Internet of Things for Industry and Human Applications Fundamentals of Internet of Things

Internet of Things
for Industry and Human Applications

Fundamentals of Internet of Things

PRACTICUM

Funded by the Erasmus+ Programme of the European Union

Ministry of Education and Science of Ukraine
National Aerospace University "Kharkiv Aviation Institute"

A.V. Boyarchuk, O.A. Chemeris, O.O. Golembovska, S.Y. Hilgurt, O.O. Illiashenko, V.S. Kharchenko, M.O. Kolisnyk, O.I. Morozova, V.Y. Pevnev, V.V. Plietnov, M.V. Tsuranov

Internet of Things for Industry and Human Applications

Fundamentals of Internet of Things

Training and methodic manual

Edited by V.S. Kharchenko

Project
ERASMUS+ ALIOT "Internet of Things: Emerging Curriculum for Industry and Human Applications"
(573818-EPP-1-2016-1-UK-EPPKA2-CBHE-JP)

2019

UDC 004.415/.416](075.8)=111
I-73

Reviewers:
Dr. Mario Fusani, ISTI-CNR, Pisa, Italy
Dr. Olga Kordas, KTH University, Stockholm, Sweden
Viktor Kordas, KTH University, Stockholm, Sweden

I-73 Internet of Things for Industry and Human Application. Fundamentals of Internet of Things / V. S. Kharchenko (ed.). – Ministry of Education and Science of Ukraine, National Aerospace University KhAI, 2019. – 95 p.

ISBN 978-617-7361-96-0.

Training and methodic manual contains materials for practicum of MSc course "Fundamentals of Internet of Things" developed in frameworks of project "Internet of Things: Emerging Curriculum for Industry and Human Applications /ALIOT" (Project Number: 573818-EPP-1-2016-1-UK-EPPKA2-CBHE-JP, 2016-2019) funded by EU Program ERASMUS+. It's described practice works and seminars for modules "Concepts, domains and challenges of IoT applications", "Standards and metrics for IoT systems", "Communications and protocols of IoT systems". The book prepared by Ukrainian university teams with support of EU academic colleagues of the ALIOT consortium.

It is intended for MSc and PhD students studying IoT technologies, software and computer engineering and science. It could be useful for lecturers of universities and training centers, developers of IoT systems.

Ref. – 107 items, figures – 11, tables – 9.

Approved by Academic Council of National Aerospace University "Kharkiv Aviation Institute" (record № 4, December 19, 2018).

ISBN 978-617-7361-96-0.

Міністерство освіти і науки України
Національний аерокосмічний університет
ім. М. Є. Жуковського «Харківський Авіаційний Інститут”

А.В. Боярчук, О.А. Чемеріс, О.О. Голембовська, С.Я. Гільгурт,
О.О. Ілляшенко, В.С. Харченко, М.О. Колісник, О.І. Морозова,
В.Я. Певнев, В.В. Плєтньов, М.В. Цуранов

Інтернет речей
для індустріальних і гуманітарних застосунків

ОСНОВИ ІНТЕРНЕТУ РЕЧЕЙ

Навчально-методичний посібник

Редактор Харченко В.С.

Проект ERASMUS+ ALIOT
“Інтернет речей: нова освітня програма для потреб промисловості та суспільства”
(573818-EPP-1-2016-1-UK-EPPKA2-CBHE-JP)

2019

УДК 004.415/.416](075.8)=111
І-73

Рецензенти: Др. Маріо Фузані, ISTI-CNR, Піза, Італія
Др. Ольга Кордас, KTH University, Стокгольм, Швеція
Віктор Кордас, KTH University, Stockholm, Sweden

І-73 Інтернет речей для індустріальних і гуманітарних застосунків. Основи Інтернету речей / За ред. В. С. Харченка. - Міністерство освіти і науки України, Національний аерокосмічний університет ХАІ, 2019. - 95 с.

ISBN 978-617-7361-96-0.

Навчально-методичний посібник містить матеріали практичної частини магістерського курсу «Основи Інтернету речей», розробленого в рамках проекту Internet of Things: Emerging Curriculum for Industry and Human Applications / ALIOT, 573818-EPP-1-2016-1-UK-EPPKA2- CBHE-JP, 2016-2019, що фінансується програмою ЄС ERASMUS+. Книга складається з 3 частин для відповідних модулів: Основні поняття сфери застосування і виклики Інтернету речей; Стандарти і метрики для систем Інтернету речей; Комунікації та протоколи Інтернету речей.

Підготовлено українськими університетськими командами за підтримки колег з академічних закладів країн ЄС, що входять до консорціуму проекту ALIOT.

Призначено для магістрантів і аспірантів, які вивчають технології IoT, програмну і комп'ютерну інженерію, комп'ютерні науки. Може бути корисною для викладачів університетів і навчальних центрів, розробників систем IoT.

Рис.: 12. Посилань: 56. Таблиць: 10.

Рекомендовано до видання вченою радою Національного аерокосмічного університету імені М.Є. Жуковського «Харківський авіаційний інститут» (протокол № 4 від 19 грудня 2018 г.).

ISBN 978-617-7361-96-0.

ABBREVIATIONS

ADC – Analog-to-digital converter
CAN – Controller Area Network
IoT – Internet of Things
IEC – International Electrotechnical Commission
ITU – International Telecommunication Union
IEEE – Institute of Electrical and Electronics Engineers
LAD – Ladder Diagram
MC – Microcontroller
MQTT – Message Queuing Telemetry Transport
SPI – Serial Peripheral Interface
WMS – Warehouse Management System
WoT – Web of Things

INTRODUCTION

Practicum support package for course “Fundamentals of Internet of Things” (MC1), was designed for master students within the framework ERASMUS+ ALIOT “Internet of Things: Emerging Curriculum for Industry and Human Applications” (573818-EPP-1-2016-1-UK-EPPKA2-CBHE-JP)[1].

The main aim of the course is to give MSc students understanding of the framework, key concepts and technologies of Internet of Things. The course covers modules MC1.1-MC1.4 “Concepts, domains and challenges of IoT applications”, “Architectures and platforms for IoT systems”, “Standards and metrics for IoT systems”, “Communications and protocols of IoT systems”.

The module MC1.1 “Concepts and domains of IoT” contains 1 seminar and 2 practical works. The seminar is intended to obtain experience in analysis of concepts and challenges of IoT application in industry and human domains. The first practice is intended to development of vision and specification for Internet of Everything projects. The second practice deals with study and apply features of IoT based logistics system for warehouse.

The module MC1.2 “Architectures and platforms for IoT systems” contains 9 laboratory works. The first lab is intended to get acquainted with virtual models of IoT devices in the Proteus software environment, getting practical skills of quickly debugging programs for AVR microcontrollers in the Proteus environment.

The second lab describes construction of algorithm and program for controlling the actuator – two-coordinate electric drive with numerical program control based on hardware, software and tools of the Arduino microcontroller platform.

The third lab provides acquisition of practical management skills for outputting static and dynamic information. The fourth lab gives practical skills in using counter timers in IoT applications. The fifth lab

[1] *The European Commission's support for the production of this publication does not constitute an endorsement of the contents, which reflect the views only of the authors, and the Commission cannot be held responsible for any use which may be made of the information contained therein.*

is intended to get practical skills in organizing asynchronous microcontroller devices. The sixth lab is about exploring the capabilities and techniques of using the SPI interface in AVR microcontrollers and programming skills for synchronous IoT application sharing. The seventh lab deals with an analog-to-digital converter of a microcontroller and writing programs for processing of digital analog signals.

In the eighth lab students will learn the method of building WoT-applications for Smart Devices based on the Integrative DirectConnectivity template and to acquire programming skills of both the client side of applications in HTML, CSS and JavaScript, and the server side of applications in JavaScript in Node.js.

Finally, the ninth first lab aims to obtain practical experience of getting the acquainted with the PLCnext Engineer toolbox capabilities for configuring the controller and creating applications with simple logic operations in relay-logic language. This controller produced by Phoenix Contact Company and used for development of IIoT (Industrial Internet of Things) systems.

The module MC1.3 "Standards and metrics for IoT systems" contains 2 seminars. The first seminar is intended to obtain experience in analysis and choice of standards, requirements and metrics for IoT systems. The second seminar deals with analysis of IoT reference models.

The module MC1.4 "Communications and protocols for IoT" includes 3 laboratory works. The first lab researches one of the most popular application level protocols of IoT, MQTT. The second lab researches one of the most popular protocol for data transfer in IoT network, namely message codings of IoT devices by means of the IP protocol. The third lab researches one of the most popular method of ensuring integrity for data transfer in IoT network. It means research of algorithms of noise immunity coding in IoT devices.

The course is intended for engineers, developers and scientists engaged in the development and implementation of of IoT-based systems, for postgraduate students of universities studying in areas of IoT, cybersecurity in networks, computer science, computer and software engineering, as well as for teachers of relevant courses.

The book covers first, third and fourth modules. Labs of the module MC1.2 are described in separate book [A.P. Plakhteyev, E.V. Babeshko, V.A. Tkachenko, J.V. Zdorovets. Architectures and embedded platform based development of Internet/ Web of Things / V.S.Kharchenko (edit.). Ministry of Education and Science of Ukraine, National Aerospace University, Kharkiv, 2019, 142p.].

This book prepared by Assoc. Prof., Dr. A. V. Boyarchuk (National Aerospace University "KhAI"), Snr. Res., DrS O. A. Chemeris (Pukhov Institute for Modelling in Energy Engineering, NAS Ukraine), O.O.Golembovska (IT Alliance), Dr. O.O.Illiashenko, Prof., DrS V.S.Kharchenko, Assoc. Prof., Dr. M.O.Kolisnyk, Assoc. Prof., Dr. O.I.Morozova, Assoc. Prof., Dr. V.Y.Pevnev, PhD student V.V.Plietnov, Senior Lecturer M.V.Tsuranov (National Aerospace University "KhAI").

General editing was performed by Head of Computer Systems, Networks and Cybersecurity Department of National Aerospace University "KhAI", Prof., DrS. V. S. Kharchenko.

The authors are deeply grateful to the reviewers, colleagues, staff of the departments of academic universities, and industrial partners for valuable information, assistance and constructive suggestions that were made during the course program discussion and assistance materials.

1. Concepts and domains of IoT

Seminar 1
Analysis of concepts and challenges of IoT application in industry and human domains

Assoc. Prof., Dr A. V. Boyarchuk, Dr O. O. Illiashenko,
Prof., DrS V. S. Kharchenko (KhAI)

Practice work 1
Development of project vision and specification for IoT application

O. O. Golembovska (IT-Alliance), V. V. Plietnov,
Prof., DrS V. S. Kharchenko (KhAI)

Practice work 2
Development of project of IoT based logistics system for warehouse

Assoc. Prof., Dr. O. I. Morozova (KhAI)

Seminar 1

Analysis of concepts and challenges of IoT application in industry and human domains

1. Seminar objectives

The objectives are to provide knowledge and practical skills on:

- preparation of a report (analytical review, state of the art) on analysis of methodology, concepts, human and industrial domains and challenges of IoT applications;
- preparation of a ppt presentation according with report results for short lecture/seminar for other students;
- presentation and defence of received results.

2. Seminar preparation

Seminar preparation includes the following steps.

1) **Assignment (choice) of report subject** (analytical review, SDP) and tasks specification.

The report subject has to be agreed with a lecturer. It can be chosen by students on their own desires and interests based on the following suggested list of the key words:

- concepts, methodology, paradigms, principles…;
- methods, techniques, tools, technologies…;
- Internet of Things, Internet of Everything, Internet of Peoples…:
- industrial IoT, Internet of Business, Internet of Cars, Internet of Drones…;
- dependable Internet, safe Internet, secure Internet, trust Internet…;
- Internet of safe/unsafe Things, Internet of secure/unsecure Things, Internet of reliable/unreliable Things…;
- Big Data, Artificial Intelligence, Machine Learning, Machine Vision…;
- communication, protocols, 5G,…;

- smart buildings and cities, intelligent transport, ecology monitoring, smart grid, e-health…;
- cloud computing, fog computing, edge computing….

Suggested report subjects (can be extended):

- Comparative analysis of Internet of Things concept and its evolution for last twenty years;
- Generalized More's Law and IoT development and implementation;
- (X) Internet for (Y) (Z/Things);
- Internet of Things and Web of Things: comparative analysis of concepts and technologies;
- Paradigm of von-Neumann and development of reliable Internet of unreliable things;
- Internet of Things for smart energy: idea, problems and solutions;
- Internet of Things for smart water: idea, problems and solutions;
- Internet of Things for smart mobility and public services: idea, problems and solutions;
- Analysis of publication dynamics on IoT for the last ten years;
- IoT and challenges in safety: IoT for safety and safety of IoT;
- IoT and challenges in security: IoT for security and security of IoT;
- Big Data and IoT implementation: problems and solutions;
- Artificial intelligence and IoT implementation: problems and solutions;
- Internet of Things development in context of 5G;
- Tools for IoT development and implementation, etc.

Report subject is to be agreed with the lecturer and consist with the subject area of the course (Fundamentals of IoT and IoE).

2) **Work plan development and responsibility assignment among target group members.** Work plan can be presented as a Gantt chart that includes the main events, time-frames and assignment of responsibility among the target group members.

The target group consists of 3 persons. Time for individual work is 6x3=18 hours (+ 20 minutes for the presentation and defence). The responsibility assignment is determined by the group members.

Suggested responsibility assignment:

- manager responsible for planning and coordination of activities and presents the idea on the seminar (1st part of the overall report - task statement),
- analyst or system developer (2nd part of the report),
- application developer (3rd part of the report + style concept).

3) **Search of the information about report subject** (library, the Internet, resources from department) and primary analysis. The search of the information is conducted using the keywords given in paragraph 2 (1). Methodological guidelines and the selected readings are given individually (per groups).

Please use reference list [1-31] in particular:

- introduction, challenges and theoretical issues for IoT/IoE are described in Introduction (section 0) and Part I (sections 1-2) of the book [1];
- techniques and tools for development, assessment and implementation are considered in sections 16-31 of the book [2] and sections 32-56 of the book [3];
- additional information for preparation to seminar and development of the report and presentation presented in [4-31].

4) **Report and presentation plans development**. Report plan includes:

- introduction (relevance, reality challenges, brief analysis of the problem - references, purpose and tasks of the report, structure and contents characteristics);
- systematized description of the main report parts (classification schemes, models, methods, tools, technologies, selection of indexes and criteria for assessment, comparative studies);
- conclusions (established goal achievement, main theoretical and practical results, result validity, ways of further work on the problem);
- list of references;
- appendixes.

5) **Report writing.** The report should stand for 15-20 A4 pages (font size 14, spacing 1.5., margins 2 cm) including the title page, contents, main text, list of references, appendixes. Unstructured reports or reports compiled directly from Internet sources (more 50%), having incorrect terms and no conclusion shall not be considered.

The work plan and responsibility assignment (Gantt chart), presentation slides and an electronic version of all material related to the work are required to be included in appendixes.

6) **Presentation preparation.** The presentation is to be designed in PowerPoint and be consistent with the report plan (10-15 slides); the time-frame for the presentation is 15 minutes.

The presentation should include the slides as follows:

- title slide (specification of the educational institution, department, course of study, report subject, authors, date);
- contents (structure) of the report;
- relevance of the issues covered, the purpose and the tasks of the report based on the relevance analysis;
- slides with the details of the tasks;
- report conclusion;
- list of references;
- testing questions.

Each slide should include headers with the report subject and authors. The contents of the slides should include the keywords, figures, formulas rather than the parts from the report.

The information can be presented dynamically.

3. Presentation and defence

The presentation should be given at the seminar during 15-20 minutes including presentation (10-15 minutes) and discussion (5-10 minutes) with participation of students and lecturer(s). Time schedule can be specified by lecturer. Total time of seminar 2 hours.

4. Report assessment

The work is assessed on the following parameters:

a) report text quality (form and contents),

b) presentation quality (contents and style),

c) report quality (contents, logical composition, timing shared among parts, conclusion),

d) fullness and correctness of the answers.

Each student is given an individual mark for the report and the presentation based on the results and responsibility assignment. Mark depends on active participation of students during discussion of all projects.

5. References

1. Internet of Things for Industry and Human Application. In Volumes 1-3. Volume 1. Fundamentals and Technologies /V. S. Kharchenko (ed.) - Ministry of Education and Science of Ukraine, National Aerospace University KhAI, 2019. – 605 p.

2. Internet of Things for Industry and Human Application. In Volumes 1-3. Volume 2. Modelling and Development /V. S. Kharchenko (ed.) - Ministry of Education and Science of Ukraine, National Aerospace University KhAI, 2019. – 547 p.

3. Internet of Things for Industry and Human Application. In Volumes 1-3. Volume 3. Assessment and Implementation /V. S. Kharchenko (ed.) - Ministry of Education and Science of Ukraine, National Aerospace University KhAI, 2019. – 918 p.

4. Dependable Internet of Things for Industry and Human Domains / V. Kharchenko, Ah Lian Kor, A. Rusincki (editors), River Publishers, 2019, 622 p.

5. "Internet of Things Online Course | MIT Sloan Executive Education", *Executive.mit.edu*, 2019. [Online]. Available: https://executive.mit.edu/openenrollment/program/internet-of-things-business-implications-and-opportunities/#.XTysbuZR3IV. [Accessed: 27- Jul- 2019].

6. "Define IoT - IEEE Internet of Things", *Iot.ieee.org*, 2019. [Online]. Available: https://iot.ieee.org/definition.html. [Accessed: 27- Jul- 2019].

7. ITUIT Study Group 13 leads the work of the ITU on standards for next generation (NGN) and future networks (ITU, SERIES Y, 2005), 2005.

8. R. Journal, "That 'Internet of Things' Thing - 2009-06-22 - Page 1-RFID Journal", *Rfidjournal.com*, 2019. [Online]. Available: http://www.rfidjournal.com/article/view/4986.[Accessed: 27 Jul 2019].

9. A. Gabbai, "Kevin Ashton Describes "the Internet of Things"", *Smithsonian*, 2015. [Online]. Available: https://www.smithsonianmag.com/innovation/kevin-ashton-describes-the-internet-of-things-180953749/#CCK32kDiIlxVuB1j.99. [Accessed: 27- Jul- 2019].

10. G. Santucci, "The Internet of Things: Between the Revolution of the Internet and the Metamorphosis of Objects, 2010. Available: http://ec.europa.eu/information_society/policy/rfid/documents/iotrevolution.pdf [accessed June 01, 2018].

11. "Everything you need to know about IIoT | GE Digital", *Ge.com*, 2018. [Online]. Available: https://www.ge.com/digital/blog/everything-you-need-know-about-industrial-internet-things. [Accessed: 27- Jul- 2019].

12. T. Kochanski, "Technologies and Tools to build the Internet of Things," IEEE Electron Devices, Solid State Circuits and Computer Societies and GBC/ACM, June 8, 2011 Analog Devices Wilmington, MA 01887.

13. B. Metcalfe, "Metcalfe's Law after 40 Years of Ethernet", *Computer*, vol. 46, no. 12, pp. 26-31, 2013. Available: 10.1109/mc.2013.374.

14. 5G in Five Minutes 5G Video: Skyworks CTO Peter Gammel explains the critical components for 5G and their importance in the evolution of 5G technologies, Skyworks. Available: www.skyworksinc.com/5G [accessed May 29, 2018].

15. "Azure/ai-toolkit-iot-edge", *GitHub*. [Online]. Available: https://github.com/Azure/ai-toolkit-iot-edge. [Accessed: 28- Jul- 2019].

16. J. von Neumann, "Lectures on probabilistic logics and the synthesis of reliable organisms from unreliable components", 1952.

17. V. Kharchenko and A. Gorbenko, "Evolution of von Neumann's paradigm: Dependable and green computing", in *East-West Design & Test Symposium*, 2013.

18. H. Parkinson and G. Bamford, "The Potential for Using Big Data Analytics to Predict Safety Risks by Analysing Rail Accidents", in *Third International Conference on Railway Technology: Research, Development and Maintenance*, 2016.

19. R. Toshniwal, K. Ghosh Dastidar and A. Nath, "Big Data Security Issues and Challenges", *International Journal of Innovative Research in Advanced Engineering*, vol. 2, no. 2, pp. 15-20, 2015. [Accessed 28 July 2019].

20. Z. Alam and H. Patel, "Security and Privacy Issues of Big Data in IoT based Healthcare System using Cloud Computing", *International Journal on Recent and Innovation Trends in Computing and Communication*, vol. 5, no. 6, pp. 26-30, 2017. [Accessed 28 July 2019].

21. B. Khalid and N. Abdelwahab, "Big Data and Predictive Analytics: Application in Public Health Field", *International Journal of Computer Science and Information Technology and Security*, vol. 6, no. 5, pp. 1-6, 2016. [Accessed 28 July 2019].

22. "What is the Internet of Things? Internet of Things definitions", *i-SCOOP*, 2016. [Online]. Available: https://www.i-scoop.eu/internet-of-things/. [Accessed: 28- Jul- 2019].

23. V. Kharchenko and V. Torianyk, "Cybersecurity of the Internet of Drones: Vulnerabilities analysis and IMECA based assessment", in *2018 IEEE 9th International Conference on Dependable Systems, Services and Technologies*, 2018.

24. A. Strielkina, D. Uzun and V. Kharchenko, "Availability models for healthcare IoT systems: Classification and research considering attacks on vulnerabilities", in *2018 IEEE 9th International Conference on Dependable Systems, Services and Technologies*, 2018.

25. Yaremchuk and Kharchenko, "Big data and similarity-based software reliability assessment: The technique and applied tools", in *2018 IEEE 9th International Conference on Dependable Systems, Services and Technologies*, 2018.

26. Top 10 strategical technology trends in 2019 have been presented by Gartner company [https://www.gartner.com/en/doc/383829-top-10-strategic-technology-trends-for-2019-a-gartner-trend-insight-report].

Practice work 1

Development of vision and specification for Internet of Everything projects

1. Objectives

The objectives are to provide knowledge and practical skills on:

- preparation of vision and brief specification of developed project (VDP and SDP) on application of IoT/IoE for different domains and in combining with other modern technologies;
- (according with requirements of lecturer) 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;
- presentation and defence of received results.

2. Tasks

Task 1. Brain storming on generation of IoT/IoE application.

Task 2. Development of project vision (VDP) for one of the generated IoE applications.

Task 3. Development of project specification for application of IoT and AR (augmented reality) for the art.

3. Program, requirements and variants

Practice work consists of the following stages.

3.1. **Tasks 1 and 2** (90 mins of class/contact time and 2 hours of individual work)

Stage 1 (individual work, 4 hours). Preparation to practice and learning of literature.

The preparation is based on the results of Seminar 1 and additionally includes learning of references related to:

- top-trends of development and implementation of information technologies in general, for example, described by Gartner [1];

- trends of IoT/IoE development and application [2, sections 0,1]; [3, section 56 and selected sections 32-55];

- (for tasks 3) application of augmented reality for different domains [4-6] and the following steps. Later AR technologies and their application for art should be analysed more closely using references [7-19].

Stage 2 (classes/contact time, Tasks 1, 30 mins). Carrying on brain storming on generation variants of IoT/IoE application.

Algorithm of this stage is the following:

- explanation of brain storming plan by lecturer (5 mins);
- forming of teams consisting of 3-5 students (2 mins). All 4-5 teams get access to Google form for loading results according with time schedule;
- tossing a coin (English alphabet, 26 letters; "difficult" letters as J, Q, V, W,… can be excluded or distributed separately). Every team gets 4-5 letters depending on number of teams and students (3 mins);
- team work (Task 1), generation of list for IoX projects (20 mins) according with letters (X = A, B, C,.D,…., Z). For example for letter A it may be Internet of Art, Internet of Alpinists,…; for letter B it may be Internet of Bracelets, Internet of Brains,... Teams have to generate as many variants and explain if necessary what does IoX mean using not more 3 sentences:

1) Idea is…;
2) IoX is realized by…:
3) Benefits of the project are the following…

Results of work are download by teams to the Google disc according with time schedule.

Stage 3 (classes/contact time, Tasks 2, 25 mins). Development of project vision for one of the IoX ideas generated at the previous stage.

Teams have to prepare 5 mins elevator pitch to convince the potential investor to buy your technology. This pith shall be presented with 3-5 slides to explain the following.

1. Describe your technology (idea, structure,…)
2. Define the problems this technology might help to solve

3. Know your target market (potential customer). Where is it expected to be used? (name industries or private customers)

4. Describe the competitors: are there any similar technologies existing? Is it completely new?

5. Expected milestone (stage of technology implementation)? How is to be introduced?

Teams download presentations to the Google disc according with time schedule.

Stage 4 (classes/contact time, Tasks 1 and 2, 30 mins). Defence of the developed lists of IoX ideas and VDPs. Time for presentations not more than 6 mins.

Stage 5 (classes/contact time, Tasks 1 and 2, 5 mins). Conclusions, assessment and discussions of the results.

3.2. **Task 3** (90 mins of class/contact time and 6 hours of individual work)

Stage 1 (individual work, 1 hour). Assignment (choice) of topic and specification of developed project (SDP). Task 3 is solved by team of 3-4 students with distribution of responsibility (manager, analyst, designer).

The topic of report for team has to be agreed with a lecturer and is related to application of IoT and AR (augmented reality) for the art. General topic of projects is "Development of gallery "IoT of smart paintings". More detailed description of scenarios for solution of such task is given in [19]. Additional information can be accessed on crictechs.csn.khai.edu (CriCTechS2019-2. Golembovska O.O./ presentation and video)

Subtasks of development are the following:

Subtask 3.1. Search of animation and embedding into presentation with the selected (according with variant) painting considering understanding, feeling and suggested call of image.

Subtask 3.2. Analysis of techniques and tools for application augmented reality to present image of the painting.

Subtask 3.3. Development of project specification for presentation of the selected painting using AR tools and creation of IoT of smart paintings.

Subtask 3.4. Addition of project specification (subtask 3.3) by functionality providing choice of image from set of suggested images.

Subtask 3.5. Preparation of presentation on subtasks 3.1-3.4 solutions and defence of results as a start-up project.

Students choose variants from Table 1.

Variant introduces painting and its main image/call, set of images/calls proposed by visitors of gallery and set of key images/calls which were determined using technique of semantic similarity analysis overviewed in [19] and described in [20-24].

An example of choice of image from set of suggested images is illustrated by table 2.

Table 1 – Variants of IoT systems for the students

No	Painting and main image/call	Set of images/ calls	Key images/ calls
1	 Heaven	Wings of angels, Horse, Waves, Mountain, Haze Dragon footprint, Sky, Cosmic, Ways, Deep, Folding Earth, Dragon, River Fantasy, Feathers, Depths, Winter Nights, Magnetic Storms, Sea Whirlwind	(Example) Heaven, Ocean, Mountain, Dragon
2	 Life Events	Raindrops on glass, Old tree, Dark thicket, Confrontation, Window pane and colored rain, Distressed wood, Icon of Mystery Woods, Continuous drips, Wooden fence, Rain outside the window, Rain on the fence, Rain, Drops on glass, Havy rain, There is rain outside the window or snow, Dropped lines, Thunderstorm outside the window	

3	 Becoming	Planet Mars, Desert afternoon, Earth, ocean, Martian landscape, Ocean and desert embrace, Earth climat, Groundwater Pink Floyd, Oasis in the desert, Our planet sea, Sahara Dreams, Fragment of a planet, African Ocean	
4	 Blink	Feather of time, Sunset over waterfall, Road to the sky, Sunrise Arrow, Sunrise, Polar ways, Element, Fault Quill, Mirror reflection of a mountain in the water, Feather Waterfall in a Thunderstorm, Flames on the sea, Feather of time, Glow in the Night, Plume, Barracuda feather	
5	 Cosmos	Swimmer in a waterfall, Snow with fire, Dessert, Snowstorm, Star rain, Mixing of feelings, Ice, Bubble bath, Eruption, South Frost, Meteor shower, Sweetness, Coral reef, Fire and frosty morning, Raging waves, Sasha and the ocean	
6	 Edge	Crystal, The road to the mouth of the volcano, Void, Onyx, Multilayer protection, Life border, Golden cockerel blue-red scallop, Dark siders, Deep sea, Frosty ear, Agate, Jupiter, Space, Underwater volcano, Volcano explosion, Red agate, Island, Birth of a star	

7	 Winter	Ice drift in Antarctica, Mushrooms (Virus), Depression, Rest, The barrier, Moonlight, Devil's Mine, Spring, Snow impressions, Ice, Under the microscope, Morning tide, White mist, Antarctic, Snow, Arctic, Antarctic, Glacier, Winter song, Ice powder, Caution: thin ice!	
8	 Thought	Planet, Gallerey for us, Nulifair, Magic ball, Revolution, Wave, Time slices, Convex and concave, Moon Oil, Sorcerer, Wave, Falling meteorite, Storm, Storm on Jupiter, Earth, The flip side of the Moon, Planet zero, Earth, Earth in a dream	
9	 Galaxy	Nebula, Cloud, Space, Galaxy from Earth, Lava, Galaxy Birth, Desert Constellation, Eruption, Bubbling Lava, Microworld, Island, Naissance d'une nation, Absorption, Top view, Subjugation, Iron waves, Island, Pister of Europe, The birth of the galaxy, Constellation, The birth of a new life	
10	 Treasure of Earth	The face, Heartsore, Mars mystery, Bloody body, Ocean bottom, Halloween, Purple haze, Mars interlacing, Red glacier, Highways, Hell, Dragon Heart, Bear peers over a man and heron, Who are you? The last sighs of the Dragon	

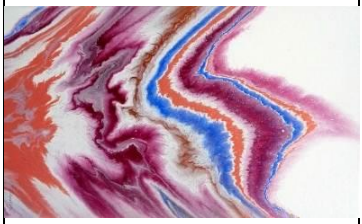
11	 4 seasons	Summer, Rainbow, Warrior, Picasso, Colour gradient, Four forces, Blue rainbow, Four seasons, Some classifications, Epochs, Individuality, Alchemy, Seasons, Minke, In crowded but not mad, 4 elements, Relay race	
12	 Splash	Explosion, Rock, Aurora, Harmony, Geyser blast, Orchid, Hippocampus, Calling occupants of Interplanetary Craft, Candy Sweets, Very tasty, Fairy, Tail rage\ anthill, Hutsul plaid, Cream, Fear, Falcon flight, Dynamic composition, Level	

Table 2 – An example of choice of image/call

Painting and main image/call	Set of images/calls	Chosen image / call
 Heaven	Wings of angels, Sky, Cosmic ways, Feather fantasy, Feathers, Depths, Winter nights, Magnetic storms, Whirlwind	Heaven
	Waves, Deep, Haze, Depths	Haze
	Mountain, Folding earth	Mountain
	Dragon river, Dragon footprint, Sea horse	Dragon

Stage 2 (individual work, 4 hours per student of team). Solving of subtasks 3.2-3.4.

Stage 3 (individual work, 1 hour per student of team)**.** Solving of subtask 3.5. Preparation of solutions presentation. The presentation is to be designed in PowerPoint and be consistent with the report plan (8-10 slides); the time-frame for the presentation is 10-12 minutes.

The presentation should include the slides as follows:

- title slide (specification of the educational institution, department, course of study, report subject, authors, date);
- contents (structure) of the report;
- relevance of the issues covered, the purpose and the tasks of the project;
- slides with the details of the tasks and solutions;
- conclusion;
- list of references.

Each slide should include headers with the report subject and authors.

Stage 4 (class/contact work, 2 hours). Presentation and defence of results as a start-up project by student teams. Assessment. Discussion and conclusions.

The presentation should be given at the seminar during 15-20 minutes including:

- presentation (10-12 minutes);
- discussion (5-8 minutes).

Time schedule can be specified by lecturer.

The work is assessed on the following parameters:

a) completeness and originality of SDP,

b) presentation quality (contents, logical composition, timing shared among parts, conclusion),

d) completeness and correctness of the answers.

Each student is given an individual mark for the presentation based on the results and responsibility assignment.

4. References

1. Top 10 strategical technology trends in 2019 have been presented by Gartner company [https://www.gartner.com/en/doc/383829-top-10-strategic-technology-trends-for-2019-a-gartner-trend-insight-report]

2. Internet of Things for Industry and Human Application. In Volumes 1-3. Volume 1. Fundamentals and Technologies /V. S. Kharchenko (ed.) - Ministry of Education and Science of Ukraine, National Aerospace University KhAI, 2019. – 605 p.

3. Internet of Things for Industry and Human Application. In Volumes 1-3. Volume 3. Assessment and Implementation /V. S. Kharchenko (ed.) - Ministry of Education and Science of Ukraine, National Aerospace University KhAI, 2019. – 918 p.

4. D. Van Krevelen, R. Poelman, “A survey of augmented reality technologies, applications and limitations”, International Journal of Virtual Reality, vol. 9 (2) , 2010, pp. 1-20.

5. A. R. M. Cuperschmid, R. C. Ruschel, M. R. de Freitas, “Technologies that support augmented reality applied in architecture and construction”, Cadernos Proarq Journal, 2019, http://www.proarq.fau.ufrj.br/revista/public/docs/Proarq19_TechnologiesReality_CuperschmidRuschelFreitas.pdf

6. J. Garbe Digital Borders and the Virtual Gallery. In: V. Geroimenko (edit.) Augmented Reality Art. Springer Series on Cultural Computing. Springer, Cham, 2014, pp 139-147.

7. Qu Meng, “The Aesthetic Experience of Augmented Reality Art”, in Proceedings of the 23rd International Symposium on Electronic Art ISEA, 2017, pp. 79–86.

8. G. Nithin, R. Bhooshan, “ARTAR-Artistic Augmented Reality”, Procedia Technology, vol. 24, 2016, pp. 1468-1474.

9. G. A. Rhodes Augmented Reality in Art: Aesthetics and Material for Expression. In: V. Geroimenko V. (edit.) Augmented Reality Art. Springer Series on Cultural Computing. Springer, Cham, 2014, pp 127-137.

10. K. C. Pucihar, M. Kljun “ART for Art: Augmented Reality Taxonomy for Art and Cultural Heritage”, In: Augmented Reality Art, 2018, pp.73-94, DOI: 10.1007/978-3-319-69932-5_3.

11. C. Chevalier and C. Kiefer, “What does Augmented Reality Mean as a Medium of Expression for Computational Artists?”, Leonardo Journal, 2018, http://sro.sussex.ac.uk/id/eprint/75178/3/Chevalierliefer__ms634_finalweb.pdf

12. https://www.culturepartnership.eu/

13. https://vimeo.com/41579089, Tele-Present Water installation, by David Bowen.

14. https://vimeo.com/15108251 eCloud installation, by Dan Goods.

15. https://nsynthsuper.withgoogle.com/ NSynth (Neural Synthesizer) Google project.

16. https://www.am-cb.net/docs/AMCB-MM-Overview.pdf

17. https://newbooksinpolitics.com/political/augmented-reality-art/

18. https://link.springer.com/content/pdf/ 10.1007%2F978-3-319-69932-5_8.pdf.

19. O. Golembovska, V. Kharchenko, I. Shostak, M. Danova, O. Feoktistova, V. Plietnov., "Augmented Reality for the Abstract Paintings: Application Scenarios, Semantic Similarity Analysis and Case Study", in Proceedings of the 23rd International Symposium on Electronic Art ISEA, 2017, pp. 1-6 (accepted).

20. T. Verhagen, B. Van de Hoof, and S. Meents, "Toward a Better Use of the Semantic Differential in IS Research: An Integrative Framework of Suggested Action," Journal of the Association for Information Systems, vol.16 (2), 2015, pp. 108–143.

21. Kuen Wai Ma, Hai Ming Wong, and Cheuk MingMak, "A systematic review of human perceptual dimensions of sound: Meta-analysis of semantic differential method applications to indoor and outdoor sounds," Building and Environment, vol. 133, 2017, pp. 123-150.

22. D. Dal Palù, E. Buiattia, G. E. Puglisi, O. Houix, P. Susini, C. De Giorgi, and A. Astolfi, "The use of semantic differential scales in listening tests: A comparison between context and laboratory test conditions for the rolling sounds of office chairs," Applied Acoustics, vol. 127, 2017, pp. 270-283.

23. A. L. Novikov, I. A. Novikova, "Semantic differential: theory and practical applications in linguistic and psychological research" [Metod semanticheskogo differentsiala: teoreticheskiye osnovy i praktika primeneniya v lingvisticheskikh i psikhologicheskikh issledovaniyakh], Vestnik RUDN, ser. Teoriya yazyka. Semiotika. Semantika, No. 3, 2011, pp. 63-71. (In Russ.).

24. P. Dalton, C. Maute, Oshida A., S. Hikichi, Y .Izumi, "The Use of Semantic Differential Scaling to Define the Multi-Dimensional Representation of Odors", Journal of sensory studies, vol. 23(4), pp. 485-497, 2008.

Practice work 2

Development of project of IoT based logistics system for warehouse

1. Objectives, tasks and synopsis

Objectives: to study and apply features of IoT based logistics system for warehouse.

Learning tasks:

- to develop a warehouse security system in the absence of working personnel;
- to regulate lighting in the warehouse using IoT technology.

Practical tasks:

- to learn main stages of organizing the implementation of IoT technology in a warehouse management system;
- to identify the specifications of sensors.

Exploring tasks:

- to compare different types of IoT technology devices;
- to organize the implementation of IoT technology in a warehouse management system.

Setting up

- to study the theoretical material contained in this manual, as well as a list of references;
- to get acquainted with he main elements of IoT based logistics system for warehouse.

Synopsis

In this practical work, you will get acquainted with the main elements of IoT based logistics system for warehouse.

2. Brief theoretical information

The complicated problem is to build a united system of educational processes management, taking into account the industrial requirements to modern IoT specialists. There appears necessity to increase the professional knowledge and skills by the implementation of new forms of education. One of the ways to resolve the problem in

question is the implementation of the dual system of education and teaching aimed at the improving of the personnel's vocational training quality. The dual system is the new and more flexible form of the vocational training organization, which stipulates for the coordinated interaction between the educational and the industrial branches for training of qualified personnel of the certain profile in the context of the organizationally different forms of training. In this connection, the topical question is the application of innovative technologies in the educational activity management, i. e. the management of knowledge, skills and experience acquisition process, in educational systems, and their realization in industry with the use of informational, communication and network technologies. Thus, there appears necessity for the development of the applied informational technologies integration principles, in systems with dual processes. The purpose of the creation of educational and industrial processes formalization technology is the development of formal representation instrumental means that can guarantee a united approach at building the special mathematical provision for informational and technological solutions in systems with dual processes. Now, let's consider industrial processes in IoT based logistics system for warehouse.

WMS (Warehouse Management System) is a hardware and software complex that allows you effectively management for the placement and movement of goods in the warehouse.

In the first phase of IoT implementation in the industrial production systems is installation of sensors, actuators, controllers and human-machine interfaces on the equipment. As a result, it becomes possible to collect information that allows management to obtain objective and accurate data about the production state. The processed data is provided to all enterprise departments. It helps to establish synergies between employees in different units and make informed decisions. Therefore, the presentation of information in an understandable form to the user is a priority. For this purpose, advanced analytical platforms are used for collecting, storing and analyzing data on technological processes and events occurring in real time [1].

Modern warehouses contain many assets that can be connected and optimized through the IoT technology. Sensors and actuators, in conjunction with radar or cameras, can allow them to interact with other devices and scan the environment for hidden objects that could cause a collision. The sensors can also be integrated into the storage infrastructure. For example, automatic lighting on/off depending on activity. Such systems regulate the energy consumption of devices, heating and ventilation systems. As a result, not only energy consumption is reduced, but also the impact on the environment is reduced [2].

The warehouse complexes in logistics system are solved the following main tasks:

- rational planning of the warehouse in the allocation of work areas, which helps to reduce costs and improve the process of cargo processing;
- effective use of space in the arrangement of equipment, which allows to increase the capacity of the warehouse;
- using the universal equipment that performs a wide range of warehouse operations;
- minimization of intra-warehouse transportation routes in order to reduce operating costs and increase the capacity of the warehouse [3].

3. Execution order and discovery questions

First various motion and light sensors should be considered before the system developing. In addition, a combination of sensors, which would present both motion and light response technology. For example, it could be selected a combined motion and light sensor KINASGARD® RBWF-LF-U [5]. The sensor has the following specifications.

Motion sensor: the principle of measurement is based on the radiation into the surrounding space of an electromagnetic field and the recording of its changes caused by reflection from objects moving in the sensitivity zone of the sensor. The protection of the measuring element is located in a housing with a plastic spherical lens. The reaction rate is less than 1 sec. Traffic Signal Output is a potential-free,

normally open contact that switches when motion is detected. The signal hold time is adjustable in the range of 4 seconds up to 16 minutes. The range of illumination measurement from 0 lux to 500 lux.

Light sensor: is a photodiode. Analog output light 0-10V, has a 3-wire connection. Linear error <± 5% of final value.

The motion and light sensor is intended for installation on the ceiling from 2 m to 10 m in height. The height of the installation practically does not affect the size of the sensitivity zone. The sensor can also be mounted on the wall at a level of 1.5-2 m from the floor to control the illumination of loading zones and goods at warehouses of different production areas.

The sensor captures the movement of a person or motor vehicle and transmits a control signal to the lighting and security system.

Main stages of organizing the implementation of IoT technology in a warehouse management system:

1. A sensor capable of collecting fluctuations along the perimeter of the warehouse should be selected, analyzing which can clearly identify the actions in the warehouse. In addition to the sensors were planned to be present control devices from the relay. The system must operate outdoors with a wide range of temperatures and weather phenomena.

2. The following should understand how to distribute information flows in the system. The organization of the network was chosen wired because wireless requires batteries. As a real-time system, the battery life will be very short. In addition, negative temperatures greatly reduce the capacity of the feed elements.

3. A bus was selected for the network architecture. However, the bus limits the length of the network and the number of devices. Therefore, a gateway has been added that has multiple buses that broadcasts data to and from the server. It also controls the power and environmental parameters. In addition, this modular approach with distributed computing load allows you to integrate a very large number of sensors into the overall system without significantly increasing server requirements. The rest of the actuators, like the sensors, are connected to the bus.

4. The following should determine how the data will be transferred. Each device in the system participates in two types of

exchange. Firstly, command from server po server response. Secondly, an asynchronous event from a device with a server.

Commands are used to change the status of the device and its setting. Events are generated when server information appears on the device. From the server side, the gateway is considered to be the same actuator as any other, since it, in addition to managing the devices on the bus, is also engaged in tracking power and temperature.

For example, it was compared two types of standards – RS-485 [6] and CAN [7]. These two standards allowed connecting many devices over long distances.

RS-485 (Recommended Standard 485) is the physical layer standard for the asynchronous interface. This standard uses one twisted pair of wires to transmit and receive data, sometimes accompanied by a screen braid or common wire. Data is transmitted by differential signals. The RS-485 standard specifies only the electrical and temporary characteristics of the interface. Also, the RS-485 standard does not specify the parameters of the signal quality, types of connectors and cables, galvanic isolation of the communication line, the exchange protocol.

CAN is an industry-standard network focused on integrating into a single network various actuators and sensors. Transmission mode is sequential, broadcast, packet. CAN is a Collision Resolution Synchronous Bus, which provides priority message access, which is particularly valuable for industrial management networks. Thus, the analysis gives preference to the CAN bus type.

5. The gateway has an Ethernet output, which is the most versatile data technology. The data transfer was organized using TCP/IP based Sockets.

4. Requirements to the content of the report

The report should include:

- title page;
- description of own selected motion and light sensor;
- results of development system with given required;
- conclusions.

5. Testing questions

1. What does mean Warehouse Management System?
2. What main tasks are solved the warehouse complexes in logistics system?
3. What are the different types of standards?
4. How the data can be transferred in IoT?
5. What are the main characteristics of the motion and light sensors?

6. References

1. Internet of Things [Online]. Available: https://www.it.ua/ru/knowledge-base/technology-innovation/internet-veschej-internet-of-things-iot.
2. INTERNET OF THINGSIN LOGISTICS. A collaborative report by DHL and Cisco on implications and use cases for the logistics industry [Online]. Available: https://discover.dhl.com/content/dam/dhl/downloads/interim/preview/updates/dhl-trend-report-internet-of-things-preview.pdf.
3. Grigoriev M.N., Uvarov S.A. Logistics. – M.: Yuryt Publishing House, 2014. – 836 p.
4. William Stallings. The Internet of Things: Network and Security Architecture [Online]. Available: http://ipj.dreamhosters.com/wp-content/uploads/issues/2015/ipj18-4.pdf.
5. KINASGARD® RBWF-LF-U [Online]. Available: https://spluss.de/ru/produkte-ru/osve-ennost-i-dvizhenie/datchiki-osve-ennosti-i-dvizheni/1401-41a1-1100-000-rbwf-lf-u/.
6. RS485 [Online]. Available: http://www.mika.ua/RS485.
7. Controller Area Network [Online]. Available: https://www.techopedia.com/definition/32255/controller-area-network-can.

2. Standards and metrics for IoT systems

Seminar 1

Choice of standards, requirements and metrics for IoT systems

Assoc. Prof., Dr. M. A. Kolisnyk,
Prof., DrS V. S. Kharchenko (KhAI)

Seminar 2

Analysis of IoT reference models

Assoc. Prof., Dr. M. A. Kolisnyk,
Prof., DrS V. S. Kharchenko (KhAI)

Seminar 1

Choice of standards, requirements and metrics for IoT systems

1. Seminar objectives

The objectives are to provide knowledge and practical skills on:

- overview of standards IEC, ITU, IEEE and others that can be used on the creation and maintenance of Internet of Things systems for industry/human domains;
- analysis of standards requirements to develop a set of non-functional requirements;
- determination of metrics to assess required attributes of IoT system;
- 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;
- preparation of a ppt presentation according with report results for short lecture/seminar for other students;
- presentation and defence of received results.

2. Seminar preparation

Seminar preparation includes the following steps.

7) **Assignment (choice) of report subject** (analytical review, SDP) and tasks specification.

The report subject has to be agreed with a lecturer. It can be chosen by students on their own desires and interests based on the following suggested list of the key words:

- standards IEC, ITU, IEEE,…for IoT and close technologies and systems;
- non-functional requirements to IoT systems, requirements to performance, functionality, reliability, security, safety, maintainability, availability,…;
- harmonization, profiling, choice of requirements;

- methods, techniques, tools, technologies…;
- Internet of Things, Internet of smart grid, Internet of smart buildings, Inernet of cities, industrial IoT, Internet of smart agriculture, Internet of cars, Internet of drones…;
- attributes, metrics, measures, indicators,…

Suggested variants of topics for report (can be extended):

Students choose variants from table 1 according with the list in the journal. Typical topics are the following:

- Analysis of standards, requirements and metrics for reliability assessment of IoT based smart buildings (variant 1);
- Analysis of standards, requirements and metrics for safety assessment of IoT based smart energy grids (variant 2)

and so on.

Table 1 – Variants of IoT systems for the students

№	IoT system	Attribute
1	Smart Building	Reliability
2	Smart Energy Grid	Safety
3	Internet of Vehicles	Availability
4	Smart Hospital	Cyber security
5	Smart Office	Reliability
6	Smart City	Safety
7	Smart Agriculture	Availability
8	Industrial IoT	Cyber security
9	Smart Parking	Reliability
10	Smart Street Lights	Usability and cost
11	Smart Hotel	Availability
12	Smart Elevators Connection	Cyber security
13	Smart Logistics	Reliability
14	Irrigation field monitoring	Effectiveness

8) **Work plan development and responsibility assignment among target group members.** Work plan can be presented as a Gantt

chart that includes the main events, time-frames and assignment of responsibility among the target group members.

The main events/tasks are the following:

- Approving of topic according with variant of tasks;
- Analysis of IoT system features for required domain;
- Selection of standards and standards requirements to attributes;
- Selection of metrics to assess system attributes;
- Preparation of report and presentation;
- Defence of report at the seminar.

The target group consists of 2 persons. Time resource is 2x6 = 12 hours (+ 20 minutes for the presentation and defence). The responsibility assignment is determined by students of the group or lecturer.

Suggested responsibility assignment:

- manager responsible for planning and coordination of activities and presents the technique of task solving (1st part of the overall report - task statement and selecting standards and requirements standards review),

- system developer/QA engineer (2nd part of the report – requirements profiling, selection of metrics).

9) **Search of the information for report and presentation** (library, the Internet, resources from department) and primary analysis. The search of the information is conducted using the keywords given in paragraph 2 of this seminar description.

IEC, ITU, IEEE and other sets of standards for IoT and related systems with short comments is presented in volume 1, section 3, subsection 3.1 [1]. Attributes and metrics, and features of domains are descrbed in subsections 3.2 and 3.3[1]. Principles, techniques and tool of development and application of IoT systems for different domains are given in volume 3[2].

Methodological guidelines and the selected readings are given individually (per groups). Please use reference list [1-21].

10) **Report and presentation plan development**. Report plan includes:

- introduction (relevance, brief analysis of the problem - references, purpose and tasks of the report, structure and contents review);
- description of the main report parts (domain, features of IoT systems, standards review, requirements selection and profiling according with attributes, selected metrics for attribute assessment);
- conclusions (established goal achievement, main practical results, result validity, ways of further work on the problem);
- list of references;
- appendixes.

11) **Report writing.** The report should stand for 15-20 A4 pages (font size 14, spacing 1.5., margins 2 cm) including the title page, contents, main text, list of references, appendixes. Unstructured reports or reports compiled directly from Internet sources (more 50%), having incorrect terms and no conclusion shall not be considered.

The work plan and responsibility assignment (Gantt chart), presentation slides and an electronic version of all material related to the work are required to be included in appendixes.

12) **Presentation preparation.** The presentation is to be designed in PowerPoint and be consistent with the report plan (10-15 slides); the time-frame for the presentation is 15 minutes.

The presentation should include the slides as follows:

- title slide (specification of the educational institution, department, course of study, report subject, authors, date);
- contents (structure) of the report;
- relevance of the issues covered, the purpose and the tasks of the report based on the relevance analysis;
- slides with the details of the tasks;
- report conclusion;
- list of references;
- testing questions.

Each slide should include headers with the report subject and authors. The contents of the slides should include the keywords, figures, formulas rather than the parts from the report.

The information can be presented isung dynamical slides.

3. Presentation and defence

The presentation should be given at the seminar during 20 minutes including: presentation (10-15 minutes); discussion (5-10 minutes).

Time schedule can be specified by lecturer.

4. Report assessment

The work is assessed on the following parameters:

a) report text quality (form and contents),

b) presentation quality (contents and style),

c) report quality (contents, logical composition, timing shared among parts, conclusion),

d) completeness and correctness of the answers.

Each student is given an individual mark for the report and the presentation based on the results and responsibility assignment.

5. Testing questions

1. What are main features of IoT systems applied in the domain (according with variant)?

2. What group of international standards on IoT and related technologies do you know?

3. Which key standards for IoT systems of specified domain do you selsct?

4. What are requirements to IoT attribute (performance, functionality, reliability, cyebr security and so on) can be selected from standards?

5. Which metrics can be used to assess the selected attribute of IoT system?

6. References

1. Internet of Things for Industry and Human Application. In Volumes 1-3. Volume 1. Fundamentals and Technologies /V. S. Kharchenko (ed.) - Ministry of Education and Science of Ukraine, National Aerospace University KhAI, 2019. – 605 p.

2. Internet of Things for Industry and Human Application. In Volumes 1-3. Volume 3. Assessment and Implementation /V. S. Kharchenko (ed.) - Ministry of Education and Science of Ukraine, National Aerospace University KhAI, 2019. – 918 p.

3. Alexander Fröde, Christopher Masara. Community-based ecological monitoring. Manual for practitioners. Harare, Aug. 2007. 64 p. SAFIRE - Southern Alliance for Indigenous Resources.

4. IoT Safety/Security Development Guidelines. Second Edition. Software Reliability Enhancement Center, Technology Headquarters, Information-technology Promotion Agency: Important Points to be understood by Software Developers toward the Smart-society. Jul., 2016. 106 p.

5. IETF Standardization in the Field of the Internet of Things (IoT): A Survey. Isam Ishaq, David Carels, Girum K. Teklemariam, Jeroen Hoebeke, Floris Van den Abeele, Eli De Poorter, Ingrid Moerman and Piet Demeester. J. Sens. Actuator Netw. 2013, 2, 235-287; doi:10.3390/jsan2020235. Journal of Sensor and Actuator Networks ISSN 2224-2708. Available at: http://www.mdpi.com/journal/jsan/.

6. IETF SG17-LS084. https://www.ietf.org/lib/dt/documents/LIAISON/liaison-2018-02-06-itu-t-sg-17-tsb-suit-ls-on-iot-secure-update-procedure-attachment-1.pdf.

7. https://www.itu.int/en/ITU-T/techwatch/Documents/1010-B_Jamoussi_IoT.pdf.

8. ITU-T SG20: Internet of things (IoT) and smart cities and communities (SC&C). 2019. https://www.itu.int/en/ITU-T/studygroups/2017-2020/20/Pages/default.aspx.

9. RFC3819. Advice for Internet Subnetwork Designers. 2004. https://tools.ietf.org/html/rfc3819

10. RFC 4944. Transmission of IPv6 Packets over IEEE 802.15.4 Networks. 2007. https://tools.ietf.org/html/rfc4944.

11. RFC 4861. Neighbor Discovery for IP version 6 (IPv6). 2007. https://tools.ietf.org/html/rfc4861.

12. RFC 5889. IP Addressing Model in Ad Hoc Networks. https://tools.ietf.org/html/rfc5889.

13. Andrey Dvornikov, Pavel Abramov, Sergey Efremov, Leonid Voskov, “QoS Metrics Measurement in Long Range IoT Networks”. [https://ieeexplore.ieee.org/document/8012393/].

14. A. Torkaman, M.A. Seyyedi. "Analyzing IoT Reference Architecture Models", International Journal of Computer Science and Software Engineering”, 5, No. 8 (2016), pp. 154-160.

15. Gerrod Andresen, Zachary Williams. Metrics, key performance indicators, and modeling of long range aircraft availability and readiness. NATO, RTO-MP-AVT-144. 12 p.

16. Internet of Things. IoT Governance, Privacy and Security Issues. European Research Cluster on the Internet of Things. Ovidiu Vermesan, Peter Friess, Coordinators of IERC Cluster. January, 2015. 128 p.

17. "Internet of Things Online Course | MIT Sloan Executive Education", *Executive.mit.edu*, 2019. [Online]. Available: https://executive.mit.edu/openenrollment/program/internet-of-things-business-implications-and-opportunities/#.XTysbuZR3IV. [Accessed 27 Jul 2019].

18. R. Journal, "That 'Internet of Things' Thing - 2009-06-22 - Page 1 - RFID Journal", *Rfidjournal.com*, 2019. [Online]. Available: http://www.rfidjournal.com/article/view/4986. [Accessed 27 Jul 2019].

19. Dependable Internet of Things for Industry and Human Domains / V. Kharchenko, Ah Lian Kor, A. Rusincki (editors), River Publishers, 2019, 622 p.

20. Z. Alam and H. Patel, "Security and Privacy Issues of Big Data in IoT based Healthcare System using Cloud Computing", *International Journal on Recent and Innovation Trends in Computing and Communication*, vol. 5, no. 6, pp. 26-30, 2017. [Accessed 28 July 2019].

21. A. Strielkina, D. Uzun and V. Kharchenko, "Availability models for healthcare IoT systems: Classification and research considering attacks on vulnerabilities", in *2018 IEEE 9th International Conference on Dependable Systems, Services and Technologies*, 2018.

Seminar 2

Analysis of IoT reference models

1. Seminar objectives

The objectives are to provide knowledge and practical skills on:
- analysis of components and architectures of IoT;
- discussion of reference model concept for IoT;
- analysis of the IoT reference models for different domains;
- analysis of the IoT reference models for different countris;
- preparation of a report on analysis of IoT reference models;
- preparation of a ppt presentation according with report results for short lecture/seminar for other students;
- presentation and defence of received results.

2. Seminar preparation

Seminar preparation includes the following steps.

1) Assignment (choice) of report subject (analytical review) and tasks specification. The report subject has to be agreed with a lecturer. It can be chosen by students on their own desires and interests based on the following suggested list of the key words:
- components, architectures, systems;
- reference model, Chinese reference model, Korean reference model,…;
- performance, functionality, reliability, security, safety, maintainability, availability,…;
- methods, techniques, tools, technologies…;
- Internet of Things, Internet of smart grid, Internet of smart buildings, parking, elevators, street lights,...

Suggested variants of topics for report (can be extended):
Students choice variants from table 1 according with the list in the journal. Typical topics are the following:

- Analysis of IoT-A reference model for smart buildings (variant 1);

- Analysis of Chinese IoT reference model for smart energy grids (variant 2)

and so on.

According with variant students should describe the layers of the IoT reference model indicating what is located on each of the layers.

Table 1 – Variants of IoT systems for the students

No	IoT system	Performance model of IoT
1	Smart Building	IoT-A
2	Smart Energy Grid	Chinese Architectural Reference Model
3	Internet of Vehicles	Korean Architectural Reference Model
4	Smart Hospital	WSO2 Architectural Reference Model
5	Smart Office	IoT-A
6	Smart City	Chinese Architectural Reference Model
7	Smart Agriculture	Korean Architectural Reference Model
8	Industrial IoT	WSO2 Architectural Reference Model
9	Smart Parking	IoT-A
10	Smart Street Lights	Chinese Architectural Reference Model
11	Smart Hotel	Korean Architectural Reference Model
12	Smart Elevators Connection	WSO2 Architectural Reference Model
13	Smart Logistics	IoT-A
14	Irrigation field monitoring	Chinese Architectural Reference Model

2) Work plan development and responsibility assignment among target group members. Work plan can be presented as a Gantt

chart that includes the main events, time-frames and assignment of responsibility among the target group members.

The main events/tasks are the following:

- Approving of topic according with variant of tasks;
- Analysis of IoT system features for required domain;
- Specifying and andlysis of reference model, its layers, services and so on;
- Preparation of report and presentation;
- Defence of report at the seminar.

The target group consists of 2 persons. Time resource is 2x6 = 12 hours (+ 20 minutes for the presentation and defence). The responsibility assignment is determined by students of the group or lecturer.

Suggested responsibility assignment:

- manager responsible for planning and coordination of activities and presents the technique of task solving (1st part of the overall report - task statement and approving features for selected IoT reference model),

- system developer/QA engineer (2nd part of the report – description of IoT reference model and its elements).

3) Search of the information for report and presentation (library, the Internet, resources from department) and primary analysis. The search of the information is conducted using the keywords given in paragraph 2 of this seminar description.

Refererence model is presented in volume 1, section 3, subsection 3.2.1 [1]. Attributes and metrics, and features of domains are descrbed in subsections 3.2 and 3.3[1]. Principles, techniques and tool of development and application of IoT systems for different domains are given in volumes 2[2] and 3[3].

Methodological guidelines and the selected readings are given individually (per groups). Please use reference list [1-8] and the following information.

IoT components and space are presented in Fig. 1 [4]. IoT represents the convergence of several interdisciplinary domains: networking, embedded hardware, radio spectrum, mobile computing, communication technologies, software architectures, sensing

technologies, energy efficiency, information management, and data analytics. The rapid growth of IoT is driven by four key advances in digital technologies.

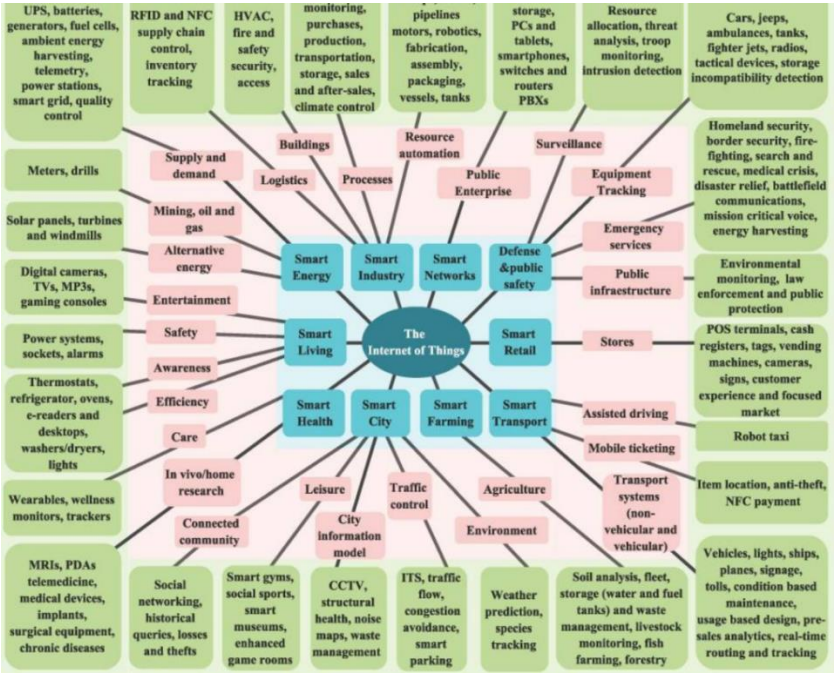


Fig. 1 – The structure of IoT space

The first one is the declining cost and miniaturization of ever more powerful microelectronics such as transducers (sensors and actuators), processing units (e.g., microcontrollers, microprocessors, SOCs (System-on-a-chip), FPGAs (Field-Programmable Gate Array), and receivers. Defense and Public Safety (PS) organizations play a critical societal role ensuring national security and responding to emergency events and catastrophic disasters.

A Reference Model is an abstract framework for understanding significant relationships among the entities of some environment. The IoT Reference Model provides the highest abstraction level for the definition of the IoT Architectural Reference Model.

Up to now, few standard committees have been researched in IoT reference model. Among them, the International Telecommunication Union (ITU) is one of the best organizations that proposed a comprehensive reference model in IoT environment. In this regard, an overview of the Internet of things (IoT) has provided by ITU-T Y.2060. It clarified the concept and scope of the IoT, identified the fundamental characteristics and high-level requirements of the IoT and described the IoT reference model. The reference model tries to establish a common grounding for IoT architectures and IoT systems. The ITU recommended reference model for IoT. It is composed of four layers as well as management and security capabilities which are associated with the four layers.

The four layers are as follows [4-6]:

- Application layer.
- Service support and application support layer.
- Network layer.
- Device layer.

Application layer: which contains IoT applications.

Service and application support layer: consists of common capabilities which can be used by different IoT applications and various detailed capability groupings, in order to provide different support functions to different IoT applications.

Network layer: provides relevant control functions of network connectivity and IoT services and applications transportation.

Device layer: includes direct/indirect device interaction with the gateway and communication network. Management capabilities: how to manage the devices, traffic and etc. Security capabilities: includes authorization, authentication, application data confidentiality and integrity protection, privacy protection, security audit, anti-virus and etc.

A Reference Architecture maps onto software elements that implements the functionality defined in the Reference Model. Actually, it models the architectural elements in the domain of the technologies, protocols, and products which used to implement the domain. A reference architecture tries to show the most complete picture of what is involved in realizing the modeled entities.

It is possible to define Reference Architectures at many levels of detail or abstraction and for many different purposes. Architecture handles requirements and forms a superset of functionalities, information structures, mechanisms and protocols.

4) Report and presentation plan development. Report plan includes:

- introduction (relevance, brief analysis of the problem – references, purpose and tasks of the report, structure and contents review);
- description of the main report parts (domain, features of IoT systems, reference IoT model description and analysis according with domain and country);
- conclusions (established goal achievement, main practical results, result validity, ways of further work on the problem);
- list of references;
- appendixes.

5) Report writing. The report should stand for 15-20 A4 pages (font size 14, spacing 1.5., margins 2 cm) including the title page, contents, main text, list of references, appendixes. Unstructured reports or reports compiled directly from Internet sources (more 50%), having incorrect terms and no conclusion shall not be considered.

The work plan and responsibility assignment (Gantt chart), presentation slides and an electronic version of all material related to the work are required to be included in appendixes.

6) Presentation preparation. The presentation is to be designed in PowerPoint and be consistent with the report plan (10-15 slides); the time-frame for the presentation is 15 minutes.

The presentation should include the slides as follows:

- title slide (specification of the educational institution, department, course of study, report subject, authors, date);
- contents (structure) of the report;
- relevance of the issues covered, the purpose and the tasks of the report based on the relevance analysis;
- slides with the details of the tasks;

- report conclusion;
- list of references;
- testing questions.

Each slide should include headers with the report subject and authors. The contents of the slides should include the keywords, figures, formulas rather than the parts from the report.

The information can be presented isung dynamical slides.

3. Presentation and defence

The presentation should be given at the seminar during 20 minutes including: presentation (10-15 minutes); discussion (5-10 minutes).

Time schedule can be specified by lecturer.

4. Report assessment

The work is assessed on the following parameters:

a) report text quality (form and contents),

b) presentation quality (contents and style),

c) report quality (contents, logical composition, timing shared among parts, conclusion),

d) completeness and correctness of the answers.

Each student is given an individual mark for the report and the presentation based on the results and responsibility assignment.

5. Testing questions

1. What does reference model mean?
2. What features of architecture reference model so you know?
3. What are main features of reference IoT model for systems applied in the domain (according with variant)?
4. What are main features of reference IoT model applied in the country (according with variant)?
5. What layers of reference model do you know?

6. References

1. Internet of Things for Industry and Human Application. In Volumes 1-3. Volume 1. Fundamentals and Technologies /V. S. Kharchenko (ed.) - Ministry of Education and Science of Ukraine, National Aerospace University KhAI, 2019. – 605 p.

2. Interrnet of Things for Industry and Human Application. In Volumes 1-3. Volume 2. Simulation and Development /V. S. Kharchenko (ed.) - Ministry of Education and Science of Ukraine, National Aerospace University KhAI, 2019. – 547 p.

3. Internet of Things for Industry and Human Application. In Volumes 1-3. Volume 3. Assessment and Implementation /V. S. Kharchenko (ed.) - Ministry of Education and Science of Ukraine, National Aerospace University KhAI, 2019. – 918 p.

4. Internet of Things. IoT Governance, Privacy and Security Issues. European Research Cluster on the Internet of Things. Ovidiu Vermesan, Peter Friess, Coordinators of IERC Cluster. January, 2015. 128 p.

5. IoT Safety/Security Development Guidelines. Second Edition. Software Reliability Enhancement Center, Technology Headquarters, Information-technology Promotion Agency: Important Points to be understood by Software Developers toward the Smart-society. Jul., 2016. 106 p.

6. A. Torkaman, M.A. Seyyedi. "Analyzing IoT Reference Architecture Models", International Journal of Computer Science and Software Engineering", 5, No. 8 (2016), pp. 154-160.

7. Gerrod Andresen, Zachary Williams. Metrics, key performance indicators, and modeling of long range aircraft availability and readiness. NATO, RTO-MP-AVT-144. 12 p.

8. Internet of Things. IoT Governance, Privacy and Security Issues. European Research Cluster on the Internet of Things. Ovidiu Vermesan, Peter Friess, Coordinators of IERC Cluster. January, 2015. 128 p.

3. Communication and protocols for IoT

Laboratory work 1
Researching the MQTT protocol for IoT

DrS., Snr. Res. O. A. Chemeris (IPME)

Laboratory work 2
Message codings of IoT devices by means of the IP protocol

Dr., Assoc. Prof. V. Y. Pevnev (KhAI)
Snr. Lectr. M. V. Tsuranov (KhAI)

Laboratory work 3
Research of algorithms of noise immunity coding in IoT devices

Dr., Assoc. Prof. V. Y. Pevnev (KhAI)
Snr. Lectr. M. V. Tsuranov (KhAI)

Laboratory work 1

Researching the MQTT protocol for IoT

1 Objectives, tasks and synopsis

Goal and objectives. This laboratory work researches one of the most popular application level protocols of IoT, MQTT. We'll analyze the properties of the MQTT protocol in terms of power and traffic consumption.

Learning objectives:

– study an example of application level protocols of IoT;

– study MQTT's power and traffic consumption metering methodology.

Practical tasks:

– acquire practical skills in working with application level protocols of IoT;

– gather information about free or partially limited MQTT brokers realized as internet service.

Exploring tasks:

– connect your mobile device to and organize the exchange of data with an MQTT broker;

– investigate how devices, which use the MQTT protocol, consumes electrical power and mobile traffic.

Setting up. In preparation for laboratory work it is necessary:

– to clear the goals and mission of the research;

– to study theoretical material contained in this manual, and in [1–6] and [7, section 4];

– to familiarize oneself with the main procedures and specify the exploration program according to defined task.

Recommended software and resources. CloudMQTT (https://www.cloudmqtt.com/docs/index.html/) free MQTT broker (as alternative MQTT broker you can use ThingMQ, ThingStudio, IBM Bluemix, Microsoft Azure IoT or Heroku). A mobile device having

wireless connection to internet (mobile phone, pad, netbook or notebook).

Synopsis. In this laboratory work you will learn one of the most popular protocols of IoT. Specifically you will use application level protocol, MQTT. You'll explore this protocol using CloudMQTT, the free MQTT broker realized as internet service.

2 Brief theoretical information

The Internet of Things (IoT) covers a huge number of areas, ranging from industry to food [1]. Among the existing application level protocols of the IoT, the most widely used protocols besides HTTP/HTTPS are MQTT, AMQP, XMPP, DDS and CoAP.

The MQTT (Message Queuing Telemetry Transport) protocol was presented by Andy Stanford Clark of IBM and Arlan Nipper of Arcom (now Eurotech) in 1999 and was standardized in 2013 at OASIS [2]. It aims at connecting embedded devices and networks with applications and middleware.

The connection operation uses a routing mechanism (one-to-one, one-to-many many-to-many) and makes MQTT the optimal connection protocol for the IoT and M2M (machine to machine interaction).

This protocol is characterized by lower overhead costs for data transmission (due to a small amount of service traffic) and lower bandwidth, rather than, for example, the HTTP/HTTPS one [3]. This protocol is well adapted for low-power devices of the IoT based on microcontrollers.

For its work, the MQTT protocol does not require a permanent connection between the client and the server. In the MQTT protocol, it is possible to set parameters responsible for the reliability of message delivery.

In this regard, this protocol of the IoT helps to solve the problem of saving resources, both energy consumption and guaranteed delivery. This is especially actually due to the increase of the number of IoT devices.

MQTT is a simple messaging protocol that implements the publish/subscribe model and is used to connect computerized devices

connected to a local or global network between themselves and various public or private Web-services.

The protocol was created to ensure openness, simplicity, minimal resource requirements and ease of implementation. MQTT is located on top of TCP/IP stack and works with the client/server model, where each sensor is a client and is connected to a server that is a broker. The MQTT protocol requires the presence of a broker that manages the distribution of data to subscribers.

All devices or actuators send data only to the broker and also accept data only from him. In a network based on the MQTT protocol, three objects are distinguished (Fig.1):

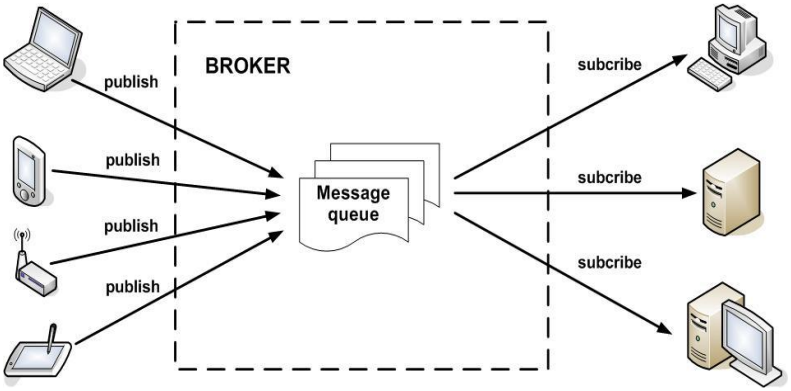


Fig. 1 – Architecture of MQTT

- Publisher – MQTT client that, when a specific event occurs, sends information about it to the broker by publishing appropriate topics;

- Broker – MQTT server that receives information from publishers and transfers it to the appropriate subscribers. It can also perform various operations related to the analysis and processing of incoming data in complex systems. Different brokers can connect with each other if they subscribe to each other's messages;

- Subscriber – MQTT client who, after subscribing to a broker, “listens” to it most of the time and is always ready to receive and process an incoming message to topics of interest from the broker.

That is, when publisher transmits message M to a specific topic T, then all customers who subscribe to topic T receive this message M. For example, three clients are connected to a broker, clients B and C subscribe to the topic “temperature”. At some time, when client A sends the value “30” to the topic “temperature”, the broker sends this message to the subscribing clients immediately after receiving it. The MQTT provides 3 options for selecting the reliability of messaging, which are provided with three levels of quality of service. (QoS) [4]:

- QoS0 – the message is transmitted only once and does not require confirmation;
- QoS1 – the message is sent at least once and requires confirmation;
- QoS2 – for the delivery of communication, a four-stage handshake mechanism is used. In addition, the standard TLS (Transport Layer Security) security level is placed on top of the TCP level. Port 8883 provides security of communication, if the broker's address works with this port, then the traffic is transmitted with encryption.

3 Execution order and discovery questions

3.1 CloudMQTT internet broker

To date, there are several free or partially limited MQTT brokers realized as internet service: ThingMQ, ThingStudio, CloudMQTT, IBM Bluemix, Microsoft Azure IoT, Heroku and others. Limitations may concern the number of users or the amount of memory provided. CloudMQTT by Amazon is one of the simplest and most usable, at the same time it does not require high programming skills [5].

3.2 Registration on the CloudMQTT broker internet site.

To start, register for free at https://www.cloudmqtt.com [6].

3.3 Creating a new instance

As the next step create a new instance by clicking the "Create New Instance" button. After that the settings window opens (Fig. 2). Name the instance as "Test-NN", where NN is the student's number. From the offered variants of an instance type choose "Cute Cat (Free)" i.e. create a free broker for up to 5 users. Select one of the available

servers, preferably the nearest one, for example, EU-West-1 (Ireland) (Fig. 3).

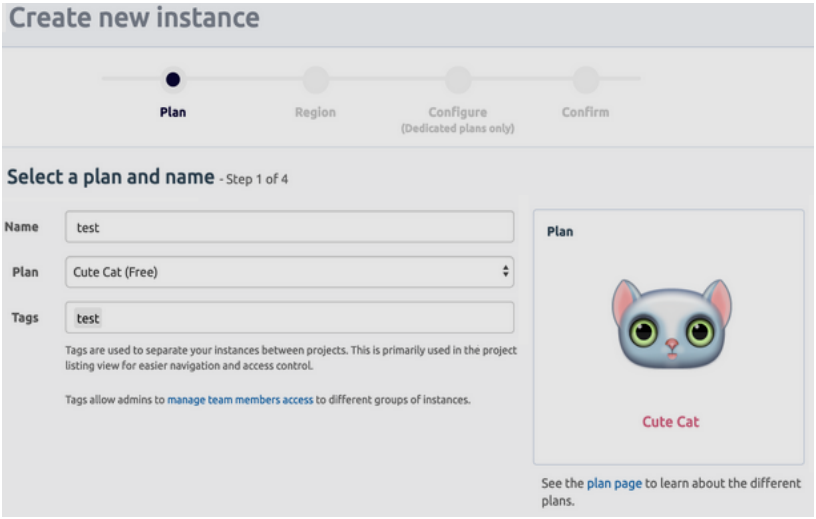


Fig. 2 – Broker settings window

The "Tags" field can be temporarily left empty because it can be edited later, after creating the instance. When the settings are completed, an instance is created and appears in the "Instances" window

3.4 Options to connect the broker

By clicking on the "Test" button, get information about the options for devices to connect to the selected broker (Fig. 4).

3.5 Installing a mobile application

With a mobile device using Android operating system ver. 4.2, download the free MQTT Dashboard application from the GooglePlay Market.

3.6 Connection to the broker

Start the installed application and create a connection to the broker. Use the connection parameters received in 3.4.

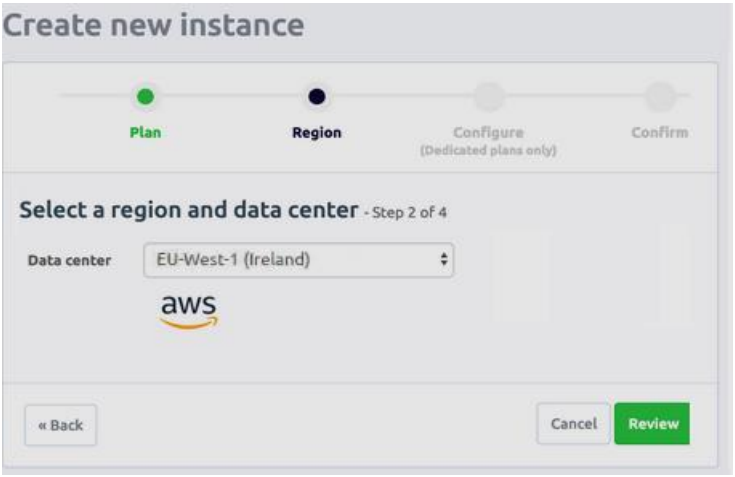


Fig. 3 – Server selecting

If successful connection, a window with the message "Connected to xxxxx" appears, where xxxxx is an address of the server – the MQTT protocol broker with whom the connection has been made. Thus, the device is ready for sending and receiving messages.

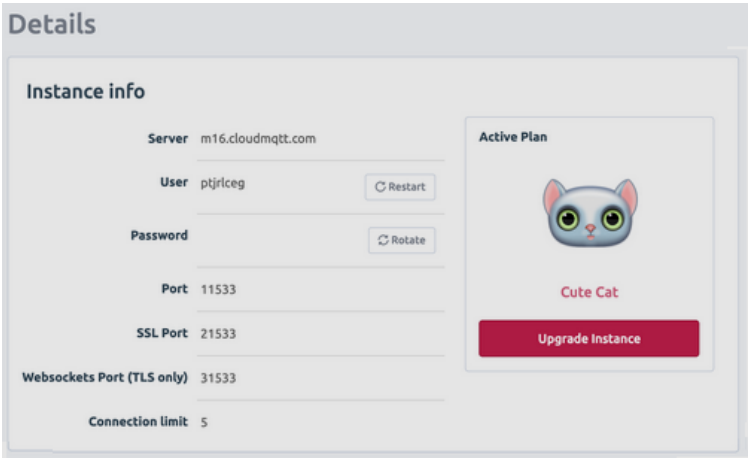


Fig. 4 – Connection options

3.7 Initializing the battery

Charge the battery pack of the mobile device fully up to 100% and disconnect it from the power source.

3.8 Resetting the mobile traffic

Save data about the current meaning of mobile internet traffic spent.

3.9 Setting the mode of the data exchange with the broker

Set the mode of cyclic GPS data sending (latitude and longitude) for the 5 sec. interval.

3.10 Setup of the second mobile device

Repeat paragraphs 3.5 to 3.8 for another mobile device with characteristics equivalent to the first device.

3.11 Setting up the mode of receiving data from broker

Set the mode of receiving data from the broker (latitude and longitude).

3.12 Starting the data exchange

Start both processes – sending and receiving – on both mobile devices simultaneously. Check time.

3.13 Stopping the data exchange

Exactly in an hour, stop both processes – sending and receiving simultaneously on both mobile devices.

3.14 Capturing data

Take readings from both mobile devices, both about the discharge of the battery and the spent traffic. Put them in the table 1.

Table 1 – Testing results

	Exchange interval, sec	Data sending		Data receiving	
		Power usage, %	Traffic usage, Mb	Power usage, %	Traffic usage, Mb
1.	5				
2.	10				
3.	20				

3.15 Repeat the tests at other intervals of data exchange

Repeat paragraphs 3.5 to 3.14 with other (10 sec. and 20 sec.) data exchange intervals. Or, to reduce the time, use two more pairs of

mobile devices with the same characteristics simultaneously with the first pair of devices. Add the results accepted to the table.

3.16 Result analysis

Analyze the information presented in the table. Compare electricity power and mobile traffic consumption depending on the mode (sending/receiving) and the exchange interval. Make conclusions.

4 Requirements to the report

Report should contain 5 sections: Introduction (I), Methods (M), Results (R), and Discussion (D):

– (I): background / theory, purpose and discovery questions

– (M): complete description of the software, and procedures which was followed in the experiment, experiment overview, figure / scheme of testing environment, procedures

– (R): narrate (like a story), tables, indicate final results;

– (D): answers on discovery questions, explanation of anomalies, conclusion / summary.

5 Test questions

1. Which IoT protocols of application level for M2M communication there are?
2. What is the main problem to use the standards HTTP/HTTPS for IoT application?
3. What elements does the MQTT protocol specification provide?
4. Which scheme does MQTT protocol utilize?
5. What advantages of MQTT protocol can be defined?
6. Which options does MQTT protocol provide for selecting the reliability of messaging, and which levels of QoS are they provided by?
7. What are the free or partially limited MQTT brokers as Internet services?
8. Does the type of data exchange affect the power consumption?
9. Does the type of data exchange affect the traffic consumption?
10. How does the type of data exchange affect the power consumption?

11. How does the type of data exchange affect the traffic consumption?

12. Does the data exchange interval affect the power consumption?

13. Does the data exchange interval affect the traffic used?

14. How does the data exchange interval affect power consumption?

15. How does the data exchange interval affect the traffic consumption?

6 References

1. Pham V., Yulchieva L., Kirichek R. Research of protocols of interaction of the Internet of Things on the basis of the laboratory bench // Information technologies and telecommunications. – 2016. – Vol. 4. № 1. – pp. 55-67.

2. Al-Fuqaha A., Guizani M., Mohammadi M., Aledhari M., Ayyash M. Internet of Things: A Survey on Enabling Technologies, Protocols and Applications // IEEE Commun. Surv. Tutorials. – Vol. 17. – № 4, 2015. – pp. 2347-2376.

3. Anusha M., Suresh B.E., Sai M.R.L., Vamsi K.A., Bhagyasree B. Performance analysis of data protocols of Internet of Things: a qualitative review // International Journal of Pure and Applied Mathematics. – Vol. 115. – № 6, 2017. – pp. 37-46.

4. Yoneyama J., Artho C., Tanabe Y., Hagiya M. Model-based network fault injection for IoT protocols // in 14th International Conference on Evaluation of Novel Approaches to Software Engineering, ENASE 2019, SciTePress, pp. 201-209.

5. Koshmak Y.S., Polishchuk I.A. Use of the MQTT protocol. Principle of operation and setting // Young Scientist. – 2018. – Vol. 57, № 5. – pp. 378-382.

6. CloudMQTT. Documentation. Getting started. available at: https://www.cloudmqtt.com/docs/index.html.

7. Internet of Things for Industry and Human Applications. In Volumes 1-3. Volume 1. Fundamentals and Technologies / V.S.Kharchenko (ed.). – Ministry of Education and Science of Ukraine, National Aerospace University “KhAI”, 2019. – 601 p.

Laboratory work 2

Message codings of IoT devices by means of the IP protocol

1. Objectives, tasks and synopsis

Goal and objectives. This laboratory work researches one of the most popular protocol for data transfer in IoT network We'll analyze user data ratio to service data.

Learning objectives:

– study an example of Network layer protocols of IoT;

– studying of opportunities of information transfer by IoT devices by means of the TCP/IP protocol.

Practical tasks:

– acquire practical skills in working with network level protocols of IoT;

– gather information about information coding principles of the TCP/IP protocol.

Exploring tasks:

– connect your mobile device to and organize the exchange of data with an TCP/IP protocol;

– investigate how devices, which use the TCP/IP protocol, exchange traffic with each other.

Setting up. In preparation for laboratory work it is necessary:

– to clear the goals and mission of the research;

– to study theoretical material contained in this manual, and in [4–9, section 4];

– to familiarize oneself with the main procedures and specify the exploration program according to defined task.

Recommended software and resources. Colasoft Packet Builder (https://www.colasoft.com/download/products/download_packet_builder.php) free software for creating custom network packets; users can use this tool to check their network protection against attacks and

intruders. A mobile device having wireless connection to internet (mobile phone, pad, netbook or notebook).

Synopsis. In this laboratory work you will learn one of the most popular protocol of IoT. Specifically you will use network level protocol, TCP/IP. You'll explore this protocol using Colasoft Packet Builder.

2 Brief theoretical information

It is the simplest to describe the exchange protocol between two IP entities by means of a format of the IP datagram shown in Fig.1 [1-5]

Fields of the datagram are listed below[7-8]:

- Version (4 bits). Version number. This field allows to develop the protocol; the current value is equal to 4 or 6.

- Internet heading Length (Internet Header Length, IHL) (4 bits). Heading length in 32-bit words. The minimum value of length is equal 5 that corresponds to 20-byte heading.

- Type of service (Type Of Service, TOS) (8 bits). Provides control of IP-of modules of an end system and routers on the way of the datagram. The structure of this field, is defined by standards:

1 RFC 791. Internet Protocol, September 1981 г.

2 RFC 1349, Type of Service in the Internet Protocol Suite, June 1992 r.

- Full length (16 bits). Full length of this fragment in bytes.

- Identifier (16 bits). Sequence number, which together with a source address, a destination address and the protocol of the user should it, is unique to identify the datagram. Thus, the identifier should be unique for a source address, a destination address and the protocol of the user for that time during which the datagram will be in the joint network.

- Flags (3 bits). Now only two bits are defined. Beat MF means More Fragments (to be continued). It is established at all fragments, except the last. The receiver recognizes by this bit whether he received all fragments of the datagram. Beat DF means Do not Fragment (not to fragment), that is a command to the router not to fragment the datagram as the receiver will not be able to recover it from fragments. When this

bit is set, the datagram will be discarded if its size exceeds maximum allowed in this subnet. Therefore, at installation of this bit it is recommended to apply source routing to avoid networks with a small maximum packet size.

- Fragment shift (13 bits). The provision of a fragment in the original datagram measured in 64-bit units. It means that length of all fragments in bytes, except length of the last fragment, has to be multiple 8.

- Lifetime (8 bits). The number of seconds during which it is authorized to packet to remain in the joint network. On each router this value should decrease at least by unit, therefore this counter usually just considers the number of routers.

- Protocol (8 bits). The following protocol of the high level, which should receive the data field of the datagram. Thus, this field identifies type of the following heading in a packet after the heading IP.

- Header control sum (16 bits). The code of error trapping protects from errors only heading. As some header fields can change by transfer of the datagram (for example, the lifetime and fields relating to segmentation), this sum is rechecked and recalculated on each router. Checksum is calculated as the sum of the 16-bit words of heading put in branching code. Before calculation of checksum, the field of checksum is nullified.

- Source address (32 bits). Allows to code differently the network and a terminal system connected to the specified network (7 24 bit, 14 16 bits or 21 8 bits).

- Receiver address (32 bits). The same characteristics, as at the source address.

- Parameters (variable length). The parameters set by the sender. Filler (variable length). It is used to guarantee multiplicity of length of heading of the datagram to 32 bits.

- Data (variable length). Field length of data in bytes should be an integer number. The maximum size of the datagram (data plus heading), can be 65,535 bytes.

In Fig.2, the ratio of the service information and data of the user in TCP/IP protocol packets is schematically represented.

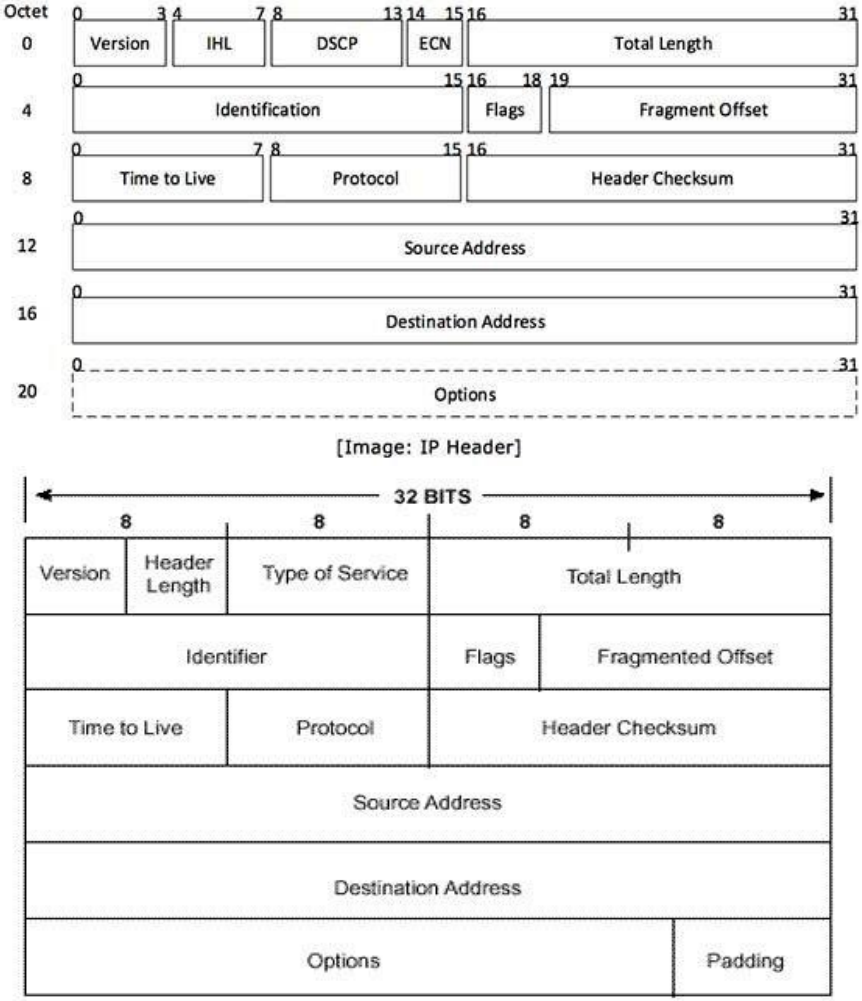


Fig. 1 – Structure of IP packet

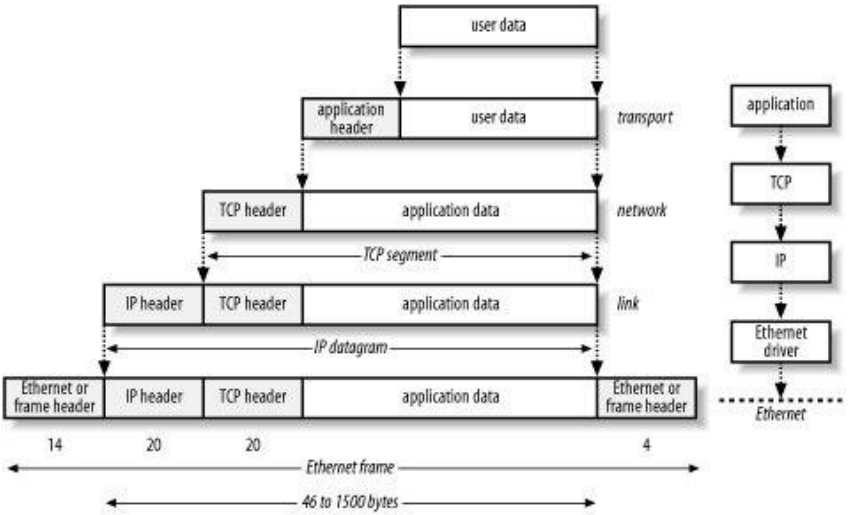


Fig. 2 – The ratio of the service information and data of the user in TCP/IP protocol packet

3 Execution order and discovery questions

Task. Organize transfer of the message between the IoT device and the server, according to option, previously having coded messages according to requirements of the IP protocol.

Variants:

1. Many hands make light work
2. Strike while the iron is hot
3. Honesty is the best policy
4. The grass is always greener on the other side of the fence
5. An apple a day keeps the doctor away
6. Better late than never
7. Don’t bite the hand that feeds you
8. It’s no use crying over spilt milk
9. Still waters run deep
10. Curiosity killed the cat
11. My hands are tied
12. Easy come, easy go
13. The forbidden fruit is always the sweetest

14. You can't make an omelette without breaking a few eggs
15. If you scratch my back, I'll scratch yours
16. Learn to walk before you run
17. Don't bite off more than you can chew
18. First things first
19. The early bird catches the worm
20. Always put your best foot forward

Work performance order:

3.1 Translate the message specified in option in a binary look, ASCII encoding.

For translating you may use site http://www.asciitohex.com. The base view of the site show on Fig. 3.

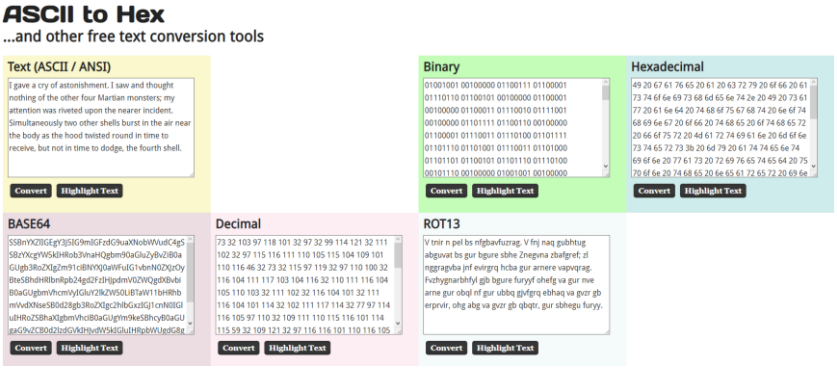


Fig. 3 – Site http://www.asciitohex.com

Strongly recommended use Hexadecimal view.

3.2 Export date to Colasoft Packet Builder. [7]

To start, download software from Colasoft Packet Builder (https://www.colasoft.com/download/products/download_packet_builder.php) [6].

3.3 Creating a new IP Packet

As the next step create a new IP Packet by clicking the "Add" button. Then chose IP packet, other option ser default. After that the settings window opens (Fig. 4).

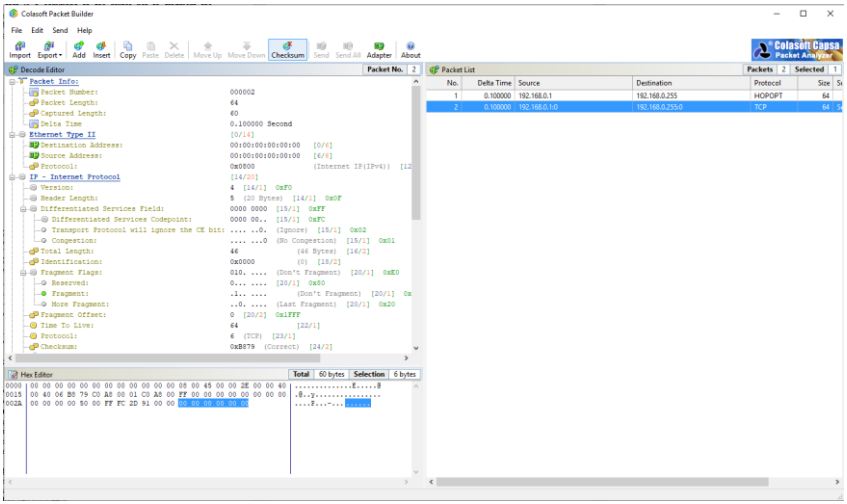


Fig. 4 – Colasoft Packet Builder TCP packet options

3.4 Data filling

Insert into the correct field data (Fig. 5), you must check address if destination and user data fields. Address of destination is IP of your IoT devices.

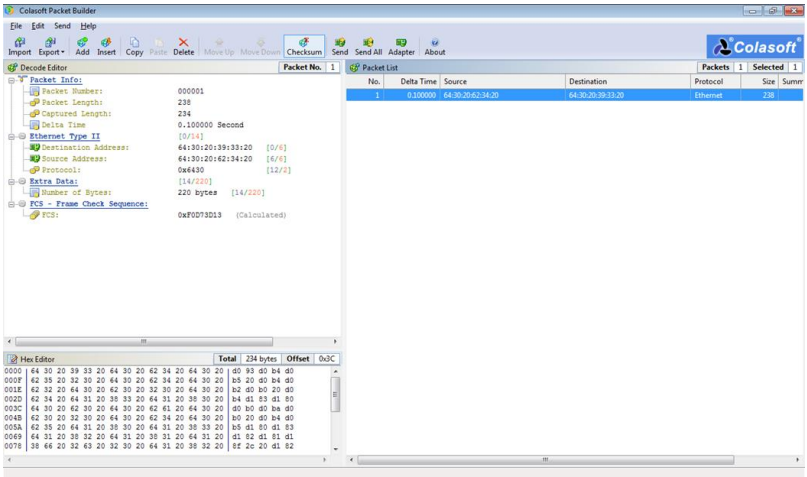


Fig. 5 – Colasoft Packet Builder fields options

3.5 Choose ethernet adapter for data transmitting

Use button Adapter for choosing PC ethernet adapter for data transmitting.

3.6 Transmit data

Use button Send or Send All (if you have several packet) for transmitting data for your IoT device.

3.7 Data interception

Use any traffic analyzer (for example Wireshark) for data interception and combine data from original packet (paragraphs 3.4) and interception packet.

4 Requirements to the report

Report should contain 5 sections: Introduction (I), Methods (M), Results (R), and Discussion (D):

– (I): background / theory, purpose and discovery questions

– (M): complete description of the software, and procedures which was followed in the experiment, experiment overview, figure / scheme of testing environment, procedures

– (R): narrate (like a story), tables, indicate final results;

– (D): answers on discovery questions, explanation of anomalies, conclusion / summary.

5 Test questions

1. Which IoT protocols of network level there are?
2. What difference between IPv4 and IPv6?
3. What difference between RFC 791 and RFC 1349?
4. What is basic principles sending data in TCP/IP protocol?
5. What is the length of user data in IP Protocol?
6. What is Fragment shift means?
7. Why we must use Hexadecimal view for ascii data?
8. Does it important what type of packet we chose in Colasoft Packet Builder?
9. Why we must choose ethernet adapter in Colasoft Packet Builder?
10. What does button checksum do?

11. Does it important correctly insert data in field Source IP?
12. What is field Delta time mean?
13. Why original packet and interception packet may be different?
14. What is traffic analyzer program?
15. Why Wireshark is most popular traffic analyzer?

6 References

1. James F. Kurose, Keith W. Ross, Computer Networking: A Top-Down Approach, 2008.

2. Forouzan, Behrouz A.; Fegan, Sophia Chung (1 August 2003). Data Communications and Networking. McGraw-Hill Higher Education. . Retrieved 12 September2016 – via Google Books.

3. Comer, Douglas (1 January 2006). Internetworking with TCP/IP: Principles, protocols, and architecture. Prentice Hall. Retrieved 12 September 2016 – via Google Books.

4. Stallings, William (1 January 2007). Data and Computer Communications. Prentice Hall.. Retrieved 12 September 2016 – via Google Books.

5. Tanenbaum, Andrew S. (1 January 2003). Computer Networks. Prentice Hall PTR. Retrieved 12 September 2016 – via Google Books.

6. Colasoft Packet Builder Documentation. Getting started. available at: http://kb.colasoft.com.

7. RFC 675 – Specification of Internet Transmission Control Program, December 1974 Version. available at: https://tools.ietf.org/rfc/rfc675.txt.

8. RFC 1180 A TCP/IP Tutorial – from the Internet Engineering Task Force (January 1991). available at: https://tools.ietf.org/html/rfc1180.

Laboratory work 3

Research of algorithms of noise immunity coding in IoT devices

1 Objectives, tasks and synopsis

Goal and objectives. This laboratory work researches one of the most popular method of ensuring integrity for data transfer in IoT network. We'll analyze noise immunity coding by comparison of codes of Hamming and a method of checksums.

Learning objectives:

– study codes of Hamming for IoT;

– study method of checksums for IoT.

Practical tasks:

– acquire practical skills in working with CRC check sum;

– gather information about ensuring integrity for data transfer in IoT.

Exploring tasks:

– comparison of codes of Hamming and a method of checksums;

– investigate how collision may change control signal of IoT devices.

Setting up. In preparation for laboratory work it is necessary:

– to clear the goals and mission of the research;

– to study theoretical material contained in this manual, and in [4–9, section 4];

– to familiarize oneself with the main procedures and specify the exploration program according to defined task.

Recommended software and resources. Example of C and C++ code for CRC check sum (https://www.thecrazyprogrammer.com/2017/02/checksum-program-in-c.html) Example of C and C++ code for Hamming Code (https://www.thecrazyprogrammer.com/2017/03/hamming-code-c.html).

Synopsis. In this laboratory work you will learn one of the most popular noise immunity coding for IoT. Specifically you will use C and C++ library for noise immunity coding. You'll explore comparison of codes of Hamming and a method of checksums CRC-1 and CRC-4.

2 Brief theoretical information

In telecommunication, Hamming codes are a family of linear error-correcting codes. Hamming codes can detect up to two-bit errors or correct one-bit errors without detection of uncorrected errors. By contrast, the simple parity code cannot correct errors, and can detect only an odd number of bits in error. Hamming codes are perfect codes, that is, they achieve the highest possible rate for codes with their block length and minimum distance of three. Richard W. Hamming invented Hamming codes in 1950 as a way of automatically correcting errors introduced by punched card readers. In his original paper, Hamming elaborated his general idea, but specifically focused on the Hamming(7,4) code which adds three parity bits to four bits of data [1].

In mathematical terms, Hamming codes are a class of binary linear codes. For each integer $r \geq 2$ there is a code with block length $n = 2^r - 1$ and message length $k = 2^r - r - 1$. Hence the rate of Hamming codes is $R = k / n = 1 - r / (2^r - 1)$, which is the highest possible for codes with minimum distance of three (i.e., the minimal number of bit changes needed to go from any code word to any other code word is three) and block length $2^r - 1$. The parity-check matrix of a Hamming code is constructed by listing all columns of length r that are non-zero, which means that the dual code of the Hamming code is the shortened Hadamard code. The parity-check matrix has the property that any two columns are pairwise linearly independent.

Due to the limited redundancy that Hamming codes add to the data, they can only detect and correct errors when the error rate is low. This is the case in computer memory (ECC memory), where bit errors are extremely rare and Hamming codes are widely used. In this context, an extended Hamming code having one extra parity bit is often used. Extended Hamming codes achieve a Hamming distance of four, which allows the decoder to distinguish between when at most one one-bit

error occurs and when any two-bit errors occur. In this sense, extended Hamming codes are single-error correcting and double-error detecting, abbreviated as SECDED [2].

If more error-correcting bits are included with a message, and if those bits can be arranged such that different incorrect bits produce different error results, then bad bits could be identified. In a seven-bit message, there are seven possible single bit errors, so three error control bits could potentially specify not only that an error occurred but also which bit caused the error.

Hamming studied the existing coding schemes, including two-of-five, and generalized their concepts. To start with, he developed a nomenclature to describe the system, including the number of data bits and error-correction bits in a block. For instance, parity includes a single bit for any data word, so assuming ASCII words with seven bits, Hamming described this as an *(8,7)* code, with eight bits in total, of which seven are data. The repetition example would be *(3,1)*, following the same logic. The code rate is the second number divided by the first, for our repetition example, 1/3.

Hamming also noticed the problems with flipping two or more bits, and described this as the "distance" (it is now called the Hamming distance, after him). Parity has a distance of 2, so one bit flip can be detected, but not corrected and any two bit flips will be invisible. The (3,1) repetition has a distance of 3, as three bits need to be flipped in the same triple to obtain another code word with no visible errors. It can correct one-bit errors or detect but not correct two-bit errors. A (4,1) repetition (each bit is repeated four times) has a distance of 4, so flipping three bits can be detected, but not corrected. When three bits flip in the same group there can be situations where attempting to correct will produce the wrong code word. In general, a code with distance k can detect but not correct $k - 1$ errors.

Hamming was interested in two problems at once: increasing the distance as much as possible, while at the same time increasing the code rate as much as possible. During the 1940s he developed several encoding schemes that were dramatic improvements on existing codes. The key to all of his systems was to have the parity bits overlap, such that they managed to check each other as well as the data.

The following general algorithm generates a single-error correcting (SEC) code for any number of bits. The main idea is to choose the error-correcting bits such that the index-XOR (the XOR of all the bit positions containing a 1) is 0. We use positions 1, 10, 100, etc (in binary) as the error-correcting bits, which guarantees it is possible to set the error-correcting bits so that the index-XOR of the whole message is 0. If the receiver receives a string with index-XOR 0, they can conclude there were no corruptions, and otherwise, the index-XOR indicates the index of the corrupted bit.

The following steps implement this algorithm [3]:

1. Number the bits starting from 1: bit 1, 2, 3, 4, 5, 6, 7, etc.
2. Write the bit numbers in binary: 1, 10, 11, 100, 101, 110, 111, etc.
3. All bit positions that are powers of two (have a single 1 bit in the binary form of their position) are parity bits: 1, 2, 4, 8, etc. (1, 10, 100, 1000)
4. All other bit positions, with two or more 1 bits in the binary form of their position, are data bits.
5. Each data bit is included in a unique set of 2 or more parity bits, as determined by the binary form of its bit position.
    1. Parity bit 1 covers all bit positions which have the least significant bit set: bit 1 (the parity bit itself), 3, 5, 7, 9, etc.
    2. Parity bit 2 covers all bit positions which have the second least significant bit set: bit 2 (the parity bit itself), 3, 6, 7, 10, 11, etc.
    3. Parity bit 4 covers all bit positions which have the third least significant bit set: bits 4–7, 12–15, 20–23, etc.
    4. Parity bit 8 covers all bit positions which have the fourth least significant bit set: bits 8–15, 24–31, 40–47, etc.
    5. In general each parity bit covers all bits where the bitwise AND of the parity position and the bit position is non-zero.

If a byte of data to be encoded is 10011010, then the data word (using _ to represent the parity bits) would be __1_001_1010, and the code word is 011100101010.

The form of the parity is irrelevant. Even parity is mathematically simpler, but there is no difference in practice.

This general rule can be shown visually in table 1.

Table 1 – General rule of Hamming codes

Parity bit coverage	Bit position	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20
	Encoded data bits	p1	p2	d1	p4	d2	d3	d4	p8	d5	d6	d7	d8	d9	d10	d11	p16	d12	d13	d14	d15
p1		✗		✗		✗		✗		✗		✗		✗		✗		✗		✗	
p2			✗	✗			✗	✗			✗	✗			✗	✗			✗	✗	
p4					✗	✗	✗	✗					✗	✗	✗	✗					✗
p8									✗	✗	✗	✗	✗	✗	✗	✗					
p16																	✗	✗	✗	✗	✗

Shown are only 20 encoded bits (5 parity, 15 data) but the pattern continues indefinitely. The key thing about Hamming Codes that can be seen from visual inspection is that any given bit is included in a unique set of parity bits. To check for errors, check all of the parity bits. The pattern of errors, called the error syndrome, identifies the bit in error. If all parity bits are correct, there is no error. Otherwise, the sum of the positions of the erroneous parity bits identifies the erroneous bit. For example, if the parity bits in positions 1, 2 and 8

indicate an error, then bit 1+2+8=11 is in error. If only one parity bit indicates an error, the parity bit itself is in error.

As you can see, if you have *m* parity bits, it can cover bits from 1 up to 2^m-1. If we subtract out the parity bits, we are left with 2m-m-1 bits we can use for the data. As *m* varies, we get all the possible Hamming codes (table 2).

Table 2 – General rule of Hamming codes

Parity bits	Total bits	Data bits	Name	Rate
2	3	1	Hamming(3,1) (Triple repetition code)	1/3 ≈ 0.333
3	7	4	Hamming(7,4)	4/7 ≈ 0.571
4	15	11	Hamming(15,11)	11/15 ≈ 0.733
5	31	26	Hamming(31,26)	26/31 ≈ 0.839
6	63	57	Hamming(63,57)	57/63 ≈ 0.905
7	127	120	Hamming(127,120)	120/127 ≈ 0.945
8	255	247	Hamming(255,247)	247/255 ≈ 0.969

In 1950, Hamming introduced the [7,4] Hamming code. It encodes four data bits into seven bits by adding three parity bits. It can detect and correct single-bit errors. With the addition of an overall parity bit, it can also detect (but not correct) double-bit errors.

3 Execution order and discovery questions

3.1 To present the surname, a name, a middle name in the form of the binary sequence.

For coding you may use site http://www.asciitohex.com. The base view of the site show on Fig. 1. For coding by Hamming's method to use DKOI-8 code (8 bits on one symbol)

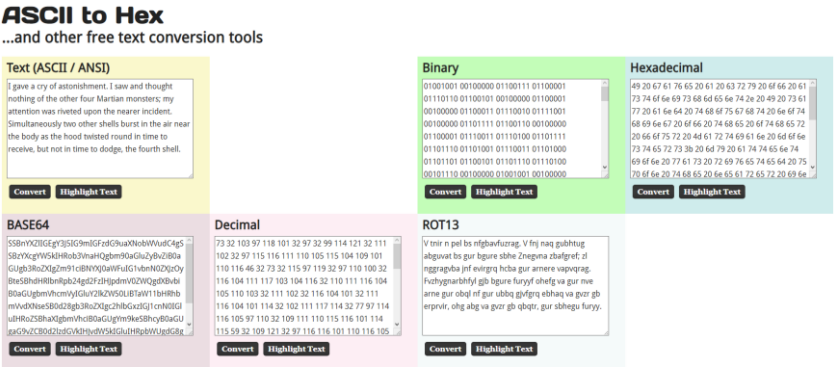


Fig. 1 – Site http://www.asciitohex.com

3.2 To present the surname, a name, a middle name in the form of CRC.

For coding the method of checksums should use table 3 (checksums are generated by the rule on each 3 bits the fourth control) [4].

Table 3 – Dictionary of coding CRC-1 mode

Decimal representation	Binary representation	Symbols of the alphabet 1	Symbols of the alphabet 2	Symbols of the alphabet 3	Symbols of the alphabet 4	Symbols of the alphabet 5
1	2	3	4	5	6	7
0	00000000	а	а	a	α	0
1	00000011	б	б	b	β	1
2	00000101	в	в	c	χ	2
3	00000110	г	г	d	δ	3
4	00001001	д	д	e	ε	4
5	00001010	е	е	f	ϕ	5
6	00001100	ж	є	g	γ	6
7	00001111	з	ж	h	η	7
8	00110000	и	з	i	ι	8
9	00110011	й	и	j	φ	9

Decimal representation	Binary representation	Symbols of the alphabet 1	Symbols of the alphabet 2	Symbols of the alphabet 3	Symbols of the alphabet 4	Symbols of the alphabet 5
10	00110101	к	і	k	κ	=
11	00110110	л	ї	l	λ	+
12	00111001	м	й	m	μ	-
13	00111010	н	к	n	ν	}
14	00111100	о	л	o	ο	{
15	00111111	п	м	p	π	]
16	01010000	р	н	q	θ	[
17	01010011	с	о	r	ρ	‘
18	01010101	т	п	s	σ	“
19	01010110	у	р	t	τ	<
20	01011001	ф	с	u	υ	>
21	01011010	х	т	v	ϖ	/
22	01011100	ц	у	w	ω	\
23	01011111	ч	ф	x	ξ	|
24	01100000	ш	х	y	ψ	*
25	01100011	щ	ц	z	ζ	&
26	01100101	ъ	ч			#
27	01100110	ы	ш			@
28	01101001	ь	щ			$
29	01101010	э	ь			%
30	01101100	ю	ю			^
31	01101111	я	я			№
32	10000000		’			~
33	100000110	,	,	,	,	,
34	10000101	:	:	:	:	:
35	10000110	;	;	;	;	;
36	10001001	_	_	_	_	_
37	10001010	?	?	?	?	?
38	10001100	!	!	!	!	!
39	10001111	(	(	(	(	(
40	10100000	)	)	)	)	)

Decimal representation	Binary representation	Symbols of the alphabet 1	Symbols of the alphabet 2	Symbols of the alphabet 3	Symbols of the alphabet 4	Symbols of the alphabet 5
41	10100011	End of the paragraph	End of the paragraph	End of the paragraph	End of the paragraph	End of the paragraph
42	10100101	Transfer	Transfer	Transfer	Transfer	Transfer
43	10100110	lower case	lower case	lower case	lower case	lower case
44	10101001	capital	capital	capital	capital	capital
45	10101010	space	space	space	space	space
46	10101100	.	.	.	.	.
47	10101111	All lower case	All lower case	All lower case	All lower case	All lower case
48	11000000					≥
49	11000011	All capital	All capital	All capital	All capital	All capital
50	11000101					≠
51	11000110		Transition to the alphabet 1	Transition to the alphabet 1	Transition to the alphabet 1	Transition to the alphabet 1
52	11001001	Transition to the alphabet 2		Transition to the alphabet 2	Transition to the alphabet 2	Transition to the alphabet 2
53	11001010					÷
54	11001100					≤
55	11001111					↔
56	11110000	Transition to the alphabet 3	Transition to the alphabet 3		Transition to the alphabet 3	Transition to the alphabet 3

Decimal representation	Binary representation	Symbols of the alphabet 1	Symbols of the alphabet 2	Symbols of the alphabet 3	Symbols of the alphabet 4	Symbols of the alphabet 5
57	11110011					≡
58	11110101					⊂
59	11110110					⊃
60	11111001	Transition to the alphabet 4	Transition to the alphabet 4	Transition to the alphabet 4		Transition to the alphabet 4
61	11111010					∃
62	11111100	space	space	space	space	space
63	11111111	Transition to the alphabet 5	Transition to the alphabet 5	Transition to the alphabet 5	Transition to the alphabet 5	⊕

3.3 Noise immune encoding

To carry out coding of the sequence received by transformation on algorithm DKOI-8 by means of an algorithm Hamming (7.4) or Hamming (15.11) [5], for a method of checksums the transferred sequence turns out by concatenation of office symbols, and symbols of the alphabet (for obtaining the sequence it is necessary to use office symbols of transition to the top and lower registers and also a gap).

3.4 Generate massifs of mistakes

To generate massifs of mistakes with probabilities specified in the table4, length of the massif of mistakes has to be not less sequences received in paragraph 3.3. The law of distribution – uniform.

3.5 Generating error messages

To impose on the sequences received in paragraph 3.3, with the 5 sequences of mistakes generated in Paragraph 3.4

3.6 Restoring the received messages

To restore the received sequence, using Hamming's algorithm and a method of checksums CRC-1 (the control bit is formed on the basis of the 3rd previous) [5, 6].

Table 4 – Probabilities of distortion of single symbols

P1	P2	P3	P4	P5
5* 10-2	3 * 10-2	2* 10-2	10-2	9* 10-3

3.7 The comparison of messages

To compare the initial sequence to restored.

3.8 Dependence of recovery time of the message on quality of the channel

To construct the schedule of dependence of recovery time of the message on quality of the channel for two methods.

3.9 Extent of redundancy from quality of the channel

To construct the schedule of the extent of redundancy from quality of the channel.

3.10 Noise immune coding depending on quality of a communication channel and the size of the transferred message

To draw conclusions on the done work, on expediency of application of this or that method of noise immune coding depending on quality of a communication channel and the size of the transferred message.

4 Requirements to the report

Report should contain 5 sections: Introduction (I), Methods (M), Results (R), and Discussion (D):

– (I): background / theory, purpose and discovery questions

– (M): complete description of the software, and procedures which was followed in the experiment, experiment overview, figure / scheme of testing environment, procedures

– (R): narrate (like a story), tables, indicate final results;

– (D): answers on discovery questions, explanation of anomalies, conclusion / summary.

5 Test questions

1. What is different between CRC-1 and CRC-4?
2. What is different between CRC and Hamming code?

3. What is different between Hamming (7.4) and Hamming (15.11)?

4. Why we use code table in paragraph 3.2?

5. How does work archviator?

6. Why integrity is important for IoT devices?

7. What is the difference between integrity control and ensuring integrity?

8. What code are more effective Hamming or CRC?

9. What is better CRC-1 or CRC-4? In what cases?

10. Why in Unicode we have one code table and in our cases 5 different table?

11. What is a polynomial? Where does it use?

12. What probabilities of distortion of single symbols in IoT networks?

13. What is code rate? Why it important?

14. How does Hamming distance use in real noise immune system?

15. What code system use in IoT devices to communicate with user? And why?

6 References

1. Hamming, Richard Wesley "Error detecting and error correcting codes". Bell System Technical Journal. 29 (2): 147–160. DOI: 10.1002/j.1538-7305.1950.tb00463.x.

2. Moon, Todd K. Error Correction Coding. New Jersey: John Wiley & Sons. 2005.

3. MacKay, David J.C. Information Theory, Inference and Learning Algorithms. Cambridge: Cambridge University Press. 2003.

4. Williams, Ross N. "A Painless Guide to CRC Error Detection Algorithms V3.0". 2019.

5. Hamming Code. Documentation. Getting started. Available at https://www.thecrazyprogrammer.com/2017/03/hamming-code-c.html

6. CRC. Documentation. Getting started. Available at https://www.thecrazyprogrammer.com/2017/02/checksum-program-in-c.html

APPENDIX A. TEACHING PROGRAM

DESCRIPTION OF THE MODULE

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

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.

Learning outcomes of module (course unit)	Teaching/learning methods	Assessment methods
At the end of course, the successful student will be able to: 1. To differentiate the concepts, domains and challenges of IoT applications	Interactive lectures, Learning in seminar and practical works, Just-in-Time Teaching	Module Evaluation Questionnaire
2. To use architectures and platforms for IoI systems	Interactive lectures, Learning in laboratories, Just-in-Time Teaching	Module Evaluation Questionnaire
3. To know standards and metrics for IoT systems	Interactive lectures, Learning in seminars, Just-in-Time Teaching	Module Evaluation Questionnaire
4. To use communications and protocols of IoT systems	Interactive lectures, Learning in laboratories, Just-in-Time Teaching	Module Evaluation Questionnaire

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. 2.3. 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	2			4				8	2.4. Preparation of vision and brief specification of developed project (VDP and SDP) on application of IoT/IoE for 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	2			2				4	3.3. Learn main stages of organizing the

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									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	2				2			4	6.4. Analyze the utilized volume of MC resources and

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									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.
In total	24		12	6	20			58	

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.

Author	Year of issue	Title	No of periodical or volume	Place of printing. Printing house or intrenet link
Compulsory literature				
V.S. Kharchenko (ed.)	2019	Internet of Things for Industry and Human Application. In Volumes 1-3.	Volume1. Fundamentals and Technologies	Ministry of Education and Science of Ukraine, National Aerospace University KhAI.
V.S. Kharchenko (ed.)	2019	Internet of Things for Industry and Human Application. In Volumes 1-3.	Volume2. Model-ling and Development	Ministry of Education and Science of Ukraine, National Aerospace University KhAI.
V.S. Kharchenko (ed.)	2019	Internet of Things for Industry and Human Application. In Volumes 1-3.	Volume3. Assessment and Implementation	Ministry of Education and Science of Ukraine, National Aerospace University KhAI.
i-SCOOP	2016	What is the Internet of Things? Internet of Things definitions	Online	Available: https://www.i-scoop.eu/internet-of-things/. [Accessed: 28-Jul- 2019].
D. Van Krevelen, R. Poelman	2010	A survey of augmented reality technologies,	vol. 9 (2)	International Journal of Virtual Reality

		applications and limitations		
K. C. Pucihar, M. Kljun	2018	ART for Art: Augmented Reality Taxonomy for Art and Cultural Heritage		Augmented Reality Art
	2015	INTERNET OF THINGSIN LOGISTICS. A collaborative report by DHL and Cisco on implications and use cases for the logistics industry	Online	Available: https://discover.dhl.com/content/dam/dhl/downloads/interim/preview/updates/dhl-trend-report-internet-of-things-preview.pdf
	2016	IoT Safety/Security Development Guidelines.	Second Edition.	Software Reliability Enhancement Center, Technology Headquarters, Information-technology Promotion Agency: Important Points to be understood by Software Developers toward the Smart-society.
Isam Ishaq, David Carels, Girum K. Teklemariam, Jeroen Hoebeke, Floris Van den	2013	IETF Standardization in the Field of the Internet of Things (IoT): A	Vol. 2	Available at: http://www.mdpi.com/ journal/jsan/.

Abeele, Eli De Poorter, Ingrid Moerman and Piet Demeester. J. Sens. Actuator Netw.		Survey.		
A. Torkaman, M.A. Seyyedi	2016	Analyzing IoT Reference Architecture Model s	Vol. 5, № 8	International Journal of Computer Science and Software Engineering
Pham V., Yulchieva L., Kirichek R.	2016	Research of protocols of interaction of the Internet of Things on the basis of the laboratory bench	Vol. 4, № 1	Information technologies and telecommunicati ons
Al-Fuqaha A., Guizani M., Mohammadi M., Aledhari M., Ayyash A	2015	Survey on Enabling Technologies, Protocols and Applications Internet of Things	Vol. 17, № 4	IEEE Commun. Surv. Tutorials
Forouzan, Behrouz A.; Fegan, Sophia Chung.	2003	Data Communica-tions and Networking.	Google Books.	McGraw-Hill Higher Education.
Additional literature				
V. Kharchenko, Ah Lian Kor, A. Rusincki	2019	Dependable Internet of Things for Industry and Human Domains	Book	River Publishers
Executive.mit.edu		Internet of Things Online	Online	Available: https://executive

		Course | MIT Sloan Executive Education		.mit.edu/openenrollment/program/internet-of-things-business-implications-and-opportunities/#.XTysbuZR3IV. [Accessed: 27- Jul- 2019].
A. Gabbai	2015	Kevin Ashton Describes "the Internet of Things"	Online	Smithsonian. Available: https://www.smithsonianmag.com/innovation/kevin-ashton-describes-the-internet-of-things-180953749/#CCK32kDiIlxVuB1j.99. [Accessed: 27- Jul- 2019].
Gartner company	2019	Top 10 strategical technology trends in 2019 have been presented by Gartner company	Online	[https://www.gartner.com/ en/doc/383829-top-10-strategic-technology-trends-for-2019-a-gartner-trend-insight-report].
J. Garbe	2014	Digital Borders and the Virtual Gallery.		Augmented Reality Art. Springer Series on Cultural Computing. Springer, Cham
D. Dal Palù, E. Buiattia, G. E. Puglisi,	2017	The use of semantic differential	Vol. 127	Applied Acoustics

O. Houix, P. Susini, C. De Giorgi, and A. Astolfi		scales in listening tests: A comparison between context and laboratory test conditions for the rolling sounds of office chairs		
William Stallings.	2015	The Internet of Things: Network and Security Architecture	Online	Available: http://ipj.dreamhosters.com/wp-content/uploads/issues/2015/ipj18-4.pdf.
Anusha M., Suresh B.E., Sai M.R.L., Vamsi K.A., Bhagyasree B.	2017	Performance analysis of data protocols of Internet of Things: a qualitative review	Vol. 115, № 6	International Journal of Pure and Applied Mathematics
Comer, Douglas	2016	Internetworking with TCP/IP: Principles, protocols, and architecture.	Google Books.	Prentice Hall

АНОТАЦІЯ

УДК 004.415/.416](075.8)=111

МС1 Інтернет речей для індустріальних і гуманітарних застосунків. Основи Інтернету речей / За ред. В.С. Харченка. – Міністерство освіти і науки України, Національний аерокосмічний університет ХАІ, 2019. – 95 с.

Навчально-методичний посібник містить матеріали практичної частини магістерського курсу «Основи Інтернету речей», розробленого в рамках проекту Internet of Things: Emerging Curriculum for Industry and Human Applications/ALIOT, 573818-EPP-1-2016-1-UK-EPPKA2-CBHE-JP, 2016-2019, що фінансується програмою ЄС ERASMUS+. Книга складається з 3 частин для відповідних модулів: Основні поняття сфери застосування і виклики Інтернету речей; Стандарти і метрики для систем Інтернету речей; Комунікації та протоколи Інтернету речей.

Підготовлено українськими університетськими командами за підтримки колег з академічних закладів країн ЄС, що входять до консорціуму проекту ALIOT.

Призначено для магістрантів і аспірантів, які вивчають технології IoT, програмну і комп'ютерну інженерію, комп'ютерні науки. Може бути корисною для викладачів університетів і навчальних центрів, розробників систем IoT.

Бібл. – 107, рисунків – 11, таблиць – 9.

ЗМІСТ

CONTENTS

Артем Володимирович Боярчук, Олена Олександрівна Голембовська,
Сергій Яковлевич Гільгурт, Олег Олександрович Ілляшенко,
Марина Олександрівна Колісник, Ольга Ігорівна Морозова,
Володимир Якович Певнев, Владислав Володимирович Плєтньов,
Вячеслав Сергійович Харченко, Михайло Віталійович Цуранов,
Олександр Анатолійович Чемеріс

Інтернет речей для індустріальних і гуманітарних застосунків. Основи Інтернету речей

Навчально-методичний посібник

(англійською мовою)

Редактор Харченко В.С.

Комп'ютерна верстка
О.О. Ілляшенко,
О.І. Морозова

Зв. план, 2019
Підписаний до друку 27.08.2019
Формат 60x84 1/16. Папір офс. No2. Офс. друк.
Умов. друк. арк. 5,52. Уч.-вид. л. 5,93. Наклад 150 прим.
Замовлення 270819-7

Національний аерокосмічний університет ім. М. Є. Жуковського
"Харківський авіаційний інститут"
61070, Харків-70, вул. Чкалова, 17
http://www.khai.edu

Випускаючий редактор: ФОП Голембовська О.О.
03049, Київ, Повітрофлотський пр-кт, б. 3, к. 32.
Свідоцтво про внесення суб'єкта видавничої справи до державного реєстру видавців,
виготовлювачів і розповсюджувачів видавничої продукції
серія ДК No 5120 від 08.06.2016 р.

Видавець: ТОВ «Видавництво «Юстон»
01034, м. Київ, вул. О. Гончара, 36-а, тел.: +38 044 360 22 66
www.yuston.com.ua
Свідоцтво про внесення суб'єкта видавничої справи до державного реєстру видавців,
виготовлювачів і розповсюджувачів видавничої продукції
серія ДК No 497 від 09.09.2015 р.