, culminating in a comprehensive report. This phase aims to lay the foundational knowledge necessary for the subsequent task. The second part of the practice is conducted collaboratively as a team. Students are tasked with developing an IoT solution to address a specified problem. The problem's thematic focus may center around concepts such as 'green campus' or 'green university,'

	encouraging solutions contributing to environmental sustainability. Upon completion of the second part, students are required to deliver a presentation detailing their collaborative efforts and the developed IoT system's functionality. This presentation serves not only as a demonstration of the practical application of their solution but also as an opportunity for peer and instructor feedback.
References to literature	1. IOT-OPEN.EU: Introduction to the IOT 2nd edition , 2024 2. Samuel Greengard, The Internet of Things, 2015, ISBN: 978-0262527736 3. Cuno Pfister. Getting Started with the Internet of Things: Connecting Sensors and Microcontrollers to the Cloud (Make: Projects), 2011, ISBN: 978-1449393571
Lab equipment	IoT HomeLab kit, VREL NextGen IoT laboratory, or similar
Virtual lab	VREL NextGen Remote lab access and management: https://iot.aei.polsl.pl
MOOC course	MOOC Courses hosting for IOT-OPEN.EU Reloaded and Multiasm grants: http://edu.iot-open.eu/course/index.php?categoryid=3 - IoT Basic Modules

4. Module: IoT Design Methodologies

Study level	Master
ECTS credits	3
Study forms	Hybrid or fully online
Module aims	To develop student’s knowledge about methodologies to design IoT systems. To offer practical experience in designing and modelling an IoT system.
Pre-requirements	Has some understanding of IoT (passed module "Introduction to IoT")
Learning outcomes	After completing this module, the student: - has an overview of existing design methodologies - understands the IoT system design concepts - understands the SysML concept and uses it to model the IoT system - understands the system thinking concepts and tools
Topics	Introduction to IoT design methodologies IoT system design principles IoT System design goals IoT System design challenges System thinking and IoT design methodology System modeling
Type of assessment	Prerequisite of a positive grade is a positive evaluation of module topics and presentation of practical work results with required documentation
Blended learning	The practical work is conducted collaboratively. The IoT system is designed using the SysML modelling technique, encompassing the following components: a requirements diagram; a block definition diagram (depicting system architecture); an internal block diagram (detailing information flow and component interactions); a use case diagram; an activity diagram (illustrating system behaviour); and requirement validation. Based on the system's description, students construct a mock-up IoT system. Upon completion, students present and report on the designed IoT system, demonstrating its functionality. Additionally, students are expected to employ systems thinking concepts and tools, such as causal loop diagrams, stocks and flows, etc., to design IoT systems. Along with MOOC course in hybrid mode.
References to literature	1. IOT-OPEN.EU, Introduction to the IoT 2nd Edition , 2024 2. Samuel Greengard, The Internet of Things, 2015, ISBN: 978-0262527736 3. Sensors and Microcontrollers to the Cloud (Make: Projects), 2011, ISBN: 978-1449393571 4. Sanford Friedenthal, Rick Steiner, Alan Moore, Practical Guide to SysML: The Systems Modeling Language 3rd edition, 2014, ISBN: 9780128002025 5. Lenny Delligatti, SysML Distilled: A Brief Guide to the Systems Modeling Language, 2013, ISBN: 9780321927866 6. The Fifth Discipline: The Art and Practice of Learning Organisation by Peter M. Senge 7. Thinking in Systems: A Primer by Donella H. Meadows
Lab equipment	1. Vensim (software) 2. Visual Paradigm (software)
Virtual lab	https://iot.aei.polsl.pl
MOOC course	http://edu.iot-open.eu/course/view.php?id=6

5. Module: IoT Architectures, inc. Networks

Study level	Master
ECTS credits	3
Study forms	Hybrid or fully online
Module aims	The Module aims to give an overview of different types of IoT networks, where they are applicable, and the pros and cons of different networks. Gives hands-on experience in designing, building, and implementing IoT networks.
Pre-requirements	Has some understanding of IoT (passed module "Introduction to IoT")
Learning outcomes	After completing this module, the student: - knows IoT system architectures - has an overview of networks (pros and cons) used in IoT systems - knows what network topologies, design methodologies, and tools are used to build IoT networks - can assemble and implement IoT networks
Topics	Topic 1 - IoT Architecures IoT networks (NFC, ZigBee, LoRA, Thread, GSM, Bluetooth, WiFi, BSM, other) IoT system architectures IoT network topologies Industrial IoT systems Topic 2 - IoT Network Design IoT communication and networking technologies IoT network design consideration and challenges IoT network design methodologies IoT network design tools
Type of assessment	Prerequisite of a positive grade is a positive evaluation of module topics and presentation of practical work results with required documentation
Blended learning	Along with MOOC course in hybrid mode.
References to literature	1. IOT-OPEN.EU, Introduction to the IoT 2nd Edition , 2024 2. Book 2
Lab equipment	
Virtual lab	
MOOC course	http://edu.iot-open.eu/course/view.php?id=7

6. Module: Data Analytics

Study level	Master
ECTS credits	3
Study forms	Hybrid or fully online
Module aims	The key aim of the course is to familiarize the students with the most important groundbreaking information technologies used in manipulating, storing, and near-real-time analyzing of data in IoT systems.
Pre-requirements	Has some understanding of IoT (passed module "Introduction to IoT")
Learning outcomes	After completing this course, the student: - identifies challenges in Data analytics - recognize main tools and frameworks for Data analytics - knows what are regression, clustering, and classification models - has overview of time series analysis in IoT - can apply data analytics on real-life IoT use case
Topics	IoT Data Analysis Data products development Data preparation for data analysis Regression models Clustering models Classification models Introduction to time series analysis Hints for further readings on AI
Type of assessment	Prerequisite of a positive grade is a positive evaluation of course topics and presentation of practical work results with required documentation
Blended learning	Along with MOOC course in hybrid mode.
References to literature	
Lab equipment	
Virtual lab	
MOOC course	http://edu.iot-open.eu/course/view.php?id=8

7. Module: IoT Security

Study level	Master
ECTS credits	3
Study forms	Hybrid or fully online
Module aims	The aim of the module is to give an introductory overview to the security issues pertaining IoT solutions. What are the usual topics that are needed to consider from a security point of view when building an IoT system.
Pre-requirements	The student/learner has based following modules: - Introduction to IoT - IoT Architectures, inc. Networks
Learning outcomes	After completing this module, the student: - has overview of cybersecurity concepts in IoT systems - understands the cybersecurity challenges and vulnerabilities in IoT system - knows how to secure and defend IoT systems against cyber attacks - can implement best cybersecurity practices on IoT systems
Topics	Topic - Cybersecurity in IoT systems Cybersecurity concepts IoT cybersecurity challenges Vulnerabilities in IoT systems Cybersecurity issues and threats in IoT systems Typical attack patterns on IoT systems Best practices of attack detection and mitigation Best practices of defense designs Procedures and other countermeasures
Type of assessment	Prerequisite of a positive grade is a positive evaluation of module topics and presentation of practical work results with required documentation
Blended learning	Along with MOOC course in hybrid mode.
References to literature	1. Jean-Paul A. Yaacoub, Hassan N. Noura, Ola Salman, Ali Chehab, Ethical hacking for IoT: Security issues, challenges, solutions and recommendations, Internet of Things and Cyber-Physical Systems 3 (2023) 280–308, Elsevier. 2. Gustavo González-Granadillo, Susana González-Zarzosa, Rodrigo Diaz, Security Information and Event Management (SIEM): Analysis, Trends, and Usage in Critical Infrastructures, Sensors, MDPI. 3. Cybersecurity: A self-teaching introduction by C. P. Gupta and K. K. Goval, M ERCURY L EARNING AND INFORMATION, Dulles, Virginia. 4. Introduction to cyber security by Jeetendra Pande, Uttarakhand Open University, Haldwani. 5. Principles of Cyber Security by DR babasaheb Ambedkar, Open University.
Lab equipment	
Virtual lab	
MOOC course	http://edu.iot-open.eu/course/management.php?categoryid=6&courseid=9

8. Module: Blockchain in IoT

Study level	Master
ECTS credits	3
Study forms	Hybrid or fully online
Module aims	ADD
Pre-requirements	Has some understanding about of (passed module "Introduction to IoT")
Learning outcomes	After completing this module, the student: - ADD - ADD - ADD - ADD
Topics	Topic - Blockchain Key concepts of blockchain Blockchain network structures and technologies Second generation applications Expanded application of Blockchain
Type of assessment	Prerequisite of a positive grade is a positive evaluation of module topics and presentation of practical work results with required documentation
Blended learning	Along with MOOC course in hybrid mode.
References to literature	1. Book 1 2. Book 2
Lab equipment	
Virtual lab	
MOOC course	http://edu.iot-open.eu/course/management.php?categoryid=6&courseid=10

9. Module: IoT Green Design

Study level	Master
ECTS credits	3
Study forms	Classical, hybrid or fully online
Module aims	The aim of the module is to give an overview of sustainable design and energy-efficient solutions in IoT systems, which are implemented in Green IoT (interconnections, network architectures, communication protocols, and the energy efficiency of devices/things). Gives hands-on experience in designing and building Green IoT systems.
Pre-requirements	The student has based following modules: - Introduction to IoT - IoT Design Methodologies - IoT Architectures, inc. Networks - Data Analytics
Learning outcomes	After completing this module, the student: - has an overview of Green IoT design (energy efficient design, mechanisms, computing, etc.) and sample use cases - understands the main design criteria for the Green IoT - knows what energy sources are used for IoT systems and how to select them - can design and assemble green IoT system
Topics	Topic - Green IoT Green IoT design Green IoT energy-efficient design and mechanisms Design consideration for energy sources for IoT devices Energy sources for IoT Energy harvesting for IoT systems Energy efficient computing Green IoT design trade-offs Green IoT Applications
Type of assessment	Prerequisite of a positive grade is a positive evaluation of module topics and presentation of practical work results with required documentation
Blended learning	Along with MOOC course in hybrid mode
References to literature	1. Bandana Mahapatra and Anand Nayyar, “Green Internet of Things”, CRC Press, Taylor & Francis Group, 2023, 978-1-003-20450-3. 2. Zhenyu Zhou and Zheng Chang and Haijun Liao, “Green Internet of Things (IoT): Energy Efficiency Perspective (Wireless Networks)”, Springer, 2021. 3. Ali Eslami Varjovi and Shahram Babaie, “Green Internet of Things (GIoT): Vision, applications and research challenges”, Sustainable Computing: Informatics and Systems, 28 (2020) 100448, Elsevier, 2023. 4. Mohammed H. Alsharif and Abu Jahid and Anabi Hilary Kelechi and Raju Kannadasan, “Green IoT: A Review and Future Research Directions”, Symmetry, 15, 757, 2023. 5. Kuaban G. Suila, Gelenbe E, Czachórski T, Czekalski P, Tangka J. Kewir. 2023. Modelling of the Energy Depletion Process and Battery Depletion Attacks for Battery-Powered Internet of Things (IoT) Devices. Sensors. 23(6183). 6. Kuaban G. Suila, Czachórski T, Gelenbe E, Sharma S, Czekalski P. In Press. A Markov model for a Self-Powered Green IoT Device with State-Dependent Energy Consumption. Proc. of the 4th International Conference on Communications, Information, Electronic and Energy Systems (CIEES 2023),
Lab equipment	Programming of the devices regarding power consumption: a laboratory node with a power meter.
Virtual lab	Not applicable
MOOC course	http://edu.iot-open.eu/course/management.php?categoryid=6&courseid=11


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