Co-funded by the Erasmus+ Programme of the European Union

Project ERASMUS+
ALIOT “Internet of Things: Emerging Curriculum for Industry and Human Applications”

(573818-EPP-1-2016-1-UK-EPPKA2-CBHE-JP)

CURRICULUM.
ERASMUS+ ALIOT

https://aliot.eu.org/

This project has been funded with support from the European Commission. This publication reflects the views only of the author, and the Commission cannot be held responsible for any use which may be made of the information contained therein.

March 2021

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INTRODUCTION

The name of the project is ALIOT, which is an acronym from the official name “Internet of Things: Emerging Curriculum for Industry and Human Applications” (reference number 573818-EPP-1-2016-1-UK-EPPKA2-CBHE-JP).

This project was financed by the Erasmus+ programme, which aims to contribute to the Europe 2020 strategy for growth, jobs, social equity and inclusion, as well as the aims of ET2020, the EU’s strategic framework for education and training. Erasmus+ also aims to promote the sustainable development of its partners in the field of higher education, and contribute to achieving the objectives of the EU Youth Strategy.

Specific objectives of Joint project (curriculum development)

The joint project in curriculum development implemented a new approach to the delivery of educational services through ongoing feedback from employers and correction of the educational process, methodological and logistical support of the educational process.

It also provided creation of a professional community in IoT, robotics, computer networks and microcontrollers. The project ensured adaptation of academic programs to the needs of the European labor market, thus enhancing the opportunities of academic and labor abundant. The novelty is in usage of the concept of accumulation and transfer of educational credits (ECTS) and the concept of learning throughout life (LLL).

Introduced a Multi-domain and Integrated IoT programme for master students in UA universities:

- MC1 – Fundemantals of IoT and IoE (Internet of Everything)
- MC2 – Data science for IoT and IoE
- MC3 – Mobile and hybrid IoT-based computing
- MC4 – IoT technologies for cyber physical systems

Introduced a Multi-Domain and Integrated IoT programme for doctoral students in UA universities:

- PC1 – Simulation of IoT and IoE-based systems
- PC2 – Software defined networks and IoT
- PC3 – Dependability and security of IoT
- PC4 – Development and implementation of IoT-based systems

Provided the mechanism for intensive capacity-building measures for UA CT tutors:

- ITM1 – IoT for Smart energy grid
- ITM2 – IoT for Smart building and city
- ITM3 – IoT for intelligent transport systems
- ITM4 – IoT for health systems
- ITM5 – IoT for ecology monitoring systems
- ITM6 – IoT for industrial systems

Established Multi-Domain IoT Cluster Network in Ukraine

This network provides an environment for knowledge sharing and transfer as well as cross-fertilisation of innovative IoT-related research ideas and practices between the academic and industrial sectors.

The aim of Multi-Domain IoT Cluster Network is to integrate all available and produced curriculum, methods and tools for providing training and consultancy services in the area of IoT-based systems for different application domains: Human, Business-critical, Safety-Critical. This network is a means for knowledge sharing, exchange, and transfer. It also promotes public awareness of the cutting edge IoT-related concepts, technologies, and applications. The structure of Network includes 7 offices incorporated at the involved department of each UA university. Each office is specialized for the specific application domain and thus is responsible for networking and cooperating of R&D, academic and industrial partners acting in the respective domain.

Target sectors

MSc/Doctoral Students, graduates, young professionals, state and private companies, HEI, professional associations, research centers, staff of national and EU IT-industry, acting different application domains of IoT.

ALIOT consortium has relevant expertise relating to IoT technologies and applications and extensive experience in curriculum development and its associated quality assurance procedures.

The project content and methodology

The Joint Project in curriculum development implemented a new approach to the delivery of educational services through ongoing feedback from employers and correction of the educational process, methodological and logistical support of the educational process. It provided the creation of a professional community in IoT, robotics, computer networks and microcontrollers.

The project ensures adaptation of academic programs to the needs of the European labor market, thus enhancing the opportunities of academic and labor abundant. Another issue is usage of the concept of accumulation and transfer of educational credits (ECTS) and the concept of learning throughout life (LLL).

International cooperation (between UA, UK, PT, SE, IT) provides creation of a modernized EU innovative learning system for training and prof. dev in the emerging field of IoT, robotics, comp. networks and microcontrollers including the development smart devices for traffic system with adapted academic programs to the req-s of UA and EU employers.

The wider objective of ALIOT is to provide studies in the emerging field of Internet of Things (IoT) according to the needs of the modern society; to bring the universities closer to changes in global ICT labour market and world education sphere; to give students an idea of various job profiles in different IoT domains.

1. TEACHING PROGRAMME OF THE COURSE ITM1 “IOT FOR SMART ENERGY GRID”

1.1. DESCRIPTION OF THE COURSE

TITLE OF THE COURSE	Code
IoT for Smart Energy Grid	**ITM1**

Teacher(s)	Department
Coordinating: Prof., DrS. E. V. Brezhnev **Others:** Module ITM1.1: Assoc. Prof., Ph.D. Z. Dombrovskyi, Prof., DrS. A. Sachenko, Ph.D. Student M. Dombrovskyi, Assoc. Prof., Ph.D. G. Hladiy. Module ITM1.2: Prof., DrS. M. P. Musiyenko, Ass. Prof., Dr. I. M. Zhuravska, Dr. Y. M. Krainyk. Modules ITM1.3: DrS. E. Brezhniev, Ph.D. M. Kolisnyk , ITM1.4: DrS. E. Brezhniev	Department of Computer systems, Networks and Cyber Security (KhAI); Department of Information and Computing Systems and Control (TNEU); Intelligent Information Systems (PMBSNU)

Study cycle	Level of the course	Type of the course
Trainings	A	Bounden

Form of delivery	Duration	Language(s)
Full-time tuition	One semester	English

Prerequisites	
Prerequisites: Foundation of Modeling; Computer Networks; Computer Systems and Embedded System; Computer electronics.	**Co-requisites (if necessary):** Foundations of Dependability and Information Security; System and Network Security.

Credits of the course	Total student workload	Contact hours	Individual work hours
4	120	56	64

1.2. COMPETENCES AND LEARNING OUTCOMES

Aim of the course	
The aim of the course is to create a knowledge base for multidisciplinary research on IoT infrastructure for smart energy grid (SEG) and to provide prerequisites for practical use of such embedded system. The study also expands the current research on SEG by combining system approach in the context of the study the monitoring and control function of IoT embedded system.	
General Competences	**Professional Competences**
• The ability to identify the scientific nature of problems in the professional sphere, to find adequate ways to solve them. • The ability to investigate problems using systems analysis, synthesis, computer modeling and optimization methods. • The ability to conduct professional research in an international environment.	• Ability to participate in project activities; ability to adapt and act in a new situation. • The ability to independently analyze and make reasonable choice of structures of complexes. • The ability to analyze and develop different levels of complexity of the IoT system using modern methods and tools, as well as taking into account modern challenges in the field of their security. • The ability to analyze and implement a reasonable choice of optimal technologies in the design and construction of energy efficient systems. • The ability to apply professional knowledge and practical skills to solve typical problems of setting up and maintaining communication of mobile systems.

Learning outcomes of course	Assessment methods	Innovative teaching/learning methods
1. To understand the model of SG and, and implementing the Cloud computing and Big Data in SG.	Course Evaluation Questionnaire	• Learning in laboratories: Just-in-Time teaching. • Cooperative learning: work in small groups; synthesis of ideas. • Collective group learning: brainstorming; case method; decision tree. • Situational modeling of phenomena: simulations or simulation games; PRES-formula (from English Position - Reason - Explanation or Example - Summary). • Elaboration of discussion issues: method of determining the discussion position; changing the position and comparing alternative positions; discussion, debate.
2. To understand the structure of integrated Smart Grid system in IOT environment	Module Evaluation Questionnaire	
3. To obtain the basic skills of integration of reliability models into safety assessment of IT infrastructure of power grid and to apply the Markov models method for the SEG assessment of dependability	Course Evaluation Questionnaire	
4. To implement the Cloud computing and Big Data in Smart Grids	Module Evaluation Questionnaire	
5. Employ the models and methods for structural organization of local SEG infrastructure	Course Evaluation Questionnaire	
6. Select appropriate hardware for control and harvesting energy flow in local SEG	Course Evaluation Questionnaire	
7. Analyze most common architecture solutions for local SEG and their main pros and cons and propose the most appropriate hardware/software set for their organization	Course Evaluation Questionnaire	
8. Leverage advantages of hardware and software components for local SEG according to its peculiarities	Course Evaluation Questionnaire	

1.3. HOURS DISTRIBUTION

Themes	Work hours							Time and tasks for individual work	
	Lectures	Consultations	Seminars	Practical work (training)	Laboratory work	Placements	**Total contact work**	**Individual work**	**Tasks**
1. Existing grid problem and its solution using the integrated Smart Grid system in IoT environment. 1.1. Existing grid problem and its solution 1.2. Problems in Power Grid and a Smart Grid conceptual model 1.3. European Smart Grid Architecture Model and New Grid Paradigms - Micro grid	6		4	4			**14**	**16**	1.1. Studying the problem of existing grid. 1.2 A conceptual model of Smart Grid 1.3. Criteria for selecting the Investment Projects to implement the Smart Grid in the existing grid
2. Applying the IoT in Smart Grid projects 2.1. Development of intelligent power grids directions. 2.2. Forming the strategic vision redistribution 2.3. Paradigm the Internet of Things	6		4	4			**14**	**16**	2.1. Studying the problem implementation of the Smart Grid 2.5. Applying the IoT in Smart Grid projects 2.3. A conceptual model applying the IoT in Smart Grid projects
3. Cloud computing and big data as a part of the IoT Smart Grid 3.1. Processes in the integrated smart grid system on cloud 3.2. Cloud-based software platform for smart grids 3.3. D2R software platform on Clouds	6		4	4			**14**	**16**	3.1. A conceptual model of Cloud computing 3.2. Integra-ting the Cloud computing and Big Data into the Smart Grid environment 3.3. Explore the possibilities of using the different types of Cloud computing and Big Data in smart grid
4. Availability assessment of IoT based IT infrastructure of Power Grids 4.1 Integration of reliability methods into safety assessment processes for it infrastructure of power grid	6			4	4		**14**	**16**	4.1 Predictive analytics, diagnostics and maintenance of SEG

4.2 Dependability assessment of Smart Grid systems 4.3 Application of STAMP method for smart grid safety/security accident analysis 4.4 Accident root cause analysis of IoT based smart grid with Five Whys Method									
5. Development of I&C and harvesting systems for local SEG 5.1. Complex interdependencies that characterize local SEG 5.2. Architecture of I&C and harvesting systems 5.3. Devising methods of I&C and harvesting systems	6			4	2		**12**	**18**	5.1. Local SEG organization 5.2. Architecture of SEG
6. Hardware components for local SEG (sensors, measurement units, control units – Raspberry Pi, STM32 boards, ESP8266, PLC, Phoenix, etc.) 6.1. Sensors, measurement units. Energy measurement systems using PLC technology (IEEE 1901) 6.2. IoT control solutions based on STM32 boards, ESP8266 6.3. PLC in SEG architecture. Mini-computers for local SEG	6			4	4		**14**	**16**	6.1. Wireless solutions architecture using ESP8266 6.2. The main types and characteristics of COM-ports in counters that record the consumption of various types of energy
7. Software components of SEG 7.1 Protocols for device communication 7.2. Cloud infrastructure used by local SEG 7.3. Local software for SEG. Software platform named “mbed” for local infrastructure IoT solution	6			4	4		**14**	**16**	7.1. Software platform named “mbed” means and methodologies 7.2 Device communica-tion protocols usage
Total	**242**		**12**	**128**	**814**		**96**	**64**	

1.4. COURSE ASSESSMENT STRATEGY

Assessment strategy	Weight in %	Deadlines	Assessment criteria
Lecture activity, including fulfilling special self-tasks	10	7,14	85% – 100% Outstanding work, showing a full grasp of all the questions answered. 70% – 84% Perfect or near perfect answers to a high proportion of the questions answered. There should be a thorough understanding and appreciation of the material. 60% – 69% A very good knowledge of much of the important material, possibly excellent in places, but with a limited account of some significant topics. 50% – 59% There should be a good grasp of several important topics, but with only a limited understanding or ability in places. There may be significant omissions. 45% – 49% Students will show some relevant knowledge of some of the issues involved, but with a good grasp of only a minority of the material. Some topics may be answered well, but others will be either omitted or incorrect.

			40% – 44% There should be some work of some merit. There may be a few topics answered partly or there may be scattered or perfunctory knowledge across a larger range. 20% – 39% There should be substantial deficiencies, or no answers, across large parts of the topics set, but with a little relevant and correct material in places. 0% – 19% Very little or nothing that is correct and relevant.
Learning in laboratories	30	7,14	85% – 100% An outstanding piece of work, superbly organized and presented, excellent achievement of the objectives, evidence of original thought. 70% – 84% Students will show a thorough understanding and appreciation of the material, producing work without significant error or omission. Objectives achieved well. Excellent organization and presentation. 60% – 69% Students will show a clear understanding of the issues involved and the work should be well written and well organized. Good work towards the objectives. The exercise should show evidence that the student has thought about the topic and has not simply reproduced standard solutions or arguments. 50% – 59% The work should show evidence that the student has a reasonable understanding of the basic material. There may be some signs of weakness, but overall the grasp of the topic should be sound. The presentation and organization should be reasonably clear, and the objectives should at least be partially achieved. 45% – 49% Students will show some appreciation of the issues involved. The exercise will indicate a basic understanding of the topic, but will not have gone beyond this, and there may well be signs of confusion about more complex material. There should be fair work towards the laboratory work objectives. 40% – 44% There should be some work towards the laboratory work objectives, but significant issues are likely to be neglected, and there will be little or no appreciation of the complexity of the problem. 20% – 39% The work may contain some correct and relevant material, but most issues are neglected or are covered incorrectly. There should be some signs of appreciation of the laboratory work requirements. 0% – 19% Very little or nothing that is correct and relevant and no real appreciation of the laboratory work requirements.
Course Evaluation Quest	60	8,16	The score corresponds to the percentage of correct answers to the test questions

2. TEACHING PROGRAM OF THE COURSE ITM2 “IOT FOR SMART BUILDING AND CITY”

2.1. DESCRIPTION OF THE COURSE

TITLE OF THE COURSE	Code
IoT for the Smart Building and City	**IT 2**

Teacher(s)	Department
Coordinating: Prof. Dmitry Maevsky **Others:** Module ITM2.1: DrS, Prof. Maevsky D. A., Ass. Prof., PhD Maevskaya O. J. Module ITM2.2: Ass. Prof., PhD Parkhomenko A.V.; Ass. Prof., PhD Gladkova O. M. Module ITM 2.3: DrS, Prof. Busher V. A, DrS, Prof. Bojko A. O. Module ITM 2.4: DrS, Prof. Drozd O. V.; Ass. Prof., PhD Martinuk O. M.	ONPU, Institute of Electro mechanics and Energetic Management; ONPU, Computer Engineering ZNTU Software Tools Department

Study cycle	Level of the module	Type of the module
Industrial Training	A	Full-time tuition

Form of delivery	Duration	Langage(s)
Full-time tuition	One semester	English

Prerequisites	
Prerequisites: Systems theory, Probability Theory and Foundations of Mathematical Statistics; Computer Systems and System Analysis, Risk Theory, Theory of Automatic Control; Computer Networks; Information-Networking Technologies, Modeling Foundation knowledge and skills in CAD	**Co-requisites (if necessary):** Experience with IDE

Credits of the module	Total student workload	Contact hours	Individual work hours
4	120	48	72

2.2. COMPETENCES AND LEARNING OUTCOMES

<table>
<tr><th colspan="3">Aim of the course</th></tr>
<tr><td colspan="3">The aim of the course is:
– To create a knowledge base for multidisciplinary research systems theory, risk analysis and risk management. The study also expands the current research on systems IoT and hierarchy of smart systems;
– To obtain the knowledge and practical skills of software/hardware engineering applied to development of Smart Building Systems;
– Studying the control, executive and sensor elements used in the development of the Smart Building Management System, as Smart House & IoT objects that are integrated into extensible networks;
– Acquisition of knowledge in wireless and hybrid technologies of component interaction for the IoT SBC systems. Obtaining skills in development and debugging of simulation models of component interaction in the IoT SBC systems.</td></tr>
<tr><th colspan="2">General Competences</th><th>Professional Competences</th></tr>
<tr><td colspan="2">• The ability to independently learn the basics of new research methods, changes in the scientific, research and production profile of their activities.
• The ability to investigate problems using systems analysis, synthesis, computer modeling and optimization methods.
• The ability to analyze, verify, assess the completeness of information in the course of professional activities, if necessary, to supplement and synthesize missing information and work in conditions of uncertainty.
• The ability to assess and ensure the quality of work performed.
• The ability to plan and manage time.</td><td>• The ability to identify, analyze and solve problems in the professional sphere.
• The ability of independent practical work in accordance with the obtained qualification.
• The ability to understand and analyze the development of distributed service-oriented systems, the ability to correctly select and use appropriate architectures, technologies and protocols in the performance of professional tasks in the design, development, implementation and application of service-oriented systems.
• The ability to use scientific and practical methods of research, use and improvement of computer systems of artificial intelligence and mastering the skills of developing neural networks.
• The ability to independently analyze, make reasonable choices and use technologies, methods and tools for the design and development of industrial IoT systems.
• The ability to analyze and implement a reasonable choice of optimal technologies and tools in the design and construction of energy efficient systems.</td></tr>
<tr><th>Learning outcomes of module (course unit)</th><th>Assessment methods</th><th>Innovative teaching/learning methods</th></tr>
<tr><td>1. Understand the difference between natural and artificial systems.</td><td>Module Evaluation Questionnaire</td><td rowspan="5">• Interactive lectures: lecture-conversation; lecture-discussion.
• Learning in laboratories: Just-in-Time teaching; analysis of errors & incidents; method of analysis and diagnosis of the situation.
• Cooperative learning: pair learning; work in small groups; synthesis of ideas.
• Collective group learning: general circle;
• brainstorming; decision tree; master classes.
• Situational modeling of phenomena: Competitive learning: division of students into groups according to educational tasks; educational activities of students in groups; presentation of collective learning tasks (public speech).</td></tr>
<tr><td>2. Be able to distinguish the main function of artificial systems and classify these systems according to their main function.</td><td>Module Evaluation Questionnaire</td></tr>
<tr><td>3. Build hierarchical structures of systems based on their separation on the basis of arbitrary.</td><td>Module Evaluation Questionnaire</td></tr>
<tr><td>4. To perform a risk assessment of artificial technical systems.</td><td>Module Evaluation Questionnaire</td></tr>
<tr><td>5. Use the method of peer review for risk assessment in IoT systems.</td><td>Module Evaluation Questionnaire</td></tr>
</table>

2.3. HOURS DISTRIBUTION

Themes	Contact work hours							Time and tasks for individual work	
	Lectures	Consultations	Seminars	Practiacl work	Laboratory work	Placements	**Total contact work**	**Individual work**	**Tasks**
1. Elements of System Theory 1.1. Key concepts of System Theory 1.2. Natural and artificial systems 1.3. Main function of artificial systems 1.4. The concept of an ideal system	2				4			10	Decomposition and main functions of smart building systems Decomposition and main functions of smart city systems
2. Internet of Thing: Hierarhy of Smart Systems. 2.1. Build hierarchical structures of smart systems 2.2. The concept of risk and methods of its evaluation 2.3. Build of risk matrices and its analysis	2				4			10	2.1. Risk analysis of smart building systems 2.2. Risk analysis of smart city systems.
3 Embedded systems as the basis of the IoT infrastructure									
3.1 Embedded systems design techniques.	1						1	2	Reading literature and preparing presentation
3.2 Hardware /software platforms for embedded systems realization. Software/ hardware development based on Arduino platform. Development of interactive graphical interface for interaction with Arduino platform.					2		2	3	Working on individual tasks and preparing lab's reports
3.3 Software /hardware development based on Arduino platform. Working with sensors and actuators.					2		2	3	

3.4 Protocols and technologies for embedded systems interaction with other devices and Internet	1						1	3	Working on individual tasks and preparing lab's reports
4 Implementation of the software/hardware platform for Smart Building System.									
4.1 The development of Smart Building System architecture.	1						1	2	Reading literature and carrying Remote experiments using REIoT complex
4.2 The usage of Raspberry Pi and OpenHAB platforms for Smart Building System control. Raspberry Pi minicomputer implementation as a server for Smart building system. Integration of SBS subsystems based on OpenHAB platform.					4		4	3	Working on individual tasks and preparing labs reports
4.3 The application of the remote laboratory Smart House&IoT for Smart Building System prototyping	1						1	2	Working on individual tasks and preparing labs reports
5 Classification of the Building Management System, the purpose and basic properties of control, executive and sensor elements. 5.1 Introduction in Smart House and IoT systems. 5.2Classification of intellectual components, sensors, executive units of Building Management Systems. 5.3 Subsystems of Smart House: microclimate control, lighting, security in residential and industrial premises.	2				2 2		**6**	9	Reading literature and preparing presentation
6 Organization of the interaction of subsystems and elements of Smart House & IoT. 6.2Microclimate control – functions, executive and sensor units, 6.3Lighting – lux meters, astronomical timers, security components as sensor and control units in lighting subsystem.	2						**6**	9	Working on individual tasks and preparing lab's reports

6.4Security subsystem – interaction with lighting, access control and protection subsystems. 6.5 Study of the security and lighting control system, shutters and blinds based on Theben-Luxor controllers 6.6 Construction of Smart House & IoT subsystems based on Moeller / Eaton xComfort Home-Manager equipment with wireless RF-EIB / KNX networks 6.7 Studying the principles of managing components of Smart House & IoT based on the controller Siemens Logo! with a module for connecting to the KNX network 6.8 Study the principles of configuring intelligent control systems for building and residential engineering systems in the KNX network in the ETS software environment					2 2				
7 Technologies of behavioral interaction of device processes in the IoT Smart Building and Sity (SBC) systems. 7.1 Introduction to behavioral technologies of component processes interaction into the structures of IoT SBC systems. 7.2 Work benches for development and verification of models in interaction of device proccesess in the IoT SBC systems. 7.3 Simulation models of behavior and synchronization for the IoT SBC systems with component integrity monitoring. 7.4 Features of simulation models of behavior and synchronization for the IoT SBC systems with component integrity monitoring. 7.5 Simulation models of behavior and synchronization for the IoT SBC systems with component integrity monitoring.	2			4			**6**	12	1.6. Features of simulation models of the IoT SBC systems with a changeable traffic in the multipoint environment of wireless dynamic access
8-Technologies of synchronize interaction of devices in the IoT SBC systems	2			4			**6**	12	2.5. Debugging of simulation models of component interaction in

8.1 Introduction to synchronize technologies of component interaction in the IoT SBC systems. 8.2 Work benches of development and verification of synchronize models in component interaction of the IoT SBC systems 8.3 Development of simulation synchronize models for the IoT SBC systems with secure authorization. 8.4. Simulation of component synchronize interaction in the IoT SBC systems with secure authorization.									the IoT SBC systems with a changeable traffic in the multiroute hybrid environment
Total	**16**			**8**	**24**		**48**	**72**	

2.4. COURSE ASSESSMENT STRATEGY

Assessment strategy	Weight in %	Deadlines	Assessment criteria
Lecture activity, including fulfilling special self-tasks	10	7,14	85% – 100% Outstanding work, showing a full grasp of all the questions answered. 70% – 84% Perfect or near perfect answers to a high proportion of the questions answered. There should be a thorough understanding and appreciation of the material. 60% – 69% A very good knowledge of much of the important material, possibly excellent in places, but with a limited account of some significant topics. 50% – 59% There should be a good grasp of several important topics, but with only a limited understanding or ability in places. There may be significant omissions. 45% – 49% Students will show some relevant knowledge of some of the issues involved, but with a good grasp of only a minority of the material. Some topics may be answered well, but others will be either omitted or incorrect. 40% – 44% There should be some work of some merit. There may be a few topics answered partly or there may be scattered or perfunctory knowledge across a larger range. 20% – 39% There should be substantial deficiencies, or no answers, across large parts of the topics set, but with a little relevant and correct material in places. 0% – 19% Very little or nothing that is correct and relevant.
Learning in laboratories	30	7,14	85% – 100% An outstanding piece of work, superbly organised and presented, excellent achievement of the objectives, evidence of original thought. 70% – 84% Students will show a thorough understanding and appreciation of the material, producing work without significant error or omission. Objectives achieved well. Excellent organisation and presentation. 60% – 69% Students will show a clear understanding of the issues involved and the work should be well written and well organised. Good work towards the objectives.

			The exercise should show evidence that the student has thought about the topic and has not simply reproduced standard solutions or arguments. 50% – 59% The work should show evidence that the student has a reasonable understanding of the basic material. There may be some signs of weakness, but overall the grasp of the topic should be sound. The presentation and organisation should be reasonably clear, and the objectives should at least be partially achieved. 45% – 49% Students will show some appreciation of the issues involved. The exercise will indicate a basic understanding of the topic, but will not have gone beyond this, and there may well be signs of confusion about more complex material. There should be fair work towards the laboratory work objectives. 40% – 44% There should be some work towards the laboratory work objectives, but significant issues are likely to be neglected, and there will be little or no appreciation of the complexity of the problem. 20% – 39% The work may contain some correct and relevant material, but most issues are neglected or are covered incorrectly. There should be some signs of appreciation of the laboratory work requirements. 0% – 19% Very little or nothing that is correct and relevant and no real appreciation of the laboratory work requirements.
Module Evaluation Quest	60	8,16	The score corresponds to the percentage of correct answers to the test questions

3. TEACHING PROGRAM OF THE COURSE ITM3 “IOT FOR INTELLIGENT TRANSPORT SYSTEMS”

3.1. DESCRIPTION OF THE COURSE

TITLE OF THE MODULE	Code
IoT for intelligent transport systems	**TM 3**

Teacher(s)	Department
Coordinating: Prof., DSc Sachenko A.O. **Others:** Assoc. Prof., Dr Kochan V.V., Dr Bykovyy P.E., Dr. Zahorodnia D.I., Dr Osolinskyi O.R., Prof., DSc Skarga-Bandurova I.S., Ph.D. Student Derkach M.V., Prof., DSc Kharchenko V.S., Prof., DSc Orekhov O.O., Dr Stadnik A.O., Assoc. Prof., Dr Fesenko H.V..	Information Computing Systems and Control, TNEU Computer science and Engineering, V. Dahl EUNU Computer Systems, Networks and Cyber Security Department of National Aerospace University “KhAI”

Study cycle	Level of the module	Type of the module
Trainings	A	Full-time tuition

Form of delivery	Duration	Language(s)
Full-time tuition	One semester	English

Prerequisites	
Prerequisites: Intelligent Systems, Neural Networks and Evolutionary Algorithms, Intelligent Robotic Systems, Digital electronics, Microcontrollers, Cooperative Human-Machine Interfaces, In-Vehicle Information Systems, Internet of things	**Co-requisites (if necessary):**

Credits of the module	Total student workload	Contact hours	Individual work hours
1	30	20	10

3.2. COMPETENCES AND LEARNING OUTCOMES

<table>
<tr><th colspan="3">Aim of the module (course unit): competences foreseen by the study programme</th></tr>
<tr><td colspan="3">A goal of the module is the practical use of earned students knowledge's in computational intelligence with the followed training in different applications of intelligent transport systems within IoT environment</td></tr>
<tr><th colspan="2">General Competences</th><th>Professional Competences</th></tr>
<tr><td colspan="2">• The ability to identify the scientific nature of problems in the professional sphere, to find adequate ways to solve them.
• The ability to plan and manage time.
• Skills of using information and communication technologies. The ability to plan and manage time.
• The ability to investigate problems using systems analysis, synthesis, computer modeling and optimization methods.
• The ability to manage projects, organize teamwork, take the initiative to improve activities.
Knowledge of foreign language (languages).</td><td>• The ability to analyze and make reasonable choices of technologies, methods and tools for developing energy efficient solutions for IoT and embedded systems.
• The ability to analyze and make an reasonable choice of technologies, methods and tools for the development of fault-tolerant systems.
• The ability to apply professional skills to implement practical tasks in accordance with the acquired qualifications.
• The ability to use scientific and practical methods of research, use and improvement of computer systems of artificial intelligence and mastering the skills of developing neural networks.
• The ability to analyze and reasonably choose the technical means of developing software and hardware systems and systems for IoT solutions.
• The ability to independently analyze and make reasonable choice of technologies, methods and tools for assessing and ensuring security at the design stage of critical IT infrastructures.</td></tr>
<tr><th>Learning outcomes of module (course unit)</th><th>Assessment methods</th><th>Innovative teaching/learning methods</th></tr>
<tr><td>At the end of module, the successful student will be able to:
1. Understand the general concepts and areas of applying the IoT in transport systems and in cooperative human-machine interfaces.
Acquire practical skills in working an integrated, formal and automated methodology for public transport information services</td><td>Module Evaluation Questionnaire</td><td rowspan="3">• Interactive lectures: lecture-conversation; lecture-discussion.
• Learning in laboratories: Just-in-Time teaching;
• analysis of errors & incidents; method of analysis and diagnosis of the situation; project method.
• Cooperative learning: pair learning; work in small groups; synthesis of ideas; joint project;
• Collective group learning: brainstorming; case method; discussion and debate.
• Situational modeling of phenomena:PRES-formula (from English Position - Reason - Explanation or Example - Summary); Problem solving method.
•
• Elaboration of discussion issues: method of determining the discussion position; discussion, debate.</td></tr>
<tr><td>2. Using the IoT equipment in transport area. Study and independently assemble the device to determine the geographical coordinates of the vehicle.
Using the IoT for development cooperative HMI systems</td><td>Module Evaluation Questionnaire</td></tr>
<tr><td>3. Developing the algorithms and software for Intelligent Transport Systems
Analyze the results of applying various methods for calculating the spherical distance for the actual data set.</td><td>Module Evaluation Questionnaire</td></tr>
</table>

4. Independently assemble a device for displaying information with optimal technical characteristics of components for assembly.	Module Evaluation Questionnaire	

3.3. HOURS DISTRIBUTION

Themes	Contact **work hours**							**Time and tasks for individual work**	
	Lectures	Consultations	Seminars	Practiacl work	Laboratory work	Placements	**Total contact work**	**Individual work**	**Tasks**
1.Studying the hardware of traffic intensity monitoring 1.1 General structure of IoT monitoring system 1.2 Used Software **Training**: Studying the hardware of traffic intensity monitoring	2				4		6	4	1.3 Formation of images database
2.Recognition and data processing of objects in a video frame 2.1 Calibrate the camera and adjust the resulting image 2.2 Calculate the length and width of vehicles different types **Training**: Recognize and data processing of the objects in a video frame	2				4		6	5	2.3 Receiving and recognizing the images of vehicles different types
3 Recognizing and data processing of objects array in a video stream 3.1 Counting the number of vehicles different type passed through the camera field of view at fixed intervals 3.2 Determining the coefficient of filling the road by different types of vehicles **Training:** Recognize and data processing of the objects array in a video stream	2			2			4	5	3.3 Virtual Instruments with ThingSpeak
4. Public transport (PT) systems 4.1Automatic vehicle location 4.2Demand responsive transport and IoT	2							2	4.3 PT priority systems and new innovations in PT delivery and operation
5. Tools and techniques for real-time public transport information acquisition and arrival time prediction based on GPS Data 5.1Real-time PT information service infrastructure 5.2Objective and challenges **Lab.** Exploring of components for vehicle location tracking device **Lab.** Exploring various ways to calculate the distance between geographic coordinates	2				8			3	5.3Arrival time prediction models

6. PT monitoring, analysis, and management 6.1General strategy of PT information service delivering and sharing 6.2Information boards, ETA/ETD on bus-stops 6.3Implementation of ITS to support the principles of demand management **Lab.** Exploring of information board components **Lab.** Exploring integrated development environment	2				8			3	6.4 Case studies
7. Areas of applying the IoT for cooperative human-machine interfaces	2		4					6	7.1 Examples of possible using the IoT for cooperative human-machine interfaces. 7.2 Development trends of cooperative HMI of intelligent transport systems based on the Internet of things.
8. Development of IoT based cooperative HMI systems	2							5	8.1 Comm-unication and protocols 8.2 On-board systems interaction
8. Assessment of cooperative human-machine interfaces of intelligent transport systems **Seminar:** Development and application of cooperative human-machine interfaces for intelligent transport systems based on the internet of things **Lab:** Safety assessment of cooperative human-machine interfaces of intelligent iot based transport systems	2				4			5	8.1 Methods of safety assessment for cooperative HMI 8.2 Safety assessment method for cooperative HMI based on research into hazards and capacity of HAZOP;
9. Internet of drone-based systems 9.1. Introduction into drone fleets 9.2. Internet of drones 9.3. Case studies **Training 1:** Determining the optimum number of single operator controlled unmanned aerial vehicles for npp monitoring missions **Training 2:** Optimal redistribution of UAVS in case of changing monitoring zones after an NPP accident	6			6					9.4. Airborne Communicate on networks for small unmanned aircraft systems 9.5. Flying ad-hoc networks: Routing protocols, mobility models, issues
Total	24		4	8	28		16	38	

3.4. COURSE ASSESSMENT STRATEGY

Assessment strategy	Weight in %	Deadlines	Assessment criteria
Lecture activity, including fulfilling special hometask	10	2,4	90–100% (A) – Outstanding work, showing a full grasp of all the questions answered. 85–89% (B) – Perfect or near perfect answers to a high proportion of the questions answered. There should be a thorough understanding and appreciation of the material. 75–84% (C) – A very good knowledge of much of the important material, possibly excellent in places, but with a limited account of some significant topics.

			65–74% (D) – There should be a good grasp of several important topics, but with only a limited understanding or ability in places. There may be significant omissions. 60–64% (E) – Students will show some relevant knowledge of some of the issues involved, but with a good grasp of only a minority of the material. Some topics may be answered well, but others will be either omitted or incorrect. 35–59% (F) – There should be substantial deficiencies, or no answers, across large parts of the topics set, but with a little relevant and correct material in places 1–34% (FX) – Very little or nothing that is correct and relevant.
Learning in laboratories	30	3,4	90% – 100% An outstanding piece of work, superbly organised and presented, excellent achievement of the objectives, evidence of original thought. 85-89% (B) – Students will show a thorough understanding and appreciation of the material, producing work without significant error or omission. Objectives achieved well. Excellent organisation and presentation. 75-84% (C) -. Students will show a thorough understanding and appreciation of the material, producing work without significant error or omission. When performing laboratory work student completely provide results and make the right conclusions, but admits inaccuracies or errors. 65-74 (D) – The student can solve simple problems and has the ability to perform basic operations and basic transformation and some algorithmic, but is not able to independently formulate task and determine the solution. When performing laboratory work the student execute it with errors. He draws conclusions, but not sufficient to understand the purpose of work. 60-64% (E) – The student can solve simple problems by using teacher support to perform basic operations and basic transformation, but not able to formulate the problem by verbal description to determine the solution. 35-59% (F) – When performing practical (laboratory) work the student knows how to use computers, but is unable to complete the task. The work may contain some correct and relevant material, but most issues are neglected or are covered incorrectly. 1-34% (FX) – The student does not perform the tasks. Very little or nothing that is correct and relevant and no real appreciation of the laboratory work requirements.
Module Evaluation Quest	60	4	The score corresponds to the percentage of correct answers to the test questions

4. TEACHING PROGRAMME OF THE COURSE ITM4 “IOT FOR HEALTHCARE SYSTEMS”

4.1. DESCRIPTION OF THE COURSE

TITLE OF THE COURSE	Code
IoT for Healthcare Systems	**ITM4**

Teacher(s)	Department
Coordinating: Prof., DrS. V.S. Kharchenko **Others:** Modules ITM4.1, ITM4.2: Prof., DrS. V.S. Kharchenko, Dr. D.D. Uzun, A.A. Strielkina. Module ITM4.3: Prof., DrS. I.S. Skarga-Bandurova, Dr. T.O. Biloborodova, A.Y. Velykzhanin. Module ITM4.4: Prof., DrS. I.S. Skarga-Bandurova, Dr. T.O. Biloborodova, O.V. Berezhnyi	Computer Systems, Networks and Cybersecurity (KhAI) Computer science and Engineering (EUNU)

Study cycle	Level of the course	Type of the course
Postgraduate – for industry experts	A	Full-time tuition

Form of delivery	Duration	Language(s)
Full-time tuition	One semester	English

Prerequisites	
Prerequisites: Digital electronics, Microcontrollers, Embedded systems, Cybersecurity, System analysis, Theory of reliability, Foundations of Modeling; Programming, Telecommunications Foundations, Probability Theory and Foundations of Mathematical Statistics, Intelligent Systems	**Co-requisites (if necessary):**

Credits of the course	Total student workload	Contact hours	Individual work hours
4	120	56	64

4.2. COMPETENCES AND LEARNING OUTCOMES

Aim of the course: competences foreseen by the study programme
The aim of the module is to give a PhD students a deep knowledge of principles and aspects of the IoT-based technologies in healthcare and medical infrastructures: teach to analyze existing and promising technologies to model, develop, investigate, deploy and support healthcare IoT infrastructures; teach to analyze existing and promising technologies of cybersecurity and privacy providing of the healthcare IoT infrastructures; teach to developing and testing smart biomedical devices, perform real-time data analyzing; teach to developing and testing smartphone applications to vital signs monitoring, perform real-time data processing and analyzing

<table>
<tr><th>General Competences</th><th colspan="2">Professional Competences</th></tr>
<tr><td>• The ability to identify the scientific nature of problems in the professional sphere, to find adequate ways to solve them.
• The ability to independently learn the basics of new research methods, changes in the scientific, research and production profile of their activities.
• The ability to analyze, verify, assess the completeness of information in the course of professional activities, if necessary, to supplement and synthesize missing information and work in conditions of uncertainty.
• The ability to manage projects, organize teamwork, take the initiative to improve activities.
The ability to assess and ensure the quality of work performed.</td><td colspan="2">• The ability to identify, analyze and solve problems in the professional sphere.
• Ability to participate in project activities; ability to adapt and act in a new situation.
• The ability to analyze and make reasonable choices of technologies, methods and tools for developing energy efficient solutions for IoT and embedded systems.
• The ability to independently analyze and make reasonable choice of structures of onboard complexes.
• The ability to analyze and reasonably choose the technical means of developing software and hardware systems and systems for IoT solutions.
• The ability to understand and analyze the development of distributed service-oriented systems, the ability to correctly select and use appropriate architectures, technologies and protocols in the performance of professional tasks in the design, development, implementation and application of service-oriented systems.
• The ability to use scientific and practical methods of big data processing and the ability to use existing technologies and systems in big data processing.</td></tr>
<tr><th>Learning outcomes of course</th><th>Assessment methods</th><th>Innovative teaching/learning methods</th></tr>
<tr><td>At the end of course, the successful student will be able to:
1. Explain and discuss basic healthcare technologies based on the IoT, strategies for integrating IoT innovation into healthcare technology.</td><td>Course Evaluation Questionnaire</td><td rowspan="11">• Interactive lectures: lecture-conversation; problem-oriented lecture.
• Learning in laboratories: Just-in-Time teaching; method of analysis and diagnosis of the situation; project method.
• Cooperative learning: pair learning; work in small groups; joint project;
• Collective group learning: master classes.
• Situational modeling of phenomena: simulations or simulation games.
• Problem solving method.
• Elaboration of discussion issues: method of determining the discussion position; changing the position and comparing alternative positions; discussion.</td></tr>
<tr><td>2. Enumerate and describe main requirements of healthcare IoT standards.</td><td>Course Evaluation Questionnaire</td></tr>
<tr><td>3. Describe and develop the healthcare IoT infrastructure architecture.</td><td>Course Evaluation Questionnaire</td></tr>
<tr><td>4. Explain integrating of simulation models into healthcare IoT infrastructures deployment.</td><td>Course Evaluation Questionnaire</td></tr>
<tr><td>5. Explain a providing communication link between the network nodes, the Internet and other medical equipment.</td><td>Course Evaluation Questionnaire</td></tr>
<tr><td>6. Explain integrating of context-aware mechanisms for ease exploitation of the core networks' functionality.</td><td>Course Evaluation Questionnaire</td></tr>
<tr><td>8. Compare and contrast of vital signs data acquisition approaches.</td><td>Course Evaluation Questionnaire</td></tr>
<tr><td>9. Describe concepts, use the principles of IoT-based cloud storage.</td><td>Course Evaluation Questionnaire</td></tr>
<tr><td>10. Explain a providing communication link between the smartphone application and healthcare cloud storage</td><td>Course Evaluation Questionnaire</td></tr>
<tr><td>11. Explain integrating of context-aware mechanisms for ease exploitation of the cloud storage functionality.</td><td>Course Evaluation Questionnaire</td></tr>
</table>

4.3. HOURS DISTRIBUTION

Themes	Contact work hours							Time and tasks for individual work	
	Lectures	Consultations	Seminars	Practiacl work (training)	Laboratory work	Placements	**Total contact work**	**Individual work**	**Tasks**
1. Technologies of IoT infrastructure for healthcare systems realization 1.1. Standards and requirements in IoT for health systems 1.2. Existed and prospected techniques in IoT for health systems realization **Seminar:** Internet of healthcare Things: trends, problems and solutions	2		4				**6**	**6**	1.3. Analysis of machine learning driven healthcare Internet of Things
2. Developing and modeling infrastructure of IoT for healthcare systems 2.1. Basic elements of the architecture of healthcare IoT infrastructure 2.2. Model range for healthcare IoT systems **Training:** Functional behavior of networked healthcare device modeling	4			3			**7**	**6**	2.3. Analysis of software tools on healthcare IoT infrastructure modeling
3 Standards and requirements for security and privacy of healthcare IoT infrastructure 3.1. Standards and requirements in IoT for health systems 3.2. Resources for managing healthcare security **Seminar:** Analysis of normative profile-generated base for security and privacy of healthcare systems	2		4				**6**	**7**	3.3. Analysis of national standards for privacy of healthcare Internet of Things
4. Security and privacy gaps according to special features of IoT infrastructure for health systems 4.1. Possible vulnerabilities and threats analysis 4.2. Possibilities of modeling of cyber security processes of healthcare IoT systems **Training:** Modeling of cyber security processes of IoT healthcare systems	4			3			**7**	**6**	4.3. Analysis of software tools for cybersecurity assessment of healthcare IoT
5. Biomedical sensors and data acquisition techniques 5.1 Analyzing IoT sensor data in medicine 5.2 Study of health data acquisition techniques in IoT	2			3			**5**	**6**	5.3 Study configuration and connection of hardware to ECG devices setting-up

environments **Training:** Design, architecture and hardware for remote monitoring systems									
6. Biomedical signal processing models for real time health data analytics 6.1 Real time tagging, aggregation, and temporal correlation **Training:** Exploring the network stack in health IoT-based systems	2			3			**5**	**6**	6.2 Research on using coupled oscillators approach in time series analysis
7. Developing and testing smart wearable devices 7.1 Embedded and wearable IoT-based systems for biomedical applications 7.2 Wearable IoT device configuration 7.3 Data analysis and prediction techniques 7.4 Cases **Training:** Analysis data fusion technique for real-time biomedical monitoring	2			3			**5**	**6**	7.5 Embedded gateway configuration 12.6 Embedded context prediction
8. IoT-based systems for remote health monitoring 8.1 A Personal Mobile Sensing System for Motor Symptoms Assessment of Parkinson's Disease 8.2 Medical Aspect 8.3 Sensors and devices for Parkinson's disease assessment **Training:** Exploring the stage of smartphone application development for human vital signs monitoring	2			3			**5**	**8**	8.3 Study smartphone application development
9. Healthcare IoT-based systems architecture 9.1 System Architecture 9.2 Basic system components utilized and launched on the smartphone 9.3 A mobile application of the personal health monitoring system **Training:** Discovering sensor data transmission using smartphone IoT based application	2			3			**5**	**6**	9.4 Research on principles and aspects of smartphone embedded sensor
10. Healthcare IoT-based systems implementation, Results and Classification 10.1 Implementation and Results 10.2 Classification of test data **Training:** Real-time accelerometer data processing and analysis technique	2			3			**5**	**7**	10.3 Research on data obtaining technique by smartphone embedded sensor
Total	**24**		**8**	**24**			**56**	**64**	

4.4. COURSE ASSESSMENT STRATEGY

Assessment strategy	Weight in %	Deadlines	Assessment criteria
Lecture activity, including fulfilling special self-tasks	10	7,14	85% – 100% Outstanding work, showing a full grasp of all the questions answered. 70% – 84% Perfect or near perfect answers to a high proportion of the questions answered. There should be a thorough understanding and appreciation of the material. 60% – 69% A very good knowledge of much of the important material, possibly excellent in places, but with a limited account of some significant topics. 50% – 59% There should be a good grasp of several important topics, but with only a limited understanding or ability in places. There may be significant omissions. 45% – 49% Students will show some relevant knowledge of some of the issues involved, but with a good grasp of only a minority of the material. Some topics may be answered well, but others will be either omitted or incorrect. 40% – 44% There should be some work of some merit. There may be a few topics answered partly or there may be scattered or perfunctory knowledge. 20% – 39% There should be substantial deficiencies, or no answers, across large parts of the topics set, but with a little relevant and correct material in places. 0% – 19% Very little or nothing that is correct and relevant.
Learning in laboratories	30	7,14	85% – 100% An outstanding piece of work, superbly organized and presented, excellent achievement of the objectives, evidence of original thought. 70% – 84% Students will show a thorough understanding and appreciation of the material, producing work without significant error or omission. 60% – 69% Students will show a clear understanding of the issues involved and the work should be well written and well organized. Good work towards the objectives. The exercise should show evidence that the student has thought about the topic and has not simply reproduced standard solutions or arguments. 50% – 59% The work should show evidence that the student has a reasonable understanding of the basic material. There may be some signs of weakness, but overall the grasp of the topic should be sound. The presentation and organization should be reasonably clear, and the objectives should at least be partially achieved. 45% – 49% Students will show some appreciation of the issues involved. The exercise will indicate a basic understanding of the topic, but will not have gone beyond this, and there may well be signs of confusion about more complex material. There should be fair work towards the laboratory work objectives. 40% – 44% There should be some work towards the laboratory work objectives, but significant issues are likely to be neglected. 20% – 39% The work may contain some correct and relevant material, but most issues are neglected or are covered incorrectly. There should be some signs of appreciation of the laboratory work requirements. 0% – 19% Very little or nothing that is correct and relevant and no real appreciation of the laboratory work requirements.
Course Evaluation Quest	60	8,16	The score corresponds to the percentage of correct answers to the test questions

5. TEACHING PROGRAMME OF THE COURSE ITM5 “IOT FOR INDUSTRIAL SYSTEMS”

5.1. DESCRIPTION OF THE COURSE

TITLE OF THE COURSE	Code
IoT for Industrial Systems	**ITM6**

Teacher(s)	Department
Coordinating: Prof., DrS. V.S. Kharchenko	Computer Systems Networks and Cyber Security (KhAI)
Others: Modules	Software Tools (ZNTU)
ITMM5.1: Assoc. Prof., Dr. S.V. Morshchavka, Assoc. Prof., Dr. R.K. Kudermetov	Computer Engineering (EUNU)
ITMM5.2: Prof., DrS. I.S. Skarga-Bandurova, Assoc. Prof., Dr. T.O. Biloborodova, Ph.D. Student A.Y. Velykzhanin, Ph.D. Student Y.O. Krytska	
ITMM5.3: Prof., DrS. V.S. Kharchenko, Assoc. Prof., Dr. H.V. Fesenko	Computer Systems Networks and Cyber Security (KhAI)
ITMM5.4: Assoc. Prof., Dr. D. D. Uzun, PhD student O.O. Solovyov, PhD student Al-Khafaji Ahmed Waleed	

Study cycle	Level of the course	Type of the course
Trainings	A	Bounden

Form of delivery	Duration	Language(s)
Full-time tuition	One semester	English

Prerequisites	
Prerequisites: Software Control Systems in Industry; Internet-of-Drone-based systems; Information-Networking Technologies in Industry; Foundations of Modeling; Computer Systems and System Analysis; Theory of Automatic Control; Programming, Telecommunications Foundations; Probability Theory and Foundations of Mathematical Statistics; Foundation of Modeling; Intelligent Systems; Computer Systems and System Analysis.	**Co-requisites (if necessary):** IoT for Smart Energy Grid; IoT for Smart Building and City; IoT for Intelligent Transport Systems; IoT for Health Systems; IoT for Industrial Systems.

Credits of the course	Total student workload	Contact hours	Individual work hours
4	120	56	64

5.2. COMPETENCES AND LEARNING OUTCOMES

<table>
<tr><th colspan="3">Aim of the course: competences foreseen by the study programme</th></tr>
<tr><td colspan="3">The aim of the course is to create a knowledge base for multidisciplinary research in the field of the building and further use of IoT-based systems for, to give students practical skills in designing and implementation of modern systems based on IoT as well modernization of existing ecology, safety and security monitoring systems using IoT technology. The IoT technologies considered to implement the monitoring and control tasks of industrial facilities, as well as the issues of industrial networks security are considered. The study expands theoretical background of IoT-based ecology, safety and security monitoring systems, also considers intelligent approaches to efficiency improving of IoT-based ecology, safety and security monitoring systems. In addition, the local aim of course is to create a knowledge base for multidisciplinary research on intelligence technologies of IoT for ecology, safety and security monitoring systems and to provide a prerequisites for practical use of intelligence methods for application of IoT technologies in engineering. The study also expands the current research on IoT for ecology, safety and security monitoring by combining intelligence technologies and theory of ecology, safety and security monitoring systems in the context of the study of IoT technologies in engineering.</td></tr>
<tr><th>General Competences</th><th colspan="2">Professional Competences</th></tr>
<tr><td>• Skills of using information and communication technologies.
• The ability to generate new ideas (creativity), identify, pose and solve problems, find optimal ways to solve them.
• The ability to conduct professional research in an international environment.
The ability to assess and ensure the quality of work performed.</td><td colspan="2">• The ability to independently analyze and make reasonable choice of structures of onboard complexes.
• The ability to use scientific and practical methods of research, use and improvement of computer systems of artificial intelligence and mastering the skills of developing neural networks.
• The ability to apply professional knowledge and practical skills to solve typical problems of setting up and maintaining communication of mobile systems.
• The ability to analyze and make reasonable choice of technologies and tools for developing critical software software and hardware systems for IoT solutions.</td></tr>
<tr><th>Learning outcomes of course</th><th>Assessment methods</th><th>Innovative teaching/learning methods</th></tr>
<tr><td>At the end of course, the successful student will be able to:</td><td></td><td rowspan="6">• Interactive lectures: problem-oriented lecture.
• Learning in laboratories: Just-in-Time teaching; project method.
• Cooperative learning: synthesis of ideas.
• Collective group learning: brainstorming; master classes.
• Elaboration of discussion issues: method of determining the discussion position; changing the position and comparing alternative positions; discussion.</td></tr>
<tr><td>1. Learn the physical principles and basics of work of sensors for monitoring artificial ecosystems</td><td>Course Evaluation Questionnaire</td></tr>
<tr><td>2. Learn the basic concepts and architecture of IoT water monitoring systems (WMS)</td><td>Course Evaluation Questionnaire</td></tr>
<tr><td>3. Create own IoT WMS for industrial and (or) municipal water data</td><td>Course Evaluation Questionnaire</td></tr>
<tr><td>4. Learn the basic concepts and architecture of Multi-version drone-based systems for monitoring of NPP severe accidents</td><td>Course Evaluation Questionnaire</td></tr>
<tr><td>5. Learn the development of summary project for IOT based physical security systems of buildings and campuses</td><td>Course Evaluation Questionnaire</td></tr>
</table>

5.3. HOURS DISTRIBUTION

Themes	Contact work hours							Time and tasks for individual work	
	Lectures	Consultations	Seminars	Practiacl work (training)	Laboratory work	Placements	**Total contact work**	**Individual work**	**Tasks**
1. IOT systems for controlling small artificial ecological systems 1.1. Sensors for monitoring artificial ecosystems, the basics of work and physical principles 1.2. Features of the collection and analysis of information about the state of ecosystems by using IoT devices 1.3. Examples of control systems for small artificial ecosystems	6		2	6			**14**	**16**	1.4. Estimating parameters of fields and other ecological systems via UAV 1.5. IoT systems for agriculture
2. IoT technologies for monitoring and control tasks implementation in industry 2.1. IoT Water Monitoring System (WMS) 2.2. Parameters and data management in IoT WQMS 2.3. IoT WQMS evolution: from collecting data and data visualization to real-time predictive analytics	6			8			**14**	**16**	2.4. Collation of the available features and components of IoT WMS to implement water monitoring, selection of specified components 2.5. Determination of the completeness and objectivity of water quality characteristics that were investigated (critical assessment algorithms forecasting)
3. IoT-based systems for monitoring of severe accidents 3.1. General information on systems for monitoring of critical industry objects/NPP accidents 3.2. Multi-version drone-based systems for monitoring of NPP severe accidents 3.3. Reliability of IoD-based systems for monitoring of NPP severe accidents	6			8			**14**	**16**	3.4. Survivability of drone-based systems for monitoring of NPP severe accidents 3.5. Using the travelling safety problem with drones approaches for NPP monitoring mission planning
4. IoT based physical security systems of buildings and campuses 4.1. Physical security systems assessment and development tasks 4.2. IoT based physical security systems development 4.3. Models of physical security systems risk analysis	6			8			**14**	**16**	4.4. Ehe main features of the PSME(C)A technique 4.5. PSMECA based assessment of physical security systems
Total	**24**		**2**	**30**			**56**	**64**	

5.4. COURSE ASSESSMENT STRATEGY

Assessment strategy	Weight in %	Deadlines	Assessment criteria
Lecture activity, including fulfilling special self-tasks	10	7,14	85% – 100% Outstanding work, showing a full grasp of all the questions answered. 70% – 84% Perfect or near perfect answers to a high proportion of the questions answered. There should be a thorough understanding and appreciation of the material. 60% – 69% A very good knowledge of much of the important material, possibly excellent in places, but with a limited account of some significant topics. 50% – 59% There should be a good grasp of several important topics, but with only a limited understanding or ability in places. There may be significant omissions. 45% – 49% Students will show some relevant knowledge of some of the issues involved, but with a good grasp of only a minority of the material. Some topics may be answered well, but others will be either omitted or incorrect. 40% – 44% There should be some work of some merit. There may be a few topics answered partly or there may be scattered or perfunctory knowledge. 20% – 39% There should be substantial deficiencies, or no answers, across large parts of the topics set, but with a little relevant and correct material in places. 0% – 19% Very little or nothing that is correct and relevant.
Learning in laboratories	30	7,14	85% – 100% An outstanding piece of work, superbly organized and presented, excellent achievement of the objectives, evidence of original thought. 70% – 84% Students will show a thorough understanding and appreciation of the material, producing work without significant error or omission. Objectives achieved well. Excellent organization and presentation. 60% – 69% Students will show a clear understanding of the issues involved and the work should be well written and well organized. Good work towards the objectives. The exercise should show evidence that the student has thought about the topic and has not simply reproduced standard solutions or arguments. 50% – 59% The work should show evidence that the student has a reasonable understanding of the basic material. There may be some signs of weakness, but overall the grasp of the topic should be sound. The presentation and organization should be reasonably clear, and the objectives should at least be partially achieved. 45% – 49% Students will show some appreciation of the issues involved. The exercise will indicate a basic understanding of the topic, but will not have gone beyond this, and there may well be signs of confusion about more complex material. There should be fair work towards the laboratory work objectives. 40% – 44% There should be some work towards the laboratory work objectives. 20% – 39% The work may contain some correct and relevant material, but most issues are neglected or are covered incorrectly. There should be some signs of appreciation of the laboratory work requirements. 0% – 19% Very little or nothing that is correct and relevant and no real appreciation of the laboratory work requirements.
Course Evaluation Quest	60	8,16	The score corresponds to the percentage of correct answers to the test questions

6. TEACHING PROGRAMME OF THE COURSE ITM6 “IOT FOR INDUSTRIAL SYSTEMS”

6.1. DESCRIPTION OF THE COURSE

TITLE OF THE COURSE	Code
IoT for Industrial Systems	**ITM6**

Teacher(s)	Department
Coordinating: Prof., DrS. Yu.P. Kondratenko **Others:** Modules ITMM6.1, ITMM6.2: Assoc. Prof., Dr. G.V. Kondratenko, Assoc. Prof., Dr. O.V. Kozlov, Ph.D. Student A.M. Topalov, Ph.D. Student O.S. Gerasin. Module ITMM6.3: Prof., DrS. S.O. Subbotin, Assoc. Prof., Dr. A.O. Oliinyk, Assoc. Prof., Dr. D.V. Pavlenko, PhD Student S.D. Leoshchenko. Module ITMM6.4: Assoc. Prof., Dr. R.M. Babakov, Prof., DrS. V.S. Kharchenko, Dr. O.O. Illiashenko	Intelligent Information Systems (PMBSNU) Software Tools (ZNTU) Computer Systems and Networks (KhAI)

Study cycle	Level of the course	Type of the course
Trainings	A	Bounden

Form of delivery	Duration	Language(s)
Full-time tuition	One semester	English

Prerequisites	
Prerequisites: Software Control Systems in Industry; Industrial Computer Networks; Information-Networking Technologies in Industry; Foundations of Modeling; Computer Systems and System Analysis; Theory of Automatic Control; Programming, Telecommunications Foundations; Probability Theory and Foundations of Mathematical Statistics; Foundation of Modeling; Intelligent Systems; Computer Systems and System Analysis.	**Co-requisites (if necessary):** IoT for Smart Energy Grid; IoT for Smart Building and City; IoT for Intelligent Transport Systems; IoT for Health Systems; IoT for Industrial Systems.

Credits of the course	Total student workload	Contact hours	Individual work hours
4	120	56	64

6.2. COMPETENCES AND LEARNING OUTCOMES

Aim of the course: competences foreseen by the study programme
The aim of the course is to create a knowledge base for multidisciplinary research in the field of the building and further use of industrial branched IoT systems, to give students practical skills in designing and implementation of modern industrial systems based on IoT as well modernization of existing industrial control systems using IoT technology. The IoT technologies considered to implement the monitoring and control tasks of industrial facilities, as well as the issues of industrial networks security are considered. The study expands theoretical background of IoT-based control and monitoring systems for models of different industry systems, also considers intelligent approaches to efficiency improving of IoT-based industrial systems. In addition, the local aim of course is to create a knowledge base for multidisciplinary research on intelligence technologies of IoT for industrial systems and to provide a prerequisites for practical use of intelligence methods for application of IoT technologies in engineering. The study also expands the current research on IoT for industrial systems by combining intelligence technologies and theory of industrial systems in the context of the study of IoT technologies in engineering.

<table>
<tr><th>General Competences</th><th colspan="2">Professional Competences</th></tr>
<tr><td>• The ability to plan and manage time.
• The ability to independently learn the basics of new research methods, changes in the scientific, research and production profile of their activities.
• The ability to investigate problems using systems analysis, synthesis, computer modeling and optimization methods.
• The ability to generate new ideas (creativity), identify, pose and solve problems, find optimal ways to solve them.
• The ability to manage projects, organize teamwork, take the initiative to improve activities.
The ability to assess and ensure the quality of work performed.</td><td colspan="2">• Ability to participate in project activities; ability to adapt and act in a new situation.
• The ability to apply professional knowledge and practical skills to solve typical problems in the specialty.
• The ability to analyze and make reasonable choices of technologies, methods and tools for developing energy efficient solutions for IoT and embedded systems.
• The ability to apply professional skills to implement practical tasks in accordance with the acquired qualifications.
• The ability to use scientific and practical methods of research, use and improvement of computer systems of artificial intelligence and mastering the skills of developing neural networks.
• The ability to independently analyze and make reasonable choice of technologies, methods and tools for assessing and ensuring security at the design stage of critical IT infrastructures.
• The ability to analyze and make reasonable choice of technologies and tools for developing critical software software and hardware systems for IoT solutions.</td></tr>
<tr><th>Learning outcomes of course</th><th></th><th>Innovative teaching/learning methods</th></tr>
<tr><td>At the end of course, the successful student will be able to:
1. Learn the basic concepts and definitions of IoT-based industrial systems</td><td>Assessment methods</td><td rowspan="12">• Interactive lectures: lecture-discussion; problem-oriented lecture.
• Learning in laboratories: analysis of errors & incidents; project method.
• Cooperative learning: pair learning; synthesis of ideas; joint project;
• Collective group learning: decision tree;
• master classes.
• Situational modeling of phenomena: simulations or simulation games; PRES-formula (from English Position - Reason - Explanation or Example - Summary).
• Elaboration of discussion issues: method of determining the discussion position; changing the position and comparing alternative positions; discussion, debate.
• Competitive learning: division of students into groups according to educational tasks; educational activities of students in groups; presentation of collective learning tasks (public speech).</td></tr>
<tr><td>2. Apply software and hardware and modern high-level language for the development and maintenance of wired and wireless networks of the IoT</td><td>Course Evaluation Questionnaire</td></tr>
<tr><td>3. Develop information protection in network with technology VPN, setting Firewall, and data encryption</td><td>Course Evaluation Questionnaire</td></tr>
<tr><td>4. Select and apply software and hardware means, as well as programming languages for the development and maintenance of modern industrial systems based on IoT</td><td>Testing based on alternative method of assessment</td></tr>
<tr><td>5. Estimate main quality indicators of IoT-based control systems of floating docks and industrial robots</td><td>Course Evaluation Questionnaire,
Testing based on alternative method of assessment</td></tr>
<tr><td>6. Modernize and analyze different industrial systems based on IoT</td><td>Course Evaluation Questionnaire,
Testing based on alternative method of assessment</td></tr>
<tr><td>8. Prepare and analyse data samples for modelling of complex objects and processes based on IoT technologies</td><td>Course Evaluation Questionnaire</td></tr>
<tr><td>9. Perform pattern recognition for developing of intelligent information systems in engineering</td><td>Course Evaluation Questionnaire</td></tr>
<tr><td>10. Analysis of development and implementation of industrial IoT and other modern technologies in Industry 4.0 and Industry 5.0</td><td>Course Evaluation Questionnaire</td></tr>
<tr><td>11. Algebraic synthesis of microprogrammed FSM with DT.</td><td>Course Evaluation Questionnaire</td></tr>
</table>

6.3. HOURS DISTRIBUTION

Themes	Contact work hours							Time and tasks for individual work	
	Lectures	Consultations	Seminars	Practiacl work (training)	Laboratory work	Placements	**Total contact work**	**Individual work**	**Tasks**
1. General approach to structures and models building of IoT-based industrial systems 1.1. The current state of development and implementation of the IoT 1.2. The basic principles and levels of the IoT 1.3. Branched structures and models of industrial systems based on the IoT	2		2				**4**	**5**	1.4. Internet-interaction solutions and SCADA-systems. The strategy of clients applications 1.5. Directions of industrial applications of the IoT
2. IoT technologies for monitoring and control tasks implementation in industry 2.1. Wired and wireless technologies for IoT networks building 2.2. Software components and protocols for IoT wired networks 2.3. Software components and protocols for IoT wireless networks	2			4			**6**	**4**	2.4. IoT Cloud Services 2.5. Wireless data transmission technology Z-Wave
3. Security problems in industrial IoT-based systems 3.1. Main types of attacks in the Internet 3.2. Recognized standards for data encryption in industrial networks based on IoT 3.3. Security policy of industrial systems based on IoT	2			2			**4**	**7**	3.4. User authentication in the IoT networks 3.5. Packet Solstice Fire Wall-1 and its settings
4. Design and implementation of IoT-based control and monitoring systems for floating docks 4.1. Introduction in control and monitoring systems for floating docks 4.2. IoT-based control and monitoring system of a floating dock for low-tonnage vessels 4.3. Hardware and software means for implementation of IoT-based control and monitoring systems for floating docks	2			4			**6**	**6**	4.4. Main quality indicators and ways of IoT-based control systems comparison 4.5. Peculiarities of big data analysis during discrete measurements
5. Design and implementation of IoT-based control and monitoring systems in robotics 5.1. Main principles and tasks of robots control and monitoring systems development 5.2. IoT-based control and monitoring system of mobile robots	2		2				**4**	**5**	5.4. IoT-based control system of crawler type mobile robot development with obstacles monitoring 5.5. Smart sensors and materials

able to move on inclined and vertical surfaces 5.3. Hardware and software means for implementation of IoT-based control and monitoring systems for industrial and specialized robots									application in robotics
6. Approaches to modernization of complex objects in different industrial systems based on IoT 6.1. Modernization conceptions in different industrial systems 6.2. IoT-based modernization of computer control and monitoring system of specialized pyrolysis complex 6.3. The IoT-based modernization of slippage registration system of industrial robot's adaptive gripper	2			2			**4**	**5**	6.4. Recursive Least Square (RLS) method for adaptive filtration in IoT-based systems 6.5. Quality and efficiency estimation of modernized system implementa-tion
7. Application of IoT technologies in the processes of high-tech enterprise management 7.1. Methodologies of enterprise management 7.2. Smart logistics 7.3. Material resource management	2						**2**	**5**	7.4. Service maintenance management 7.5. Enterprise representation
8. Intelligent information technologies and mathematical support of IoT in mechanical engineering 8.1. Information technologies for designing in mechanical engineering 8.2. Statistical analysis of factors affecting the endurance of product components 8.3. Intelligent control in the Internet of Things with the example of the hardening process of gas turbine air-engine details	2			4			**6**	**6**	8.4. Optimization of production modes by the method of linear programming. 8.5. Optimization of test modes using smart technologies.
9. Application of IoT technologies for diagnostics, monitoring and prediction of complex technical system state 9.1. Expert evaluation of state of products based on fuzzy sets and IoT methods 9.2. Selection of geometric parameters and synthesis of the model of the compressor frequency response 9.3. Methods and IoT technologies for the synthesis of recognition models 9.4. Intelligent data processing in the IoT with the example of a gas turbine air-engine testing	2			4			**6**	**5**	9.5. Methods and IoT technologies of diagnostic models synthesis 9.6. Optimization tasks in production products life cycle
10. Hardware optimization in IoT devices 10.1 The problem of hardware expenses optimization in IoT devices 10.2. The IoT device control unit in the form of finite state machine with canonical structure 10.3. The IoT device control unit in the form of finite state	2			2			**4**	**4**	10.4. Generalizations for an FSM with counter 10.5. Datapath of transitions

machine with counter									
11. Synthesis of IoT device control unit in the form of finite state machine with datapath of transitions 11.1. Stages of structural synthesis of FSM with DT 11.2. Algebraic synthesis of FSM with DT 11.3. Algebraic synthesis by an exhaustive search	4			2			**6**	**5**	11.4. Evaluation of the effectiveness of FSM with DT 11.5. Integration of FSM with DT into IoT device
12. Industrial Internet of Things and trends of technologies in industry 4.0/5.0 12.1. Analysis of concepts, principles and technologies applied in Industry 4.0/5.0 enterprises 12.2. Digital twins and IoT for Industry 4.0 12.3. Cyber security challenges for IoT application in enterprises Industry 4.0			4				**4**	**7**	12.4. Augmented and virtual reality for Industry 4.0 12.5. Predictive analytics and IoT for Industry 4.0
Total	**24**		**8**	**24**			**56**	**64**	

6.4. COURSE ASSESSMENT STRATEGY

Assessment strategy	Weight in %	Deadlines	Assessment criteria
Lecture activity, including fulfilling special self-tasks	10	7,14	85% – 100% Outstanding work, showing a full grasp of all the questions answered. 70% – 84% Perfect or near perfect answers to a high proportion of the questions answered. There should be a thorough understanding and appreciation of the material. 60% – 69% A very good knowledge of much of the important material, possibly excellent in places, but with a limited account of some significant topics. 50% – 59% There should be a good grasp of several important topics, but with only a limited understanding or ability in places. There may be significant omissions. 45% – 49% Students will show some relevant knowledge of some of the issues involved, but with a good grasp of only a minority of the material. Some topics may be answered well, but others will be either omitted or incorrect. 40% – 44% There should be some work of some merit. There may be a few topics answered partly or there may be scattered or perfunctory knowledge across a larger range. 20% – 39% There should be substantial deficiencies, or no answers, across large parts of the topics set, but with a little relevant and correct material in places. 0% – 19% Very little or nothing that is correct and relevant.
Learning in laboratories	30	7,14	85% – 100% An outstanding piece of work, superbly organized and presented, excellent achievement of the objectives, evidence of original thought. 70% – 84% Students will show a thorough understanding and appreciation of the material, producing work without significant error or omission. Objectives achieved well. Excellent organization and presentation. 60% – 69% Students will show a clear understanding of the issues involved and the work should be well written and well organized. Good work towards the objectives. The exercise should show evidence that the student has thought about the topic and has

			not simply reproduced standard solutions or arguments. 50% – 59% The work should show evidence that the student has a reasonable understanding of the basic material. There may be some signs of weakness, but overall the grasp of the topic should be sound. The presentation and organization should be reasonably clear, and the objectives should at least be partially achieved. 45% – 49% Students will show some appreciation of the issues involved. The exercise will indicate a basic understanding of the topic, but will not have gone beyond this, and there may well be signs of confusion about more complex material. There should be fair work towards the laboratory work objectives. 40% – 44% There should be some work towards the laboratory work objectives, but significant issues are likely to be neglected, and there will be little or no appreciation of the complexity of the problem. 20% – 39% The work may contain some correct and relevant material, but most issues are neglected or are covered incorrectly. There should be some signs of appreciation of the laboratory work requirements. 0% – 19% Very little or nothing that is correct and relevant and no real appreciation of the laboratory work requirements.
Course Evaluation Quest	60	8,16	The score corresponds to the percentage of correct answers to the test questions

7. TEACHING PROGRAMME OF THE MASTER COURSE MC1 "FUNDAMENTALS OF IOT AND IOE (INTERNET OF EVERYTHING)"

7.1. DESCRIPTION OF THE COURSE

TITLE OF THE MODULE	Code
Fundamentals of Internet of Things	**MC1**

Teacher(s)	Department
Coordinating: Prof., DrS Kharchenko V.S. **Others:** Snr. Res., DrS Chemeris O.A., Assoc. Prof., Dr. Boyarchuk A.V., Golembovska O.O., Dr. Illiashenko O.O., Assoc. Prof., Dr. Kolisnyk M.O., Assoc. Prof., Dr. Morozova O.I., Assoc. Prof., Dr. Pevnev V.Y., Plietnov V.V., Senior Lecturer Tsuranov M.V.	Computer Systems, Networks and Cybersecurity Department of National Aerospace University "KhAI", Pukhov Institute for Modelling in Energy Engineering

Study cycle	Level of the module	Type of the module
MSc	A	Full-time tuition

Form of delivery	Duration	Langage(s)
Full-time tuition	One semester	English

Prerequisites			
Prerequisites: Fundamentals of Modelling, Fundamentals of Artificial Intelligence and Machine Learning, Basics of Programming; Theory of algorithms			**Co-requisites (if necessary):**
Credits of the module	**Total student workload**	**Contact hours**	**Individual work hours**
1	30	20	10

7.2. COMPETENCES AND LEARNING OUTCOMES

Aim of the module (course unit): competences foreseeen by the study programme	
The aim of study is giving to students the knowledges in concepts, domains and challenges of IoT applications, architectures and platforms for IoI systems, standards and metrics for IoT systems, communications and protocols of IoT systems.	
General Competences	**Professional Competences**
• The ability to independently learn the basics of new research methods, changes in the scientific, research and production profile of their activities. The ability to investigate problems using systems analysis, synthesis, computer modeling and optimization methods.	• The ability to apply professional knowledge and practical skills to solve typical problems in the specialty. • The ability to analyze and make reasonable choices of technologies, methods and tools for developing energy efficient solutions for IoT and embedded systems. • The ability to analyze and reasonably choose the technical means of developing software and hardware systems and systems for IoT solutions. • The ability to apply professional knowledge and practical skills to solve typical problems of setting up and maintaining communication of mobile systems.

Learning outcomes of module (course unit)	Assessment methods	Innovative teaching/learning methods
At the end of course, the successful student will be able to: 1. To differentiate the concepts, domains and challenges of IoT applications	Module Evaluation Questionnaire	• Interactive lectures: lecture-discussion. • Learning in laboratories: analysis of errors & incidents; project method. • Cooperative learning: synthesis of ideas; joint project. • Collective group learning: decision tree. • Situational modeling of phenomena: simulations or simulation games. • Elaboration of discussion issues: changing the position and comparing alternative positions; discussion, debate.
2. To use architectures and platforms for IoI systems	Module Evaluation Questionnaire	
3. To know standards and metrics for IoT systems	Module Evaluation Questionnaire	
4. To use communications and protocols of IoT systems	Module Evaluation Questionnaire	

7.3. HOURS DISTRIBUTION

Themes	Contact work hours							Time and tasks for individual work	
	Lectures	Consultations	Seminars	Practiacl work	Laboratory work	Placements	Total contact work	Individual work	Tasks
1. Concepts and challenges of IoT application in industry and human domains 1.1. Concepts of IoT application in industry and human domains. 1.2. Challenges of IoT application in industry and human domains. **Seminar:** Analysis of concepts and challenges of IoT application in industry and human domains	2		6						1.3. Preparation of a report (analytical review, state of the art) on analysis of methodology, concepts, human and industrial domains and challenges of IoT applications. 1.4. Preparation of a ppt presentation according with report results for short lecture/seminar for other students. 1.5. Presentation and defence of received results.
2. Project vision and specification for IoT application 2.1. Brain storming on generation of IoT/IoE application. 2.2. Development of project vision (VDP) for one of the generated IoE applications.	2			4				8	2.4. Preparation of vision and brief specification of developed project (VDP and SDP) on application of IoT/IoE for

2.3. Development of project specification for application of IoT and AR (augmented reality) for the art. Practical tasks: **Practical work:** Development of project vision and specification for IoT application									different domains and in combining with other modern technologies. 2.5. Preparation draft of business plan for developed project for start-up battle or/and hackathon; - preparation of a ppt presentation according with VDP and SDP results for stress-testing and assessment by lecturers, experts and other students. 2.6. Presentation and defence of received results.
3. IoT based logistics system for warehouse 3.1. Develop a warehouse security system in the absence of working personnel. 3.2. Regulate lighting in the warehouse using IoT technology. Practical tasks: **Practical work:** Development of project of IoT based logistics system for warehouse	2			2				4	3.3. Learn main stages of organizing the implementation of IoT technology in a warehouse management system. 3.4. Identify the specifications of sensors.
4. Platforms for IoI systems 4.1. Creating and uploading a controller configuration. 4.2. Creating an application in LAD. 4.3. Learn how to analyze and design devices using Arduino virtual microcontrollers, debugging tools. 4.4. Learn how to use ready-made virtual devices (projects) based on Arduino boards in a Proteus environment. Practical tasks: **Lab:** Configuring the controller and creating applications with simple logic operations in relay-logic language. **Lab:** Rapid development of IoT devices in the Proteus virtual simulation environment.	2				2			4	4.5. Learn how to perform configuration, simulate the developed scheme using user programs. 4.6. Explore the Proteus virtual environment. 4.7. Presentation and defence of received results.
5. Digital control system based on Arduino platform 5.1. Construction of the table by the management of movements. 5.2. Construction of timing diagrams for movement management. 5.3. Construction of the scheme of the algorithm of movement control. 5.4. Fixing IoT device development skills. Practical tasks: **Lab:** Development of digital control system based on Arduino platform **Lab:** Displaying symbolic information on the indicator	2				2			4	5.5. Assignment of lines for control outputs. 5.6. Presentation and defence of received results.

6. IoT application development 6.1. Develop and deploy asynchronous exchange programs using virtual devices and tools. 6.2. Learn how to debug programs and analyze pulse signals using virtual devices and tools. 6.3. Develop and deploy asynchronous exchange programs using virtual devices and tools. Practical tasks: **Lab:** IoT application development using counter timers **Lab:** Asynchronous exchange between IoT devices	2				2			4	6.4. Analyze the utilized volume of MC resources and to analyze the time diagrams of pulse signals. 6.5. Presentation and defence of received results.
7. Architectures for IoI systems 7.1. Principles of managing exchange for SPI. 7.2. Realize formation of step voltage by means of a digital potentiometer. 7.3. Investigate the implementation of ADC on the Arduino. 7.4. Investigate the basic characteristics and principle of operation of the analog temperature sensor. 7.5. Implement the directory for the WoT application and the framework of the application. Practical tasks: **Lab:** Development of IoT applications using SPI **Lab:** Analog IoT application interface **Lab:** Development of WoT applications based on the built-in platform					2			4	7.6. Implement the server and client side of the WoT application. 7.7. Presentation and defence of received results.
8. Standards, requirements and metrics for IoT systems 8.1. Overview of standards IEC, ITU, IEEE and others that can be used on the creation and maintenance of IoT systems for industry/human domains. 8.2. Analysis of standards requirements to develop a set of non-functional requirements. 8.3 Determination of metrics to assess required attributes of IoT system. **Seminar:** Choice of standards, requirements and metrics for IoT systems	3		3					9	8.4. Preparation of a report (analytical review, state of the art) on analysis of standards requirements to IoT systems, human and industrial domains and challenges of applications. 8.5. Preparation of a ppt presentation according with report results for short lecture/seminar for other students. 8.6. Presentation and defence of received results.
9. IoT reference models 9.1. Analysis of components and architectures of IoT. 9.2. Discussion of reference model concept for IoT. 9.3. Analysis of the IoT reference models for different domains; 9.4. Analysis of the IoT reference models for different countris; **Seminar:** Analysis of IoT reference models	3		3					9	9.5. Preparation of a report on analysis of IoT reference models. 9.6. Preparation of a ppt presentation according with report results for short lecture/seminar for other students.

									9.7. Presentation and defence of received results.
10. MQTT protocol for IoT 10.1. Study an example of application level protocols of IoT. 10.2. Study MQTT's power and traffic consumption metering methodology. Practical tasks: **Lab:** Researching the MQTT protocol for IoT	2				4			4	10.3. Acquire practical skills in working with application level protocols of IoT. 10.4. Gather information about free or partially limited MQTT brokers realized as internet service.
11. Message codings of IoT devices 11.1. Study an example of Network layer protocols of IoT. 11.2. Studying of opportunities of information transfer by IoT devices by means of the TCP/IP protocol. Practical tasks: **Lab:** Message codings of IoT devices by means of the IP protocol	2				4			4	11.3. Acquire practical skills in working with network level protocols of IoT. 11.4. Gather information about information coding principles of the TCP/IP protocol.
12. Algorithms of noise immunity coding in IoT devices 12.1. Study codes of Hamming for IoT. 12.2. Study method of checksums for IoT. Practical tasks: **Lab:** Research of algorithms of noise immunity coding in IoT devices	2				4			4	12.1. Acquire practical skills in working with CRC check sum. 12.2. Gather information about ensuring integrity for data transfer in IoT.
Total	24		12	6	20			58	

7.4. COURSE ASSESSMENT STRATEGY

Assessment strategy	Weight in %	Deadlines	Assessment criteria
Lecture activity, including fulfilling special hometask	10	2,4	90–100% (A) – Outstanding work, showing a full grasp of all the questions answered. 85–89% (B) – Perfect or near perfect answers to a high proportion of the questions answered. There should be a thorough understanding. 75–84% (C) – A very good knowledge of much of the important material, possibly excellent in places, but with a limited account of some significant topics. 65–74% (D) – There should be a good grasp of several important topics, but with only a limited understanding or ability in places. There may be significant omissions. 60–64% (E) – Students will show some relevant knowledge of some of the issues involved, but with a good grasp of only a minority of the material. Some topics may be answered well, but others will be either omitted or incorrect. 35–59% (F) – There should be substantial deficiencies, or no answers, across large parts of the topics set, but with a little relevant and correct material in places. 1–34% (FX) – Very little or nothing that is correct and relevant.
Learning in laboratories	30	3,4	90% – 100% An outstanding piece of work, superbly organised and presented, excellent achievement of the objectives, evidence of original thought. 85-89% (B) - Students will show a thorough understanding and appreciation of the material, producing work without significant error or omission. Objectives achieved well. Excellent

			organisation and presentation. 75-84% (C) – Students will show a thorough understanding and appreciation of the material, producing work without significant error or omission. When performing laboratory work student completely provide results and make the right conclusions, but admits inaccuracies or errors. 65-74 (D) – The student can solve simple problems and has the ability to perform basic operations and basic transformation and some algorithmic, but is not able to independently formulate task and determine the solution. When performing laboratory work the student execute it with errors. 60-64% (E) – The student can solve simple problems by using teacher support to perform basic operations and basic transformation, but not able to formulate the problem by verbal description to determine the solution. 35-59% (F) – When performing practical (laboratory) work the student knows how to use computers, but is unable to complete the task. The work may contain some correct and relevant material, but most issues are neglected or are covered incorrectly. 1-34% (FX) – The student does not perform the tasks. Very little or nothing that is correct and relevant and no real appreciation of the laboratory work requirements.
Module Evaluation Quest	60	4	The score corresponds to the percentage of correct answers to the test questions.

8. TEACHING PROGRAMME OF THE MASTER COURSE MC2 "DATA SCIENCE FOR IOT AND IOE"

8.1. DESCRIPTION OF THE COURSE

TITLE OF THE MODULE	Code
Data Science for IoT and IoE	**MS2**

Teacher(s)	Department
Coordinating: Prof. I. Skarga-Bandurova, Prof. A. Gorbenko **Others:** Assoc. Prof., Dr. T. Biloborodova, Prof. DrS. A. Sachenkko, Assoc. Prof., Dr. V.Koval, Assoc Prof. Dr. O. Tarasiuk	Computer science and Engineering, V. Dahl EUNU, Computer systems and cybersecurity, NAU "KhAI" Information Computing Systems and Control, TNEU

Study cycle	Level of the module	Type of the module
MSc	A	Full-time tuition

Form of delivery	Duration	Langage(s)
Full-time tuition	One semester	English

Prerequisites	
Prerequisites: Machine Learning, Artificial Intelligence, Modelling, Basics of Programming; Theory of algorithms	**Co-requisites (if necessary):**

Credits of the module	Total student workload	Contact hours	Individual work hours
1	30	20	10

8.2. COMPETENCES AND LEARNING OUTCOMES

Aim of the module (course unit): competences foreseeen by the study programme	
The aim of study is giving to students the knowledges in artificial intelligence, neural networks and application of deep neural network for IoT.	
General Competences	**Professional Competences**
• The ability to generate new ideas (creativity), identify, pose and solve problems, find optimal ways to solve them. The ability to manage projects, organize teamwork, take the initiative to improve activities.	• Ability to participate in project activities; ability to adapt and act in a new situation. • The ability to apply professional knowledge and practical skills to solve typical problems in the specialty. • The ability to apply professional skills to implement practical tasks in accordance with the acquired qualifications. • The ability to analyze and reasonably choose the technical means of developing software and hardware systems and systems for IoT solutions. • The ability to apply professional knowledge and practical skills to solve typical problems of setting up and maintaining communication of mobile systems.

Learning outcomes of module (course unit)	Assessment methods	Innovative teaching/learning methods
At the end of course, the successful student will be able to: 1. To differentiate the architectures of artificial neural network for the tasks of IoT systems	Module Evaluation Questionnaire	• Interactive lectures: lecture-discussion. • Learning in laboratories: project method. • Cooperative learning: pair learning; joint project. • Collective group learning: master classes; discussion and debate. • Competitive learning: division of students into groups according to educational tasks; educational activities of students in groups; presentation of collective learning tasks (public speech).
2. To design specialized architecture of deep neural network for different IoT solutions	Module Evaluation Questionnaire	
3. To provide correct learning and simulating of the artificial neural network for IoT task solutions	Module Evaluation Questionnaire	
4. To use Matlab and other toolboxes of deep neural network for implementation and simulating of IoT systems	Module Evaluation Questionnaire	

8.3. HOURS DISTRIBUTION

Themes	Contact **work hours**							**Time and tasks for individual work**	
	Lectures	Consultations	Seminars	Practiacl work	Laboratory work	Placements	**Total contact work**	**Individual work**	**Tasks**
1. IoT and IoE ecosystem 1.1 Data science for IoT vs traditional data science 1.2 The IoT ecosystem and IoT problems in data science (Overview: time series data, enterprise IoT edge computing, real--time processing, cognitive computing, image processing, introduction to deep learning algorithms, geospatial analysis for IoT/managing massive geographic scale, strategies for integration with hardware, sensor fusion) 1.3 IoT datasets (IoT datasets by application: social networks, healthcare, smart cities, enterprises and manufacturing, energy etc. Data from IoT devices) **Lab:** Discovering of data processing technique for time series	2				4		6	4	1.4 Extracting meaning from data 1.5 Handling large scale data, handling poor data quality

2. Scientific analytics models used in IoT verticals 2.1 Supervised algorithms, unsupervised algorithms (classification, regression, clustering, dimensionality reduction etc) applicable to IoT datasets 2.2. Data fusion and time series data processing from IoT devices **Lab:** Exploring of signal segmentation and using of window function	2				4		6	5	2.3 Applying predictive learning algorithms to IoT datasets 2.4 Enterprise IoT edge computing and Manufacturing: Predictive maintenance, anomaly detection, forecasting and missing event interpolation.
3 Data fusion and data processing from IoT device 3.1 Data Fusion Challenges 3.2 Mathematical methods of Data Fusion **Lab:** Anomaly detection in time series using clustering	2			2			4	5	3.3 ARIIMA: Real IoT implementation of a machine learning architecture for reducing energy consumption
3. Data mining models for IoT 3.1Basic idea of using data mining for IoT 3.2Classification for IoT 3.3Clustering for IoT 3.4Frequent Pattern Mining for IoT 3.5Association analysis **Lab:** Exploratory data analysis and data visualization for IoT **Lab:** Classification and prediction modeling in IoT systems	2				4		6	4	4.6 Outlier detection 4.7 Spatial and temporal patterns mining for IoT
4. Mining of Massive Datasets 4.1CRISP-DM data mining process methodology for IoT domain 4.2Map reduce 4.3Finding Similar Items **Lab:** Association analysis for frequent pattern mining in IoT systems	2				4		6	4	5.4 Similarity-preserving summaries of sets 5.5 Methods for High Degrees of Similarity
5. Stream mining 5.1Stream Processing and Streaming Analytics: introduction and motivation 5.2Real-Time Data-Stream Analysis 5.3Data Streaming Models & Basic Mathematical Tools **Lab:** Analysis of interestingness measures in frequent pattern of IoT data	2				4		6	4	6.4 Kafka Streams 6.6 Streaming models (Landmark Streams, Sliding Window)
6. Basics of Machine Learning and Neural Networks 7.1 Introduction to machine learning and artificial intelligence 7.2 The model of neuron 7.3 The classification of artificial neural networks **Lab:** Recognition of alphanumeric information by using artificial neural network	2				4		6	4	7.4 Modern trends of Machine learning and Neural Networks

7. Deep Learning Neural Networks 8.1 The specifics of deep learning neural networks architecture 8.2 The training methods of deep learning neural network **Seminar:** Data preparation for deep neural network **Lab:** Image classification for IoT devices by using deep neural network	2		2		4		8	4	8.3 Specifics of deep neural network design and training
8. Deep Learning Neural Network Applications for IoT 9.1 Attack detection scheme using deep learning approach for IoT 9.2 Deep learning for the real-time embedded systems for IoT 9.3 Pattern recognition for IoT **Lab:** Deep learning speech recognition for IoT	2				4		6	2	9.4 Implementation of Deep Neural Networks for IoT applications
9. Big data and NoSQL databases 9.1 A concept of Big data 9.2 NoSQL databases 10.3 Big data trade-offs between consistency, availability and latency **Lab:** Deploy an HDInsight Hadoop cluster on Linux	2				4		6	2	10.4 Database decisions for the Internet of Things
10. Big data modelling using Cassandra NoSQL data storage 11.1 The Cassandra NoSQL database 11..2 Cassandra consistency model 11..3 Cassandra data model 11..4 Basic rules of Cassandra data modeling 11.5 An example of Cassandra database design for IoT system **Lab:** Connect to the cluster via SSH **Lab:** Analyze an Apache log file with Hive	2				4		6	1	11.5 Big data analytics using Cassandra
11. Cassandra performance benchmarking 12.1 Experimental setup and benchmarking scenario 12.2 Raw data analysis and the cold start phenomenon 12.3 Read/write latency and throughput statistics 12.4 Theoretical regressions of the Cassandra performance **Lab:** Use MapReduce to analyze a text file with Python	2				4		6	2	12.5 Real-time data analysis with Cassandra
12. Methodology of optimal consistency setup 12.1 Finding the optimal consistency settings 13.2 Experimental-based methodology for optimal coordination of consistency settings **Lab:** Delete the Hadoop cluster	2				4		6	1	13.3 Core features of Microsoft Azure cloud platform
Total	26		2	2	48		78	42	

8.4. COURSE ASSESSMENT STRATEGY

Assessment strategy	Weight in %	Deadlines	Assessment criteria
Lecture activity, including fulfilling special hometask	10	2,4	90–100% (A) – Outstanding work, showing a full grasp of all the questions answered. 85–89% (B) – Perfect or near perfect answers to a high proportion of the questions answered. There should be a thorough understanding and appreciation of the material. 75–84% (C) – A very good knowledge of much of the important material, possibly excellent in places, but with a limited account of some significant topics. 65–74% (D) – There should be a good grasp of several important topics, but with only a limited understanding or ability in places. There may be significant omissions. 60–64% (E) – Students will show some relevant knowledge of some of the issues involved, but with a good grasp of only a minority of the material. Some topics may be answered well, but others will be either omitted or incorrect. 35–59% (F) – There should be substantial deficiencies, or no answers, across large parts of the topics set, but with a little relevant and correct material in places 1–34% (FX) – Very little or nothing that is correct and relevant.
Learning in laboratories	30	3,4	90% – 100% An outstanding piece of work, superbly organised and presented, excellent achievement of the objectives, evidence of original thought. 85-89% (B) - Students will show a thorough understanding and appreciation of the material, producing work without significant error or omission. Objectives achieved well. Excellent organisation and presentation. 75-84% (C) -. Students will show a thorough understanding and appreciation of the material, producing work without significant error or omission. When performing laboratory work student completely provide results and make the right conclusions, but admits inaccuracies or errors. 65-74 (D) – The student can solve simple problems and has the ability to perform basic operations and basic transformation and some algorithmic, but is not able to independently formulate task and determine the solution. When performing laboratory work the student execute it with errors. He draws conclusions, but not sufficient to understand the purpose of work. 60-64% (E) – The student can solve simple problems by using teacher support to perform basic operations and basic transformation, but not able to formulate the problem by verbal description to determine the solution. 35-59% (F) – When performing practical (laboratory) work the student knows how to use computers, but is unable to complete the task. The work may contain some correct and relevant material, but most issues are neglected or are covered incorrectly. 1-34% (FX) – The student does not perform the tasks. Very little or nothing that is correct and relevant and no real appreciation of the laboratory work requirements.
Module Evaluation Quest	60	4	The score corresponds to the percentage of correct answers to the test questions

9. TEACHING PROGRAM OF THE MASTER COURSE MC3 "MOBILE AND HYBRID IoT COMPUTING"

9.1. DESCRIPTION OF THE COURSE

TITLE OF THE MODULE	Code
Mobile and hybrid IoT-based computing	**MC3**

Teacher(s)	Department
Coordinating: Dr. Butenko V.O. **Others: Dr. Odarushchenko O.N., Dr. Strjuk A.Y., Dr. Odarushchenko E.B., Butenko D.A.**	Computer Systems, Networks and Cybersecurity

Study cycle	Level of the module	Type of the module
MC	A	Full-time tuition

Form of delivery	Duration	Langage(s)
full-time tuition, distance tuition	Five weeks	English

Prerequisites	
Prerequisites: Need for training of developers creating software for connected devices or the Internet of Things	**Co-requisites (if necessary):**

Credits of the module	Total student workload	Contact hours	Individual work hours
7,5	230	148	82

9.2. COMPETENCES AND LEARNING OUTCOMES

Aim of the module (course unit): competences foreseeen by the study programme	
The aim of the module is to introduce the students to design and of mobile and IoT applications and services.	
General Competences	**Professional Competences**
• The ability to independently learn the basics of new research methods, changes in the scientific, research and production profile of their activities. • The ability to investigate problems using systems analysis, synthesis, computer modeling and optimization methods.	• The ability to apply professional knowledge and practical skills to solve typical problems in the specialty. • The ability to use scientific and practical methods of research, use and improvement of computer systems of artificial intelligence and mastering the skills of developing neural networks. • The ability to analyze and develop different levels of complexity of the IoT system using modern methods and tools, as well as taking into account modern challenges in the field of their security. • The ability to independently analyze and make reasonable choice of technologies, methods and tools for assessing and ensuring security at the design stage of critical IT infrastructures.

Learning outcomes of module (course unit)	Assessment methods	Innovative teaching/learning methods
At the end of course, the successful student will be able to: 1.Evaluate critical design tradeoffs for different mobile and IoT technologies, architectures, interfaces impact on usability, security, privacy of mobile and IoT computing services and applications; design, develop and publish their apps on different OS	Module Evaluation Questionnaire	• Interactive lectures: lecture-discussion; problem-oriented lecture. • Learning in laboratories: analysis of errors & incidents; project method. • Cooperative learning: pair learning; synthesis of ideas; joint project; • Collective group learning: decision tree; master classes. • Competitive learning: division of students into groups according to educational tasks; educational activities of students in groups.
2. Perform the basic of cloud computing on various architectures, such as SaaS, PaaS, IaaS	Module Evaluation Questionnaire	
3. Capture, analyze, search, share, store, process and intergrade big data for mobile applications	Module Evaluation Questionnaire	

9.3. HOURS DISTRIBUTION

Themes	Contact work hours							Time and tasks for individual work	
	Lectures	Consultations	Seminars	Practiacl work	Laboratory work	Placements	**Total contact work**	**Individual work**	**Tasks**
1.Mobile and Networking	44			36			**80**	**38**	1.1 Introduction to the course: history of mobile, cloud and IoT development, basic standards, development guidelines. Developing applications for Android. Basic interaction types of IoT and Android applications. Developing applications for iOS. Basic interaction types of IoT and iOS applications. Usability, security and privacy concepts for Android and iOS apps. Basics of wearable programming Applications development for Android wearable. Applications development for iOS wearable.
2. Cloud Computing and IoT	20		6	12			**38**	**22**	2.1 Introduction to the Cloud

									Computing. Dynamic interactions and computing architectures – SaaS, PaaS, IaaS benefits, issues and concerns Economics of Cloud Computing. Service models, value and risks. Perform computing in Android applications on the cloud. Perform computing of iOS applications on the cloud.
3. Intregration of big data and IoT/IoE technologies	18		6	6			**30**	**22**	3.1 Integration of Big Data and IOT Technologies. Foundations for Big Data Systems for IoT. Big Data characteristics and tyeps. Big Data platform stack and tools. Architectures of Big Data systems. Requirements for Big Data systems
Total	**82**		**12**	**54**			**148**	**82**	**230**

9.4. COURSE ASSESSMENT STRATEGY

Assessment strategy	Weight in %	Deadlines	Assessment criteria
Lecture activity, learning in laboratories	40	4	85% – 100% Outstanding work, showing a full grasp of all the questions answered. 70% – 84% Perfect or near perfect answers to a high proportion of the questions answered. There should be a thorough understanding and appreciation of the material. 60% – 69% A very good knowledge of much of the important material, possibly excellent in places, but with a limited account of some significant topics. 50% – 59% There should be a good grasp of several important topics, but with only a limited understanding or ability in places. There may be significant omissions. 45% – 49% Students will show some relevant knowledge of some of the issues involved, but with a good grasp of only a minority of the material. Some topics may be answered well, but others will be either omitted or incorrect. 40% – 44% There should be some work of some merit. There may be a few topics answered partly or there may be scattered or perfunctory knowledge across a larger range. 20% – 39% There should be substantial deficiencies, or no answers, across large parts of the topics set, but with a little relevant and correct material in places. 0% – 19% Very little or nothing that is correct and relevant.
Module Evaluation Quest	60	4	The score corresponds to the percentage of correct answers to the test questions

10. TEACHING PROGRAM OF THE MASTER COURSE MC4 "IOT TECHNOLOGIES FOR CYBER PHYSICAL SYSTEMS"

10.1. DESCRIPTION OF THE COURSE

TITLE OF THE COURSE	Code
IoT Technologies for Cyber Physical Systems	**MC4**

Teacher(s)	Department
Coordinating: Assoc. Prof., Dr. H. I. Vorobets **Others:** Assist.of Lect. V. E. Horditsa, Assist.of Lect. O. O. Pshenychnyi **Coordinating:** Prof., DrS. V. S. Kharchenko **Coordinating:** Assoc. Prof., Dr. R. K. Kudermetov **Others:** Assoc. Prof., Dr. M. Yu. Tiahunova, Senior Lecturer O. V. Polska	Computer Systems and Networks Computer Systems, Networks and Cybersecurity Computer Systems and Networks

Study cycle	Level of the module	Type of the module
MsS	A	Bounden

Form of delivery	Duration	Langage(s)
Full-time tuition	One semester	English

Prerequisites	
Prerequisites: Computer Electronics; Computer circuitry; Microcontrollers; Computer Networks; Architecture of Computers	**Co-requisites (if necessary):** Cryptography; Means of Artificial Intelligence; Protection of information & Cybersecurity

Credits of the course	Total student workload	Contact hours	Individual work hours
4	120	60	60

10.2. COMPETENCES AND LEARNING OUTCOMES

Aim of the course: competences foreseen by the study program
The purpose of the course is: deep understanding of the peculiarities of Cyber-Physical Systems and the Internet of Things technologies as specialized computer systems and networks; gaining new theoretical knowledge and practical skills of independent scientific activity and the development of new ideas in the field of IoT and CPS; mastering the methods of design, analysis and synthesis of intelligent computer systems. Acquiring relevant knowledge and skills is based on the assimilation and application of modern methods and technologies of system analysis, machine learning, teamwork, multi-criteria decision making. Attention is focused on the practical application of modern network information IoT technologies and distributed information resources (cloud, fog, edge computing) for solving scientific and applied tasks both in information support and in the modeling and design of complex CPS. A separate sub-task is the programming of computer networks for general and specialized purposes

(sensor networks, mesh networks, etc.), the functioning of telecommunication and telemetric data transmission systems, and intellectual analysis and information processing. As a result of studying this course, a base of knowledge and skills for decision making and project management is formed to create complex self-organizing, self-configuring intelligent CPS based on IoT technologies application.

General Competences	Professional Competences
• The ability to investigate problems using systems analysis, synthesis, computer modeling and optimization methods. The ability to manage projects, organize teamwork, take the initiative to improve activities.	• The ability to apply professional knowledge and practical skills to solve typical problems in the specialty. • The ability to analyze and make reasonable choices of technologies, methods and tools for developing energy efficient solutions for IoT and embedded systems. • The ability to independently analyze and make reasonable choice of technologies, methods and tools for assessing and ensuring security at the design stage of critical IT infrastructures. • The ability to analyze and make reasonable choice of technologies and tools for developing critical software software and hardware systems for IoT solutions.

Learning outcomes of course	Assessment methods	Innovative teaching and learning methods.
At the end of course, the successful student will be able to: 1. Justify the basic criteria for choosing a platform, tools and technical solutions for the development of CPS/IoT projects.	Course Evaluation Questionnaire Testing based on alternative method of assessment	• Interactive lectures: lecture-discussion. • Cooperative learning: pair learning. • Collective group learning: decision tree; master classes. • Situational modeling of phenomena:PRES-formula (from English Position - Reason - Explanation or Example - Summary). • Elaboration of discussion issues:method of determining the discussion position; changing the position and comparing alternative positions; discussion, debate.
2. Analyze physical objects and processes and justify the selection of optimal algorithms for the CPS/IoT technical solutions implementation.	Course Evaluation Questionnaire	
3. Evaluate the necessary hardware and software resources for the CPS/IoT project implementation.	Course Evaluation Questionnaire	
4. Select the technical base, hardware-software tools, and platforms for preliminary prototyping and construction of CPS/IoT systems.	Course Evaluation Questionnaire	
5. Evaluate the feasibility and technical-economic efficiency of the proposed solutions.	Course Evaluation Questionnaire,	
6. Optimize projects based on a systematic approach to the CPS/IoT analysis and synthesis.	Course Evaluation Questionnaire	
7. Identify CPS information models, describe their functionality and limitations, using existing tools, means, and technologies.	Course Evaluation Questionnaire, Testing based on alternative method of assessment	
8. Carry out modeling and simulating of individual algorithms, modules and systems of CPS/IoT using Model-Based Systems Engineering for the Cyber-Physical Systems technologies - UML, MARTE, SysML.	Course Evaluation Questionnaire	
9. Analyze cybersecurity methods and technologies of CPS/IoT systems.	Course Evaluation Questionnaire	
10. Evaluate and choose protocols and standards for the implementation of communications, processing and data transmitting for the designed CPS/IoT system using cloud, fog, edge computing.	Testing based on alternative method of assessment	
11 Propose technical solutions and apply PoE technologies to create distributed smart CPS/IoT systems.	Course Evaluation Questionnaire	
12. Manage the development and implementation of modern smart CPS/IoT systems in various problem-oriented industries.	Testing based on alternative method of assessment	

10.3. HOURS DISTRIBUTION

Themes	Contact work hours							Time and tasks for individual work	
	Lectures	Consultations	Seminars	Practical work (training)	Laboratory work	Placements	**Total contact work**	**Individual work**	**Tasks**
1. CPS and IoT as a basis Industry 4.0. Basic principles for the organization and functioning of IoT and CPS ecosystems 1.1. Evolution, Standards, Development Prospects for IoT and CPS 1.2. Conceptual diagrams of IoT and CPS 1.3. Motivation and examples of IoT and CPS for industry and the human applications 1.4 IoT services and technologies for CPS	2			2			**4**	**4**	1.5. Opera-tion of the CPS in conditions of uncertainty of input data 1.6. Built-in computer facilities reconfigu-rable CPS 1.7.Evolution of the cyber-component of mechatro-nic systems
2. System approach for the analysis and synthesis of IoT and CPS structures 2.1 Setting problem-oriented tasks 2.2 Definition and study of the target function of the CPS synthesis problem 2.3. Self-organization principles of CPSs 2.4. 3S model of CPS 2.5. Examples of structural solutions	2			2			**4**	**4**	2.6. Linear and branched algorithms for conditionally defined input data 2.7. Methods for finding optimal trajectories
3. Data processing in the CPS 3.1. Estimation of computing resources 3.2 Transmission, processing, display, storage of data 3.3. Parallel, cloud, fog, edge calculations and resources	2		2		2		**6**	**4**	3.4 Assessment of the effectiveness of artificial intelligence
4 Mathematical and informational support of IoT and CPS technologies 4.1. Stages and tasks of modeling of information processing 4.2. Functional IoT and CPS algorithms (in terms of application) 4.3. Mathematical models of CPS 4.4 Information models of mass service systems (MSS) in CPS 4.5 Models of Petri Networks for IoT and CPS technologies	2				2		**4**	**5**	1.6. Software package Symulink 4.7.Genetic Algorithms 4.8. Neural Networks 4.9 Methods of fuzzy logic 4.10 Bio-inspiring and bio-integrated CPS and IoT technologies
5. IoT technology in the problems of synthesis and analysis of CPS. Modern elemental and technological base for CPS and IoT 5.1. Evolution of microcontroller facilities and systems. 32- and 64-bit ARM architecture	2				4		**6**	**6**	5.4. Architec-tural decisions of reconfigurable CPS 5.5. Means of artificial intelligence in CPS

5.2. Principles of synthesis of CPS based on industrial microprocessor modules 5.3. Principles of synthesis of CPS on the basis of programmable logic environments CPLD, FPGA									5.6. Dynamic redistribution of computing load
6. Interfaces of open systems and network protocols IoT 6.1 Sensor networks, nonstandard protocols of physical level in CPS 6.2. Mesh networks, Zigbee protocols in CPS 6.3. IR, Bluetooth, RFID for local data transmit in CPS 6.4. Network protocols and computer network programming for CPS	2				4		**6**	**7**	6.5. Methods of information protection in IoT technology for CPS
7. Specialized software packages for simulation and synthesis of IoT and CPS 7.1. RTOS 7.2. Features of FPGA programming by Altera 7.3 Features of FPGA Programming by Xilinx 7.4 Means for the synthesis and analysis of analog and digital circuits Altium Designer	2				4		**6**	**6**	7.5. Software package Ptolemy II 7.6. Linux RTOS
8.1 IoT and scalability of CPS 8.2 Conception and advantages of Power over Ethernet 8.2.1 Conception of PoE method. State of the art 8.2.2 Advantages of the PoE method	2		2		0		**4**	**4**	8.3 Examples of PoE applications
9. System Power of Ethernet based architecture 9.1 General architecture view 9.2 System requirements 9.3 Sensor hub classes 9.4 Configuration and operation modes of the system 9.5 Parameters, organization and data processing	2		2				**4**	**4**	9.6 Data processing and presentation 9.7 The systems hierarchy
10. Neural networks incorporation, network testing, general integration flow 10.1 Incorporation of neural networks 10.2 Testing of the network 10.3 General integration flow	2		2				**4**	**4**	
11. Model-based systems engineering for CPS. Modeling methodologies for CPS 11.1 Rationale MBSE approaches for analysis, specification, design, and verification of CPS 11.2 An overview of the general-purpose modeling languages and its benefits for CPS 11.3 Technology platforms for CPS modeling	2				2		**4**	**4**	
12. MARTE profile of UML foundations 12.1 An introduction to UML profiles	2				2		**4**	**4**	

12.2 Specifying non-functional properties 12.3 Modeling time and resources									
13. Modeling CPS with SysML and MARTE 13.1 The SysML profile 13.2 Methods of combining SysML and MARTE for modeling CPS 13.3 Basics of model-based analysis of CPS	2				2		**4**	**4**	
Total	**26**		**8**	**4**	**22**		**60**	**60**	

10.4. COURSE ASSESSMENT STRATEGY

Assessment strategy	Weight in %	Deadlines	Assessment criteria
Lecture activity, including fulfilling special self-tasks	10	7,14	85% – 100% Outstanding work, showing a full grasp of all the questions answered. 70% – 84% Perfect or near perfect answers to a high proportion of the questions answered. There should be a thorough understanding and appreciation of the material. 60% – 69% A very good knowledge of much of the important material, possibly excellent in places, but with a limited account of some significant topics. 50% – 59% There should be a good grasp of several important topics, but with only a limited understanding or ability in places. There may be significant omissions. 45% – 49% Students will show some relevant knowledge of some of the issues involved, but with a good grasp of only a minority of the material. Some topics may be answered well, but others will be either omitted or incorrect. 40% – 44% There should be some work of some merit. There may be a few topics answered partly or there may be scattered or perfunctory knowledge across a larger range. 20% – 39% There should be substantial deficiencies, or no answers, across large parts of the topics set, but with a little relevant and correct material in places. 0% – 19% Very little or nothing that is correct and relevant.
Learning in laboratories	30	7,14	85% – 100% An outstanding piece of work, superbly organized and presented, excellent achievement of the objectives, evidence of original thought. 70% – 84% Students will show a thorough understanding and appreciation of the material, producing work without significant error or omission. Objectives achieved well. Excellent organization and presentation. 60% – 69% Students will show a clear understanding of the issues involved and the work should be well written and well organized. Good work towards the objectives. The exercise should show evidence that the student has thought about the topic and has not simply reproduced standard solutions or arguments. 50% – 59% The work should show evidence that the student has a reasonable understanding of the basic material. There may be some signs of weakness, but overall the grasp of the topic should be sound. The presentation and organization should be reasonably clear, and the objectives should at least be partially achieved. 45% – 49% Students will show some appreciation of the issues involved. The exercise

			will indicate a basic understanding of the topic, but will not have gone beyond this, and there may well be signs of confusion about more complex material. There should be fair work towards the laboratory work objectives. 40% – 44% There should be some work towards the laboratory work objectives, but significant issues are likely to be neglected, and there will be little or no appreciation of the complexity of the problem. 20% – 39% The work may contain some correct and relevant material, but most issues are neglected or are covered incorrectly. There should be some signs of appreciation of the laboratory work requirements. 0% – 19% Very little or nothing that is correct and relevant and no real appreciation of the laboratory work requirements.
Course Evaluation Quest	60	8,16	The score corresponds to the percentage of correct answers to the test questions

11. TEACHING PROGRAMME OF THE COURSE PC1 “SIMULATION OF IOT AND IOE-BASED SYSTEMS”

11.1. DESCRIPTION OF THE COURSE

TITLE OF THE COURSE	Code
Simulation of IoT-based Systems	**PCM 1**

Teacher(s)	Department
Coordinating: Prof. Dmitry Maevsky **Others:** Module PCM1.1: DrS, Prof. Tabunshchyk G. Module PCM1.2: Ass. Prof., PhD Maevskaya O. Module PCM1.3: DrS, Prof. Drozd O., Ass. Prof., PhD Martinuk O. M. Module PCM1.4: DrS, Prof. Kharchenko V., Ass. Prof., PhD Kolisnyk M.	ONPU, Institute of Electro mechanics and Energetic Management; ZNTU, Software Tools Department Computer Engineering KhAI, Computer systems, networks and cyber security

Study cycle	Level of the module	Type of the module
Master	A	Full-time tuition

Form of delivery	Duration	Langage(s)
Full-time tuition	One semester	English

Prerequisites	
Prerequisites: Foundation of Modeling; Computer Systems and System Analysis, Machine Learning, Modeling Foundation knowledge and skills in CAD; Computer Networks; Information-Networking Technologies, Theory of computation; Programming Languages; Digital signal processor.	**Co-requisites (if necessary):**

Credits of the module	Total student workload	Contact hours	Individual work hours
4	138	64	74

11.2. COMPETENCES AND LEARNING OUTCOMES

Aim of the module (course unit): competences foreseeen by the study programme
The aim of the course is: – To give students of overview of IoT systems architecture and classification of interaction and tools of their simulation and implementation based on case studies approach. – To create a knowledge base on practical using of program tools for simulation in IoT. The study also expands the notion about interactions between microprocessor and sensors as well as between microprocessor and actuators – Acquisition of knowledge in simulation of IoT and IoE-based systems and their components regarding architecture, behavior and process synchronization. Obtaining skills in simulation of IoT and IoE-based systems in the modern instrumental environments with use of UML charts, Petri nets and temporal logic. – Acquisition of general approach to structures and models building of IoT-based industrial systems

General Competences	Professional Competences	
• The ability to independently learn the basics of new research methods, changes in the scientific, research and production profile of their activities. • The ability to investigate problems using systems analysis, synthesis, computer modeling and optimization methods. • The ability to assess and ensure the quality of work performed.	• The ability to apply professional knowledge and practical skills to solve typical problems in the specialty. • The ability to analyze and reasonably choose the technical means of developing software and hardware systems and systems for IoT solutions. • The ability to analyze and make reasonable choice of technologies and tools for developing critical software software and hardware systems for IoT solutions.	
Learning outcomes of module (course unit)	**Assessment methods**	**Innovative teaching and learning methods.**
At the end of course, the successful student will be able to: 1 Formulate the main ideas of creation, simulation and verification of IoT and IoE-based systems.	Module Evaluation Questionnaire	• Interactive lectures: lecture-discussion; problem-oriented lecture. • Learning in laboratories: project method. • Cooperative learning: pair learning; joint project; • Competitive learning: division of students into groups according to educational tasks; educational activities of students in groups; presentation of collective learning tasks (public speech).
2 To distinguish tasks for simulation m2m, d2d different architecture levels of IoT systems	Module Evaluation Questionnaire	
3 To use Interaction Flow Modeling Language for modelling interactions for different IoT solutions	Module Evaluation Questionnaire	
4 Features of designing and debugging programs for microprocessors ARDUINO and Raspberry Pi	Module Evaluation Questionnaire	
5 To execute simulation and verification in architecture of IoT and IoE-based systems with use of UML charts.	Module Evaluation Questionnaire	
6 To build, simulate and execute verification of the formal behavior models of an automata and Petri nets for IoT and IoE-based systems.	Module Evaluation Questionnaire	
7. To execute the description of synchronization processes in IoT and IoE-based systems with use of LTL models. 8. To apply the mathematical method of Markov models for the final probabilities of model states assessment of IoT systems for the availability function assessment of IoT systems	Module Evaluation Questionnaire	

11.3. HOURS DISTRIBUTION

Themes	Contact work hours							Time and tasks for individual work	
	Lectures	Consultations	Seminars	Practiacl work	Laboratory work	Placements	**Total contact work**	**Individual work**	**Tasks**
1 Introduction into infrastructure in the IoT systems	2						**2**		Group work

2 Classification of the interactions in the IoT systems	2						**2**		Group work on Patterns Analysis
3 Interaction Flow Modeling Language Usage of FSM models for interaction modelling	2			2	2		**6**	**1** **1**	1 Individual tasks in developing IFML artifacts for IoT systems 2 Implementation of developed models in Remote Laboratory GOLDi
4 Verification of IoT systems. Case Studies	2		2		4		**8**	**10**	1 Implementation developed models in Remote Laboratories GOLDi and ISRT
									2 Simulation with the Bluemix platform simulations for such systems: Smart Campus, e-Health, Intelligent Transport
5 Types of program tools for IoT simulations. 5.1 Classification and terminology. Real-world objects and kinds of it simulation. 5.2 Physical and computer simulations. 5.3 Virtual simulation. Common user interaction systems for virtual simulations.	2						**2**	**2**	1 Difference between physical and computer simulation. 2 Kinds of computer simulation
6 Simulation IoT devices based on Arduino platform. 6.1 General information about the Arduino platform. 6.2 Arduino and Arduino-compatible boards. 6.3 Arduino IDE and IO system. 6.4 Software development. Arduino C/C++ sketch. 6.5 Program tools for simulations of Arduino-based systems.	2				4		**6**	**4**	1 Simulation of the Arduino devices in Proteus 8 Professional. 2 VIRTRONIX – Simulator for Arduino. 3 Fritzing Arduino Simulator
7 Simulation IoT devices based on Raspberry Pi platform. 7.1 Single-board computers Raspberry Pi – architecture. 7.2 Command system and programming features. 7.3 Autodesk Electronic Lab – simulation workbench.	2				2		**4**	**4**	1 RISK processors. 2 General purpose input-output (GPIO). 3 Windows 10 IoT Core operation sysstem. 4 Simulation of IoT systems in Autodesk Electronic Lab
8 Application of event-oriented programming and UML diagrams for simulation and design of IoT devices 8.1 Event-oriented programming 8.2 What is UML and UML diagrams 8.3 Using of UML diagrams for simulation and design of IoT devices	2				2		**4**	**4**	1 UML-modelling for IoT devices 2 An Internet of Things visual domain specific modeling language
9 Simulation and verification in architecture of IoT	2				2		**4**	**8**	1 Simulation and debugging of static visual UML

and IoE-based systems with use of UML charts 9.1 Introduction to representation of architecture of IoT and IoE-based systems with use of visual UML charts (precedents, components, classes, activities, the sequences of actions). 9.2 Static visual UML charts for the description of architecture of IoT and IoE-based systems. 9.3 Features of dynamic visual UML charts for the description of architecture of IoT and IoE-based systems. 9.4 The analysis of static visual UML charts in the description of architecture of IoT and IoE-based systems. 9.5 Features of the analysis of dynamic visual UML charts in the description of processes into architecture of IoT and IoE-based systems.									charts in the description of architecture of IoT and IoE-based systems 2 Features of simulation and debugging of dynamic visual UML charts in the description of architecture of IoT and IoE-based systems.
10 Simulation and verification in behavior of IoT and IoE-based systems on basis of the expanded automata and hierarchical Petri nets 10.1 Introduction to the description of IoT and IoE-based systems behavior with use of expanded automata, networks of queuing service and the hierarchical colored Petri nets. 10.2 The review of the instrumental environments for simulation in behavior of IoT and IoE-based systems and their components 10.3 Development and simulation of imitation models of queuing services for IoT and IoE-based systems and their components in the instrumental environments OMNet ++, GPSS World, ExtendSim. 10.4 Development of the formal models of an automata and Petri nets for the description in behavior of IoT and IoE-based systems and their components. 10.5 Simulation and verification of the formal behavior models of an automata and Petri nets in the instrumental environment CPNTools.	2		2		2		**6**	**12**	1 The analysis of a correctness of the formal behavior models of an automatic class on the basis of graphs of achievable marking, invariants of line items and transitions. 2 Verification and testing in behavior of IoT and IoE-based systems on the basis of the structural and behavioral tests synthesized for Petri nets.
11 Simulation and verification of synchronization processes in IoT and IoE-based systems on the basis of temporal logic 11.1 Introduction to temporal logic for the description of process synchronization in IoT and IoE-based systems.	2			2	2		**6**	**12**	1 Coordination in levels of simulation for IoT and IoE-based systems with use of UML charts, Petri nets and temporal logic

11.2 The description of synchronization processes with use of LTL models in the Promela language. 11.3 Features of process synchronization for IoT and IoE-based systems in the instrumental environments SPIN, XSPIN. 11.4 Temporal verification of processes in IoT and IoE-based systems and their components on the basis of temporal logic. 11.5 Composition temporal output of LTL logic on the basis of the proof of precedence for conditions and events of processes.									
12 Final probabilities assessment of IoT based systems with use of Markov models mathematical apparatus 13 Availability function assessment of IoT based systems with use of Markov models mathematical apparatus 14 Semi Markov's modeling of IoT systems	6				8		**14**	**16**	1 2 Features of Markov's modeling of IoT systems considering cyber security and availability
Total	**28**		**4**	**4**	**28**		**64**	**74**	

11.4. COURSE ASSESSMENT STRATEGY

Assessment strategy	Weight in %	Deadlines	Assessment criteria
Lecture activity, including fulfilling special self-tasks	10	7,14	85% – 100% Outstanding work, showing a full grasp of all the questions answered. 70% – 84% Perfect or near perfect answers to a high proportion of the questions answered. There should be a thorough understanding and appreciation of the material. 60% – 69% A very good knowledge of much of the important material, possibly excellent in places, but with a limited account of some significant topics. 50% – 59% There should be a good grasp of several important topics, but with only a limited understanding or ability in places. There may be significant omissions. 45% – 49% Students will show some relevant knowledge of some of the issues involved, but with a good grasp of only a minority of the material. Some topics may be answered well, but others will be either omitted or incorrect. 40% – 44% There should be some work of some merit. There may be a few topics answered partly or there may be scattered or perfunctory knowledge across a larger range. 20% – 39% There should be substantial deficiencies, or no answers, across large parts of the topics set, but with a little relevant and correct material in places. 0% – 19% Very little or nothing that is correct and relevant.
Learning in laboratories	30	7,14	85% – 100% An outstanding piece of work, superbly organised and presented, excellent achievement of the objectives, evidence of original thought. 70% – 84% Students will show a thorough understanding and appreciation of the

			material, producing work without significant error or omission. Objectives achieved well. Excellent organisation and presentation. 60% – 69% Students will show a clear understanding of the issues involved and the work should be well written and well organised. Good work towards the objectives. The exercise should show evidence that the student has thought about the topic and has not simply reproduced standard solutions or arguments. 50% – 59% The work should show evidence that the student has a reasonable understanding of the basic material. There may be some signs of weakness, but overall the grasp of the topic should be sound. The presentation and organisation should be reasonably clear, and the objectives should at least be partially achieved. 45% – 49% Students will show some appreciation of the issues involved. The exercise will indicate a basic understanding of the topic, but will not have gone beyond this, and there may well be signs of confusion about more complex material. There should be fair work towards the laboratory work objectives. 40% – 44% There should be some work towards the laboratory work objectives, but significant issues are likely to be neglected, and there will be little or no appreciation of the complexity of the problem. 20% – 39% The work may contain some correct and relevant material, but most issues are neglected or are covered incorrectly. There should be some signs of appreciation of the laboratory work requirements. 0% – 19% Very little or nothing that is correct and relevant and no real appreciation of the laboratory work requirements.
Module Evaluation Quest	60	8,16	The score corresponds to the percentage of correct answers to the test questions

12. TEACHING PROGRAM OF THE COURSE PCM 2 “SOFTWARE DEFINED NETWORKS AND IOT”

12.1. DESCRIPTION OF THE COURSE

TITLE OF THE MODULE	Code
Software defined networks basics	**PCM 2.1**

Teacher(s)	Department
Coordinating: Assoc. Prof., Dr. R.K. Kudermetov **Others: Modules PCM2.1, PCM2.2**: Assoc. Prof., Dr. V.V. Shkarupylo, Assoc. Prof., Dr. R.K. Kudermetov, MSc student D.S. Mazur. **Module PCM2.3**: DrS. I.S. Skarga-Bandurova, PhD student A.Yu. Velykzhanin, Assoc. Prof. Dr. L.O. Shumova. **Module PCM2.4**: Prof., DrS V.S. Kharchenko, Assoc. Prof., Dr. D.D. Uzun, Senior Lecturer Y.O. Uzun, PhD student P.A. Hodovaniuk	Computer systems and networks (ZNTU), Computer Engineering (EUNU), Computer Systems, Networks and Cybersecurity Department (KhAI)

Study cycle	Level of the module	Type of the module
PhD	A	Full-time tuition

Form of delivery	Duration	Language(s)
full-time tuition, distance tuition	Four weeks	English

Prerequisites			
Prerequisites: Computer Systems and Networks, Software Engineering, Modern Programming Methods, Modeling Basics		**Co-requisites (if necessary):**	
Credits of the module	**Total student workload**	**Contact hours**	**Individual work hours**
4	120	56	64

12.2. COMPETENCES AND LEARNING OUTCOMES

Aim of the module (course unit): competences foreseen by the study program	
The aim of the course is to give PhD students a deep understanding of Software Defined Networking (SDN) – the important emerging network technology – to teach to select, evaluate and implement SDN controllers for various platforms and applications, theoretical and practical skills in the field of research, design and modelling safety systems based on SDN with emphasize on IoT. During the training, graduate students can study and analyze approaches to managing the IoT with SDN, smart routing and scheduling, traffic management and optimization in IoT.	
General Competences	**Professional Competences**
• The ability to plan and manage time. • The ability to investigate problems using systems analysis, synthesis, computer modeling and optimization methods. • The ability to manage projects, organize teamwork, take the initiative to improve activities.	• Ability to participate in project activities; ability to adapt and act in a new situation. • The ability to use scientific and practical methods of research, use and improvement of computer systems of artificial intelligence and mastering the skills of developing neural networks. • The ability to analyze and reasonably choose the technical means of developing software and hardware systems and systems for IoT solutions.

	• The ability to apply professional knowledge and practical skills to solve typical problems of setting up and maintaining communication of mobile systems. • The ability to analyze and make reasonable choice of technologies and tools for developing critical software software and hardware systems for IoT solutions.	
Learning outcomes of module (course unit)	**Assessment methods**	**Innovative teaching and learning methods.**
At the end of module the successful student will be able to: 1. Explain and discuss the basic concepts and architecture of SDN, concepts of managing the IoT applications with SDN.	Module Evaluation Questionnaire	• Interactive lectures: lecture-discussion. • Learning in laboratories: analysis of errors & incidents; project method. • Cooperative learning: synthesis of ideas. • Collective group learning: discussion and debate. • Elaboration of discussion issues:method of determining the discussion position; changing the position and comparing alternative positions; discussion, debate. • Competitive learning: division of students into groups according to educational tasks; educational activities of students in groups; presentation of collective learning tasks (public speech).
2. Compare and contrast common networking approaches and SDN.	Module Evaluation Questionnaire	
3. Describe the SDN data plane. Explain the operation of SDN control plane.	Module Evaluation Questionnaire	
4. Explain network virtualization.	Module Evaluation Questionnaire	
5. Compare and contrast OpenFlow releases.	Module Evaluation Questionnaire	
6. Formulate requirements for configuration SDN. Create and analyze the configuration of SDN.	Module Evaluation Questionnaire	
7. Employ obtained theoretical knowledge for the purpose of SDN simulation and deployment.	Module Evaluation Questionnaire	
8. Formulate main approaches, techniques and tools for smart routing and scheduling SDN to IoT	Module Evaluation Questionnaire	
9. Formulate traffic management tasks, traffic parameters, traffic types and related data services, traffic management mechanisms	Module Evaluation Questionnaire	
10. Use SDN-related languages and programming approaches in practice.	Module Evaluation Questionnaire	
11. Explain the operation of the SDN for support IoT scalability, agility and flexibility. Conduct SDN composing, configuring and scaling by way of simulation.	Module Evaluation Questionnaire	
12. Design the architecture of software-defined network with respect to given requirements.	Module Evaluation Questionnaire	
13. Implement the design solutions, obtained by way of simulation, in practice.	Module Evaluation Questionnaire	
14. Perform administration of the switches, management and analysis of the results of traffic monitoring.	Module Evaluation Questionnaire	

12.3. HOURS DISTRIBUTION

Themes	Contact work hours						Time and tasks for individual work
	Lectures	Seminars	Practiacl work	Laboratory work	**Total contact work**	**Individual work**	**Tasks**
1. Understanding SDN. Historical Background and Key Concepts 1.1. The Evolution of Switches and Control Planes 1.2. The Evolution of Networking Technology 1.3. Predecessors of SDN 1.4. Network Virtualization	2				**2**	**4**	1.5. Survey of Computer Networks Historical Evolution 1.6. Analysis of the Research Papers about SDN.
2. SDN Architecture and its Components. Devices, Controller, Applications 2.1. Fundamental Characteristics of SDN. Plane Separation 2.2. SDN Operation 2.3. SDN Devices 2.4. SDN Controller. Existing SDN Controller Implementations 2.5. SDN Applications	2				**2**	**4**	2.6. Perform a Comparative Analysis of Existing SDN Controller Implemen-tations 2.7. Create Existing SDN Device Implemen-tations 2.8. **Classify the Functions of SDN Application** 2.9. Compare SDN with Alternative Technologies
3. OpenFlow Protocol. The Basics, Peculiarities and Limitations 3.1. OpenFlow Overview 3.2. The OpenFlow Switch and Controller 3.3. The OpenFlow Protocol 3.4. OpenFlow Releases 1.0, 1.2, 1.3 Survey 3.5. OpenFlow Limitations	2				**2**	**4**	3.6. Overview of Open Networking Foundation Activities 3.7. Create a Chronological Report on the Development (Innovations) of OpenFlow Switch Specifications
4. Mininet installation and configuring. Building simple networking applications				2	**2**	**4**	4.1. Create the Report on the Topic and answer the Questions
5. Exploring OpenDaylight, installation and configuring. SDN Emulation with Mininet and OpenDaylight				2	**2**	**4**	5.1. Create the Report on the Topic and answer the Questions
6. SDN Simulation. The Basics, Toolboxes and Main Concepts. 6.1. Considering SDN as a System. Key Components: Controllers, Switches, Hosts. 6.2. Simulating SDN Infrastructure. Network Configuring and Scaling. 6.3 Network Orchestration and Virtualization. The Simulation of Dataflows.	2				**2**	**4**	6.4 An Overview on SDN Simulation Toolboxes. 6.5 Measurement and Assessment of QoS-related SDN- metrics.
7. SDN Testing. OpenFlow Protocol and Network Validation.	2			2	**4**	**6**	7.4. The API for SDN Programming and

7.1. Setting up the Configuration of SDN in Mininet Testing Environment. 7.2. Testing the Soundness and Consistency of SDN Infrastructure. 7.3. Dataflows Orchestration. SDN Reconfiguration and Scaling.							OpenFlow Protocol.
8. Software-defined Networks Programing and Python Scripting. 8.1. An in-depth Look at SDN-related Programming Approaches, Principles and Concepts. 8.2. Setting up SDN Configuration by Way of Python Scripting. 8.3. Sophisticating the Python Scripting. Bringing in the Automation.	2			4	**6**	**6**	8.4 The API for SDN Programming and OpenFlow Protocol.
9. Managing the IoT with SDN SLA management. 9.1. Metrics. Smart routing and scheduling in SDN. 9.2. Data streaming over SDN.	2		2	4	**8**	**6**	9.3. Metrics for evaluation performance of QoS routing algorithms. QoS routing algorithms applicable to large-scale SDN.
10. Optimization of SDN Traffic Flow for IoT. 10.1. Traffic scheduling algorithms.	2		2	4	**8**	**6**	10.2.Algo-rithms for calculating the optimal position of the SDN-controller. 10.3. Balancing algorithms in IoT-based software defined networks. 7.4. Algo-rithms for finding the optimal path in SDN networks.
11. SDN Performance prediction. 11.1. Algorithms performance metrics. 11.2. An overall approach to detect and diagnose failures in SDN.	2		2	4	**8**	**6**	11.3. Case study
12. Development of project for SDN-DevOps using modern CI/CD tools. 12.1. Principles of DevOps techniques. 12.2. To study the connection between DevOps techniques and processes of software development lifecycle.	2		4		**6**	**6**	12.3. To select the correct tools to provide dependable functioning of software development lifecycle. 12.4. To gain experience with installation and configuring all tools through the CI/CD pipeline. 12.5. To develop the summary project using configured on previous step CI/CD pipeline. 12.6. To make grounded choice of each tools during CI/CD pipeline development.
13. Methodology of DevOps in context of SDN and IoT.		4			**4**	**4**	13.1. Preparation of a report (analytical review or vision and brief specification of developed project - SDP) on analysis of: a) methodo-logy DevOps and its security related modification DevSecOps development and application;

							b) implemen-tation of methodology DevOps/DevSecOpsin context of application of software defined networks (SDN) and Internet of Things (IoT).
Total	**20**	**4**	**10**	**22**	**56**	**64**	

12.4. COURSE ASSESSMENT STRATEGY

Assessment strategy	Weight in %	Deadlines	Assessment criteria
Lecture activity, including fulfilling special self-tasks	10	2, 4	85% – 100% An outstanding piece of work, superbly organized and presented, excellent achievement of the objectives, evidence of original thought. 70% – 84% Students will show a thorough understanding and appreciation of the material, producing work without significant error or omission. Objectives achieved well. Excellent organization and presentation. 60% – 69% Students will show a clear understanding of the issues involved and the work should be well written and well organized. Good work towards the objectives. The exercise should show evidence that the student has thought about the topic and has not simply reproduced standard solutions or arguments. 50% – 59% The work should show evidence that the student has a reasonable understanding of the basic material. There may be some signs of weakness, but overall the grasp of the topic should be sound. The presentation and organization should be reasonably clear, and the objectives should at least be partially achieved. 45% – 49% Students will show some appreciation of the issues involved. The exercise will indicate a basic understanding of the topic, but will not have gone beyond this, and there may well be signs of confusion about more complex material. There should be fair work towards the laboratory work objectives. 40% – 44% There should be some work towards the laboratory work objectives, but significant issues are likely to be neglected, and there will be little or no appreciation of the complexity of the problem. 20% – 39% The work may contain some correct and relevant material, but most issues are neglected or are covered incorrectly. There should be some signs of appreciation of the laboratory work requirements. 0% – 19% Very little or nothing that is correct and relevant and no real appreciation of the laboratory work requirements.
Learning in practicums	30	3,4	85% – 100% An outstanding piece of work, superbly organized and presented, excellent achievement of the objectives, evidence of original thought. 70% – 84% Students will show a thorough understanding and appreciation of the material, producing work without significant error or omission. Objectives achieved well. Excellent organization and presentation.

			60% – 69% Students will show a clear understanding of the issues involved and the work should be well written and well organized. Good work towards the objectives. The exercise should show evidence that the student has thought about the topic and has not simply reproduced standard solutions or arguments. 50% – 59% The work should show evidence that the student has a reasonable understanding of the basic material. There may be some signs of weakness, but overall the grasp of the topic should be sound. The presentation and organization should be reasonably clear, and the objectives should at least be partially achieved. 45% – 49% Students will show some appreciation of the issues involved. The exercise will indicate a basic understanding of the topic, but will not have gone beyond this, and there may well be signs of confusion about more complex material. There should be fair work towards the laboratory work objectives. 40% – 44% There should be some work towards the laboratory work objectives, but significant issues are likely to be neglected, and there will be little or no appreciation of the complexity of the problem. 20% – 39% The work may contain some correct and relevant material, but most issues are neglected or are covered incorrectly. There should be some signs of appreciation of the laboratory work requirements. 0% – 19% Very little or nothing that is correct and relevant and no real appreciation of the laboratory work requirements.
Module Evaluation Quest	60	4	The score corresponds to the percentage of correct answers to the test questions

13. TEACHING PROGRAMME OF THE COURSE PC3 “DEPENDABILITY AND SECURITY OF IOT”

13.1. DESCRIPTION OF THE COURSE

TITLE OF THE COURSE	Code
Dependability and Security of IoT	**PC3**

Teacher(s)	Department
Coordinating: Prof., DrS. V. V. Sklyar **Others:** Modules PCM3.4: DrS. V. V. Yatskiv, Ass. Prof., Dr. N. G. Yatskiv (TNEU)	Computer Systems, Networks and Cybersecurity Department (KhAI) Cybersecurity Department (TNEU)

Study cycle	Level of the course	Type of the course
PhD	A	Bounden

Form of delivery	Duration	Language(s)
Full-time tuition	One semester	English

Prerequisites	
Prerequisites: Foundation of Modelling; Computer Systems and System Analysis, Computer Networks, Reliability Theory	**Co-requisites (if necessary):**

Credits of the course	Total student workload	Contact hours	Individual work hours
4	120	64	56

13.2. COMPETENCES AND LEARNING OUTCOMES

Aim of the course: competences foreseen by the study program	
The aim of the course is to give understanding principles of operation the dependable, safe and secure platforms and tools for IoT application. Relevant knowledge is based on a study of the features and methods of information models formation for IoT-based devices and technologies for safety and security. Obtained knowledge will allow choosing the means and technologies for the development and implementation of dependable and secure IoT-based systems.	
General Competences	**Professional Competences**
• The ability to manage projects, organize teamwork, take the initiative to improve activities. • The ability to assess and ensure the quality of work performed.	• The ability to apply professional knowledge and practical skills to solve typical problems in the specialty. • The ability to apply professional skills to implement practical tasks in accordance with the acquired qualifications. • The ability to analyze and reasonably choose the technical means of developing software and hardware systems and systems for IoT solutions. • The ability to independently analyze and make reasonable choice of technologies, methods and tools for assessing and ensuring security at the design stage of critical IT infrastructures.

Learning outcomes of course	Assessment methods	Innovative teaching and learning methods.
At the end of course, the successful student will be able to: 1. perform modelling of IoT systems dependability, safety and security	Course Evaluation Questionnaire	• Interactive lectures: lecture-discussion; problem-oriented lecture. • Learning in laboratories: analysis of errors & incidents. • Cooperative learning: pair learning; synthesis of ideas. • Collective group learning:discussion and debate. • Situational modeling of phenomena: simulations or simulation games. • Elaboration of discussion issues: method of determining the discussion position; changing the position and comparing alternative positions; discussion, debate.
2. perform quantitate and qualitative analysis of measure of IoT systems dependability, safety and security	Course Evaluation Questionnaire	
3. apply methods of assurance of IoT systems dependability, safety and security	Course Evaluation Questionnaire	
4. develop safety and security management plan	Course Evaluation Questionnaire	
5. develop structure of safety and security life cycle	Course Evaluation Questionnaire	
6. perform forward and backward requirements tracing	Course Evaluation Questionnaire	
7. recognize review, analysis and testing techniques	Course Evaluation Questionnaire	
8. analyse safety and security management documents	Course Evaluation Questionnaire	
9. define Assurance Case methodology for IoT safety and security assessment	Course Evaluation Questionnaire	
10. use software tools for development of Assurance Case	Testing based on alternative method of assessment	
11. apply methods of assurance of IoT systems safety and security	Course Evaluation Questionnaire	
12. understand how Blockchain technology can solve business problems	Course Evaluation Questionnaire	
13. Blockchain usage in the IoT projects	Testing based on alternative method of assessment	
14. development of blockchain-based project for IoT protection.	Course Evaluation Questionnaire	
15. Blockchain-based video file integrity protection.	Course Evaluation Questionnaire	

13.3. HOURS DISTRIBUTION

Themes	Contact work hours							Time and tasks for individual work	
	Lectures	Consultations	Seminars	Practical work (training)	Laboratory work	Placements	**Total contact work**	**Individual work**	**Tasks**
1. Dependability and security concepts for IoT. 1.1. Taxonomy of safety and security requirements.	2		2				4	6	1.5 Hardware and software of Arduino platform.

1.2. Dependability, safety and security attributes taxonomy. 1.3. Risk analysis fundamentals.									1.6 Control logic implementation on the base of Arduino platform.
2. Dependability and safety models of IoT. 2.1. Reference architectures of Industrial IoT. 2.2. Dependability and safety measures. 2.3. Failure Mode, Effect and Criticality Analysis (FMECA) of IoT systems.	2				4		6	4	2.5 IoT systems for safety and security critical applications.
3. Security models for IoT. 3.1. IoT systems architectures from security outlook. 3.2. Security measures. 3.3. Threats and attacks modeling for IoT systems.	2				4		6	4	3.5. Tools for dependability and security modelling.
4. Safety management requirements to IoT. 4.1. Safety & security management plan. 4.2. Human resource management. 4.3. Configuration management. 4.4. Tools selection and evaluation. 4.5. Documentation management. 4.6. Safety & security assessment.	2				4		6	4	4.7 Project management.
5. Safety and security life cycle for IoT. 5.1. Overall life cycle. 5.2. Safety & security life cycle: design top-down brunch. 5.3. Safety & security life cycle: integration down-top brunch. 5.4. Requirements tracing.	2				4		6	4	5.5. Terms used in requirements engineering.
6. Review, analysis and testing techniques for IoT. 6.1. Documents review. 6.2. Static code analysis. 6.3. Functional testing. 6.4. Code structural testing.	2		2				4	6	6.7. Penetration testing. 6.8. Terms used in software testing.
7. Assurance Case fundamentals. 7.1. Assurance Case concept and history. 7.2. Standards for Assurance Case.	2				4		6	4	1.5. Software tools for Assurance Case development.
8. Safety and security techniques and measures for IoT. 8.1. Claims, Arguments and Evidence (CAE) notation. 8.2. Update and application of Claims, Arguments and Evidence (CAE) notation 8.3. Goal Structuring Notation (GSN).	2				4		6	4	8.4. Techniques and measures overview. 8.5. Techniques directed to attacks avoidance.
9. Security informed and energy efficiency informed Assurance Case for IoT 9.1. Tools for development of Assurance Case. 9.2. Assurance Case structure for IoT systems.	2		2				4	6	9.3. Measurement of energy consumption for IoT device layer.
10. Bases of blockchain technology and examples of application	2				4		6	4	10.4. Hash Function 10.5. Generating Hash function

10.1 The principle of the blockchain technology 10.2 Block structure and Merkle tree 10.3 Blockchain cryptography									with specified parameters and study the time complexity
11. Consensus algorithms in blockchain technology 11.1 Proof-of-work algorithm 11.2 Proof of Stake algorithms 11.3 Blockchain technology for the IoT security	2		2				4	6	11.4. Research of consensus algorithm for IoT. 11.5. Comparison of consensus algorithm usage for IoT systems
12. Blockchain technology for the IoT security 12.1 Blockchain and the IoT 12.2 Benefits of Integrating Blockchain with IoT 12.3 Main challenges of blockchain in IoT 12.4 Blockchain-*based the* IoT *security* solutions	2				4		6	4	12.4. Blockchain based IoT security. 12.5. Blockchain development and simulation for data integrity protection
Total	**24**		**8**		**32**			**56**	

13.4. COURSE ASSESSMENT STRATEGY

Assessment strategy	Weight in %	Deadlines	Assessment criteria
Lecture activity, including fulfilling special self-tasks	10	7,14	85% – 100% Outstanding work, showing a full grasp of all the questions answered. 70% – 84% Perfect or near perfect answers to a high proportion of the questions answered. There should be a thorough understanding and appreciation of the material. 60% – 69% A very good knowledge of much of the important material, possibly excellent in places, but with a limited account of some significant topics. 50% – 59% There should be a good grasp of several important topics, but with only a limited understanding or ability in places. There may be significant omissions. 45% – 49% Students will show some relevant knowledge of some of the issues involved, but with a good grasp of only a minority of the material. Some topics may be answered well, but others will be either omitted or incorrect. 40% – 44% There should be some work of some merit. There may be a few topics answered partly or there may be scattered or perfunctory knowledge across a larger range. 20% – 39% There should be substantial deficiencies, or no answers, across large parts of the topics set, but with a little relevant and correct material in places. 0% – 19% Very little or nothing that is correct and relevant.
Learning in laboratories	30	7,14	85% – 100% An outstanding piece of work, superbly organized and presented, excellent achievement of the objectives, evidence of original thought. 70% – 84% Students will show a thorough understanding and appreciation of the material, producing work without significant error or omission. Objectives achieved well. Excellent organization and presentation. 60% – 69% Students will show a clear understanding of the issues involved and the work should be well written and well organized. Good work towards the objectives. The exercise should show evidence that the student has thought about the topic and has not simply reproduced standard solutions or arguments.

			50% – 59% The work should show evidence that the student has a reasonable understanding of the basic material. There may be some signs of weakness, but overall the grasp of the topic should be sound. The presentation and organization should be reasonably clear, and the objectives should at least be partially achieved. 45% – 49% Students will show some appreciation of the issues involved. The exercise will indicate a basic understanding of the topic, but will not have gone beyond this, and there may well be signs of confusion about more complex material. There should be fair work towards the laboratory work objectives. 40% – 44% There should be some work towards the laboratory work objectives, but significant issues are likely to be neglected, and there will be little or no appreciation of the complexity of the problem. 20% – 39% The work may contain some correct and relevant material, but most issues are neglected or are covered incorrectly. There should be some signs of appreciation of the laboratory work requirements. 0% – 19% Very little or nothing that is correct and relevant and no real appreciation of the laboratory work requirements.
Course Evaluation Quest	60	8,16	The score corresponds to the percentage of correct answers to the test questions

14. TEACHING PROGRAMME OF THE COURSE PC4 "DEVELOPMENT AND IMPLEMENTATION OF IOT-BASED SYSTEMS"

14.1. DESCRIPTION OF THE COURSE

TITLE OF THE COURSE	Code
Development and Implementation of IoT-based Systems	**PC4**

Teacher(s)	Department
Coordinating: Prof., DrS. Yu.P. Kondratenko **Others:** Modules PCM4.2, PCM4.3: Ass. Prof., Dr. G.V. Kondratenko, Ass. Prof., Dr. Ie.V. Sidenko, Ph.D. Student M.O. Taranov. Module PCM4.1: Prof., DrS. I.S. Skarha-Bandurova, Ph.D. Student A.Y. Velykzhanin, Senior Lect. L.V. Barbaruk	Intelligent Information Systems (PMBSNU) Computer Science and Engineering (V. Dahl EUNU)

Study cycle	Level of the course	Type of the course
PhD	A	Bounden

Form of delivery	Duration	Language(s)
Full-time tuition	One semester	English

Prerequisites	
Prerequisites: Computer Networks; Information Networking Technologies; Embedded systems; Theory of Control Systems; Network security; Multi-criteria Decision Making; Fuzzy Sets and Fuzzy Logic; Artificial Intelligence Systems; Soft Computing; Digital electronics; Microcontrollers	**Co-requisites (if necessary):** Data encryption; Modelling systems; Machine Learning; Multi-agent Systems and Technologies

Credits of the course	Total student workload	Contact hours	Individual work hours
3	90	42	48

14.2. COMPETENCES AND LEARNING OUTCOMES

Aim of the course: competences foreseen by the study programme
The aim of the course is to give deep understanding principles of operation the platforms and tools for IoT application, acquisition skills in of operating with IoT-cellular modules, configuring and administrating IoT-cloud, customization fleet of devices with cloud platform. In addition, the sub-aim is to deepen the knowledge of IoT-based systems for future practical use for the development of prototype systems, to acquire new knowledge and skills to configure IoT-based systems and their further learning to adapt to different operating conditions. Relevant knowledge is based on a study of the features and methods of information models formation for IoT-based devices and technologies for processing and transfer data between devices. In addition, corresponding knowledge is based on exploring and assimilation methods and technologies of machine learning, principles of construction of multi-agent interconnected IoT-based devices and methods of multi-criteria decision making for choosing the IoT platform for further development of own IoT system. Obtained knowledge will allow choosing the means and technologies for the development and implementation of IoT-based systems.

General Competences	Professional Competences	
• The ability to independently learn the basics of new research methods, changes in the scientific, research and production profile of their activities. • The ability to generate new ideas (creativity), identify, pose and solve problems, find optimal ways to solve them. • The ability to manage projects, organize teamwork, take the initiative to improve activities.	• The ability to apply professional knowledge and practical skills to solve typical problems in the specialty. • The ability to analyze and make reasonable choices of technologies, methods and tools for developing energy efficient solutions for IoT and embedded systems. • The ability to use scientific and practical methods of research, use and improvement of computer systems of artificial intelligence and mastering the skills of developing neural networks. • The ability to analyze and reasonably choose the technical means of developing software and hardware systems and systems for IoT solutions. • The ability to independently analyze and make reasonable choice of technologies, methods and tools for assessing and ensuring security at the design stage of critical IT infrastructures. • The ability to analyze and make reasonable choice of technologies and tools for developing critical software software and hardware systems for IoT solutions.	
Learning outcomes of course	**Assessment methods**	**Innovative teaching and learning methods.**
At the end of course, the successful student will be able to: 1. Explain and discuss the basic criteria to choose the platform and tools to design IoT application	Course Evaluation Questionnaire	• Interactive lectures: lecture-discussion; problem-oriented lecture. • Learning in laboratories: analysis of errors & incidents; project method. • Cooperative learning: pair learning; synthesis of ideas; joint project. • Collective group learning: decision tree; master classes; discussion and debate. • Situational modeling of phenomena: simulations or simulation games; PRES-formula (from English Position - Reason - Explanation or Example - Summary). • Elaboration of discussion issues: method of determining the discussion position; changing the position and comparing alternative positions; debate. • Competitive learning: division of students into groups according to educational tasks; educational activities of students in groups; presentation of collective learning tasks (public speech).
2. Choose hardware and software platforms for prototyping and building IoT systems	Course Evaluation Questionnaire	
3. Explain main principles for adding cellular connectivity to IoT projects	Course Evaluation Questionnaire	
4. Compare IoT prototyping kits and development boards	Course Evaluation Questionnaire	
5. Define the information models of IoT-based devices and describe the functional possibilities and limitations using existing tools, means and technologies, in particular, Eclipse Vorto Software	Course Evaluation Questionnaire, Testing based on alternative method of assessment	
6. Analyze methods and technologies of cybersecurity in IoT networks	Course Evaluation Questionnaire	
7. Use tools and technologies for modeling IoT devices, integrating them into an IoT system, process and analyze relevant data on product rules and forecasting methods	Course Evaluation Questionnaire, Testing based on alternative method of assessment	
8. Rate and select protocols and standards for data processing and transfer for your own IoT system and network using Fuzzy TOPSIS method	Course Evaluation Questionnaire	
9. Create and teach multi-agent IoT-based systems	Course Evaluation Questionnaire	
10. Use existing methods of multi-criteria decision making for comparing and choosing the best decision in IoT sphere	Testing based on alternative method of assessment	
11. Apply soft computing, in particular, fuzzy logic approach for the selection of specialized IoT platform	Course Evaluation Questionnaire	

12. Analyze features of methods and technologies of machine learning	Testing based on alternative method of assessment	

14.3. HOURS DISTRIBUTION

Themes	Contact work hours							Time and tasks for individual work	
	Lectures	Consultations	Seminars	Practical work (training)	Laboratory work	Placements	**Total contact work**	**Individual work**	**Tasks**
1. IoT-based system development process 1.1. Phases and deliverables of an IoT technical strategy 1.2. The IoT development strategies 1.3. Strategies to planning IoT architectures 1.4 IoT-based systems design methodologies	2		2				**4**	**4**	1.5. IoT project application areas and business models 1.6. IoT acceleration platforms
2. The base components of the IoT systems connectivity to IoT projects 2.1. Major types of technological offerings from IoT 2.2. IoT device classification 2.3. IoT device design flow 2.4. Relationship between Sensor Networks and IoT 2.5. Basic principles for adding cellular connectivity to IoT projects: working with GSM-modules	2			4			**6**	**5**	2.6. IoT system customization 2.7. Deploying modules to the edge devices 2.8. GPS/Cellular Asset tracking
3. The IoT development boards and platforms for prototyping 3.1. The IoT platforms: types and selection criteria 3.2 Evaluation of IoT device management tools 3.3. Real-time data streaming and processing	2		2				**4**	**7**	3.4. IoT device management platform vs IoT data management platform 3.5. Managing the fleet of devices
4. IoT-based devices: models and network communication protocols 4.1. Types of models for IoT-based devices 4.2. Tools and means for the development of information models 4.3. Network communication protocols for IoT-based devices	2				2		**4**	**5**	4.4. Structural and functional models of IoT-based devices 4.5. Eclipse Vorto for creating information models
5. Technologies for data processing in IoT-based systems 5.1. Technologies for data collection and analysis from IoT devices 5.2. Technologies for data processing 5.3. Methods of management and forecasting	2			2			**4**	**4**	5.4. Methods and approaches for data processing in IoT-based systems during data transfer

6. Protocols and standards for data transfer between IoT-based devices 6.1 Protocols for data transfer 6.2. Standards for data transfer 6.3. Cybersecurity of IoT-based devices	2		2		2		**6**	**7**	6.4. Methods of physical and information protection in IoT 6.5. Risks in information security
7. Management systems and IoT platforms 7.1. Types and capabilities of management systems and IoT platforms 7.2. Multi-criteria approach for choosing the IoT platform 7.3. Soft computing for the selection of specialized IoT platform	2			2	2		**6**	**6**	7.4. Platform for control and management “iRidium” 7.5. The programming environment Arduino IDE
8. Multi-agent approach for development and management of IoT systems 8.1. Types and characteristics of agents 8.2. Communication agents with the external environment 8.3. Data transfer techniques between agents in IoT systems	2		2				**4**	**4**	8.4. AnyLogic development environment. 8.5. Self-organizing IoT systems 8.6. Agent modeling
9. Methods and approaches for learning of IoT-based systems 9.1 General principles of M2M learning and self-learning systems 9.2. Technologies and applications of M2M learning 9.3. Neural networks for learning of IoT-based systems	2				2		**4**	**6**	9.4. Self-learning IoT systems 9.5. Problems and prospects of machine learning
Total	**18**		**8**	**8**	**8**		**42**	**48**	

14.4. COURSE ASSESSMENT STRATEGY

Assessment strategy	Weight in %	Deadlines	Assessment criteria
Lecture activity, including fulfilling special self-tasks	10	7,14	85% – 100% Outstanding work, showing a full grasp of all the questions answered. 70% – 84% Perfect or near perfect answers to a high proportion of the questions answered. There should be a thorough understanding and appreciation of the material. 60% – 69% A very good knowledge of much of the important material, possibly excellent in places, but with a limited account of some significant topics. 50% – 59% There should be a good grasp of several important topics, but with only a limited understanding or ability in places. There may be significant omissions. 45% – 49% Students will show some relevant knowledge of some of the issues involved, but with a good grasp of only a minority of the material. Some topics may be answered well, but others will be either omitted or incorrect. 40% – 44% There should be some work of some merit. There may be a few topics answered partly or there may be scattered or perfunctory knowledge across a larger range. 20% – 39% There should be substantial deficiencies, or no answers, across large parts of the topics set, but with a little relevant and correct material in places. 0% – 19% Very little or nothing that is correct and relevant.
Learning in laboratories	30	7,14	85% – 100% An outstanding piece of work, superbly organized and presented, excellent achievement of the objectives, evidence of original thought.

			70% – 84% Students will show a thorough understanding and appreciation of the material, producing work without significant error or omission. Objectives achieved well. Excellent organization and presentation. 60% – 69% Students will show a clear understanding of the issues involved and the work should be well written and well organized. Good work towards the objectives. The exercise should show evidence that the student has thought about the topic and has not simply reproduced standard solutions or arguments. 50% – 59% The work should show evidence that the student has a reasonable understanding of the basic material. There may be some signs of weakness, but overall the grasp of the topic should be sound. The presentation and organization should be reasonably clear, and the objectives should at least be partially achieved. 45% – 49% Students will show some appreciation of the issues involved. The exercise will indicate a basic understanding of the topic, but will not have gone beyond this, and there may well be signs of confusion about more complex material. There should be fair work towards the laboratory work objectives. 40% – 44% There should be some work towards the laboratory work objectives, but significant issues are likely to be neglected, and there will be little or no appreciation of the complexity of the problem. 20% – 39% The work may contain some correct and relevant material, but most issues are neglected or are covered incorrectly. There should be some signs of appreciation of the laboratory work requirements. 0% – 19% Very little or nothing that is correct and relevant and no real appreciation of the laboratory work requirements.
Course Evaluation Quest	60	8,16	The score corresponds to the percentage of correct answers to the test questions