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Abstract:	This report presents the information about the Closing event for the IoT-ECO project held in the Technical University of Sofia, Bulgaria in the period 24 to 28 September 2025. The report presents the Preliminary organization and Invitation, the agenda, the attendees, the photos and dissemination materials, the training package and presentations, the minutes of the discussion and decisions and the Quality report for the Closing event. The Closing event was attended by 70 participants – 41 teachers/staff and 29 students, 35 female and 35 male. Only 6 attendees were online, the others were on-site. The external quality auditor attended the event and made recommendations to the consortium.
Contact Persons:	Assoc. Prof. Dr. Galia Marinova

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Table of acronyms or abbreviations

Acronym	Illustration
IoT	Internet of Things
HEI	Higher Education Institution

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1. Introduction

The Closing event is the last event planned in the IoT-ECO project. It was realized in the period 24 to 28 September 2025 in Technical University of Sofia, Bulgaria – the coordinator's HEI. It was located in the Aula 701 of the Building 7 of the Technical University of Sofia. At the request of the coordinator the Project officer allowed the Closing event to be realized in the end of September 2025 instead of August 2025.
The report presents the preliminary organization and Invitation, the agenda, the attendees, the photos and dissemination materials, the training package and presentations, the minutes of the discussion and decisions and the quality report for the Closing event.

2. Preliminary organization and Invitation for the Closing event

The 17th of July 2025, at the IoT-ECO Summer School in UBT, Pristina, Kosovo, a Coordination meeting was organized for the preliminary organization of the Closing event. The dates of the Closing event were decided, and each partner was asked to send at least 3 teachers/staff, the partners from Albania, Kosovo and Montenegro were invited to nominate at least 5 students to attend the training at the Closing event. It was decided to invite the External quality auditor of the IoT-ECO project at the Closing event. The general agenda of the Closing event was planned. The coordinator, the head of the Quality Board and the leader of the Dissemination package were invited to prepare reports. The teachers were invited to propose presentations and training materials. Students were invited to present projects related to the topics and new pilot courses of the IoT-ECO project.

The coordinator prepared an invitation for the Closing event and distributed it to the partners by mail. The Partners' contact persons nominated the teachers/staff and students to attend the closing event and sent the lists to the coordinator. Priority was given to students who prepared projects connected to the IoT-ECO project topics.

3. Agenda of the Closing event

The agenda of the Closing event follows.

AGENDA
Closing Event of the project
101083018 - IoT-ECO, Erasmus-LS, ERASMUS-EDU-2022-CBHE, ERASMUS-EDU-2022-CBHE-STRAND-2
in Technical University of Sofia, Dates: 24-28 September 2025
Location: Aula of the Building 7 in TU-Sofia

Wednesday, 24 September 2025

Arrival and Accommodation
18:00 Registration and Welcome meeting

Thursday, 25 September 2025

8:30-9:00 Registration and Coffee
9:00-9:30 Opening. Welcome address from the Rector and officials in TU-Sofia
9:30-10:00 Presentation of achievements of the project IoT-ECO
Assoc. Prof. Dr. Galia Marinova – project coordinator

10:00-11:00 Virtual models developed in the framework of the IoT-ECO project
10:00-10:20 Tutorial: Part 1: Constructing a virtual prototype in a port environment with Microsoft Azure for Durres Port Authority. Part 2: Constructing virtual prototypes in a port environment with ADOBE AEREO
Manjola Zeneli – UAMD, Albania
10:20-10:40 Implementation of the IoT hub and Digital Twins at the UBT smart and self-sustainable city, Besnik Qehaja – UBT, Kosovo
10:40-11:00 IoT-ECO model of UoM: IoT Layer: Valve Control System
Janko Jovanovic – UoM, montenegro

11:00-11:20 Coffee Break

11:20-12:00 Towards an IoT Eco Futures: Sustainable Optical Communication and Hybrid Networks
Erich Leitgeb and Pasha Bekhrad - TU-Graz , Austria

12:00-12:40 Distributed signal processing and learning for IoT:Main concepts and recent developments
Kostas Berberidis and Christos Mavrokefalidis, University of Patras, Greece

12:40-14:00 Lunch

14:00 –14:40 The applications of IoT in industry, academy and more
Frida Gjermeni, University “Aleksander Moisiu”, Durres, Albania
14:40 – 15:20 Cloud and IoT integration.
Enida Sheme, Eduart Torba, Polytechnic University of Tirana, Albania
15:20 – 16:00 UBT Hub. UBT 5S-Small Scales Smart SelfSustained (Entrepreunerial Innovation based EcoSystem) System
Edmond Hajrizi, UBT, Pristina, Kosovo
16:00 – 16:40 Implementation of IoT concepts via Azure services
Hena Malocu, UP, Pristina, Kosovo
Presentation of 4 students’ projects connected to the IoT-ECO project

16:40 – 17:00 Coffee Break
17:00 – 17:45 Cybersecurity Challenges in Modern Smart Grids

Velimir Strugar, Mediterranean University, Podgorica, Montenegro, Faculty of Information Technologies

Friday, 26.07.2025

8:00 – 17:00
Organized cultural trip to Rila Monastery
https://www.rilamonastery.info/

Lunch in Fish restaurant "Gorski kat"

Saturday, 27.09.2025

9:30-10:00 Presentation of the Quality Board Chair: Quality Assurance and Evaluation
Mimoza Ibrani, University of Pristina, Kosovo

10:00-10:30 Presentation on the Project Dissemination
Manjola Zeneli – UAMD

10:30-10:50 Coffee Break and visit to the event „Days of the automotive audio-visul systems 2025" in the yard between Building 1 and Building 2 of TU-Sofia

10:50 – 11:20 Presentation of the IoT-ECO hub,
Kostas Berberidis and Christos Mavrokefalidis, University of Patras, Greece

11:20 –12:20 Coordination meeting of the IoT-ECO Consortium
Virtual participation of the external quality auditor Prof. Dr. Albana Halili from WBU, Tirana, Albania

12:20 – 13:30 Certificate distribution

Free time

16:00 -18:00 Guided City tour in Sofia

Sunday, 28.09.2025
Final arrangements. Departure

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4. Attendees

The Closing event of the IoT-ECO project gathered attendees from the coordinator institution TU-Sofia, which was the host and all other 8 partner HEIs. All Partners had teachers/staff attendees and the partners from Albania, Kosovo and Montenegro had students-attendees.
Two lists of attendees were filled in – one for the teachers/staff and one for the students, collected and stored by the coordinator and they are available upon request.
The total number of attendees was 70.
There were 41 teachers-attendees - 38 attendees on-site and 3 attendee – online.
Teachers/Staff attendees per Partner and per gender are presented in Table I.

Table I. Teachers/Staff attendees per Partner and per gender

Partner	Number of Attendees	On site	Online	Female	Male
TUS	8	8	-	5	3
UAMD	7	7	-	6	1
UPT	7	7	-	5	2
UP	5	5	-	4	1
UBT	3	2	1	1	2
UoM	3	3	-	1	2
UNIMED	3	3	-	2	1
TU-Graz	2	1	1	0	2
UPAT	2	2	-	0	2
WBU – external auditor	1	-	1	1	-
Total	41	38	3	25	16

Students-attendees per Partner and per gender are presented in Table II. In total there were 29 students- attendees.

Table II. Students attendees per Partner and per gender

Partner	Number of Attendees	On site	Online	Female	Male
UAMD	5	5	-	0	5
UPT	5	5	-	3	2
UP	5	5	-	3	2
UBT	2	3	3	0	2
UoM	6	6	-	3	3
UNIM	5	5	-	1	4
Total	29	29	3	10	19

The students followed all lectures and tutorials. The students from UP presented their projects related with the topics of the IoT-ECO project.

All attendees took part of all sessions in the agenda. The number of female teachers was higher than the number of male teachers and the number of male students was higher than the number of female students-attendees. In total there were 35 female and 35 male attendees, which made the event gender balanced.

5. Photos and dissemination materials

Photos were taken from all meeting, sessions, presentations and social program. 3 attendees presented videos about illustrating the IoT-ECO project achievements in their institution. All photos, videos and video-records are collected and stored by the coordinator and they are available upon request. Following the instructions at the Grant holders' meeting, the photos with attendees will not be inserted in the deliverable report.

In Figure 1 are presented the badges – blue for teachers and green for students.

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Figure 1. IoT-ECO badges for the Closing event – blue for teachers and green for students

A special poster was designed for the Closing event with embedded QR code with the Agenda and it is presented in Figure 2. The poster was used for disseminating the Closing event in TU-Sofia. In the aula and in the lobby of the Building 7 a roll-on, another poster, flyers and brochures were made available for informing about the project. Each attendee received at the registration desk an IoT-ECO bag with IoT-ECO project dissemination gadgets as notebook, pen and mug. The team from UAMD distributed promotional IoT-ECO tee-shirts and metallic round badges. The newspaper ”Technicheski avangard” of TU-Sofia sent a journalist to take notes and photos and to write an article about the event and the IoT-ECO project achievements. The event was also announced and followed in the social media of TU-Sofia and the project itself.

Figure 2. Poster for the Closing event of the IoT-ECO project in TU-Sofia

6. Training package and presentations

The coordinator presented the main achievements of the project. The training package was composed by the tutorials about the developed virtual models and digital twins.

6.1. Summary of the presentation of the coordinator

The IoT-ECO project started December 1st, 2022 with a consortium of 9 universities: Technical University of Sofia, Bulgaria – Coordinator, Technical University of Graz, Austria, University of Patras, Greece and 6 HEIs from the Western Balkans: 2 from Albania - University "Aleksander Moisiu", Durres and Polytechnic University of Tirana, 2 from Kosovo: University of Pristina and University for Business and Technology, and 2 from Montenegro – University of Montenegro and Mediterranean University of Podgorica. The project has 3 associate partners: Port of Durres Authority, Innovation Fund of Montenegro and CREA-KO SHKP. The project enters in the last trimester and will be completed December 1st, 2025. Three years of intensive work of the consortium led to tangible achievements:

- An IoT-ECO Hub was developed, and the consortium was trained to implement it.
- Teaching materials dedicated to the implementation of the IoT technology for green transformation were developed and made available at the IoT-ECO Hub - more than 30 new lectures, 20 new practical assignments, 5 tutorials.

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- 3 Virtual models – Digital Twins – Demonstrators were developed: Port of Durres (by UAMD, UPT), UBT Campus (by UBT, UP) and UoM Campus (by UoM, UNIMED).
- 10 new courses and 3 updated courses were development, accredited and probated in UAMD, UPT, UP, UBT, UoM and UNIMED. Three new modules, implementing the new courses, were proposed.
- 9 Invited guest lecturers from companies and associate partners were organized.
- More than 100 students/ teachers and staff took part of the exchange of experience.
- 231 students (84F, 147 M) followed, took exams and evaluated the new and updated courses in the academic year 2024/2025.
- More than 670 students will have studied them by the completion of the project.

The Consortium organized multiple events:

- 3 events for exchange of experience from EU countries were organized in TU-Graz, University of Patras and TU-Sofia.
- An IoT-ECO Summer School was organized in July 2025 in UBT and UP, Kosovo in order to probate the newly developed IoT-ECO modules. More than 200 students attended the IoT-ECO Summer School and received certificates.
- 16 dissemination events – open days, info-days and a webinar for people with disabilities were organized to demonstrate the achievements of the IoT-ECO project and to motivate people to contribute to the green transformation of their environment.
- 9 Memorandums of understanding were signed between the project consortium and companies in Kosovo and Albania, to implement and cooperate for the sustainability of the project results.

The achievements of the IoT-ECO project led to the integration of the IoT-ECO technologies for green transformation in the academic curricula, provided teachers, students and researchers with the necessary materials, virtual models-prototypes and demonstrators to illustrate the topic, attracted the attention of the society on it and motivated companies and administration to support it and to maintain the sustainability of the project.

6.2. Training materials on the newly developed virtual models

The teams from UAMD, UBT and UoM presented tutorials for the implementation of the virtual models, digital twins, demonstrators of the Port of Durres and the university campuses of UBT and UoM respectively. They made demonstrations with examples working in real time. The tutorials are presented in the Annex with the presentations from the Closing event.

Most of the presentations from the Closing event are also included in the Annex, except those which included photos with attendees or students. The last ones are stored in Trello and can be used internally in the consortium.

7. Minutes of the discussion and decisions

During the coordination meeting held on 27.09.2025 an intensive discussion was organized. The contact persons and the members of the Quality board of each partner HEI shared their thoughts on the IoT-ECO project and the achievements. All of them shared the satisfaction from the team work and results obtained. A desire was expressed to continue further after the completion of the IoT-ECO project, as a team and in new project applications.

Several proposals were formulated by the partners:

- To add all scientific papers produced in the framework of the IoT-ECO project in the list of dissemination activities.
- To publish at the IoT-ECO site the information about the students projects presented at the final event of the IoT-ECO project. To prepare a special issue of the IoT-ECO newsletter dedicated to the students' projects.
- To collect a specific document provided by the responsible HEIs from Bulgaria, Greece and Austria about the quality of the teaching materials and courses published at the IoT-ECO Hub by the WB HEIs.
- To intensify the work of the persons locally responsible for the Dissemination of the IoT-ECO project.
- To organize an online meeting dedicated to the final report.

The external quality auditor prof. Albana Hallili attended the coordination meeting. She made some recommendations:
- To keep the administration of the IoT-ECO site and IoT-ECO Hub after the completion of the project. The team from UBT informed the consortium that the administrative support is guaranteed for the next 5 years.
- She gave advices about the final report of the IoT-ECO project.
- She requested a special virtual meeting dedicated to the external quality report that she needs to prepare.

8. Quality report for the Closing event

The closing event of the IoT ECO project was held at the Technical University of Sofia from 24 to 28 September 2025. The event brought together representatives from all project partner institutions, including managerial staff, academic faculty, students, and external stakeholders. Throughout the program, participants presented the project's key results and deliverables, highlighting its academic and practical contributions. The agenda, along with accommodation and travel arrangements, was disseminated in advance to ensure smooth coordination. The event featured a comprehensive academic program complemented by cultural and social activities designed to foster collaboration and exchange. Following the conclusion of the event, evaluation forms were distributed to participants to collect feedback and support the development of a final quality assessment report.

Results

The results of quality survey, based on responses of 40 event participants, are summarized:

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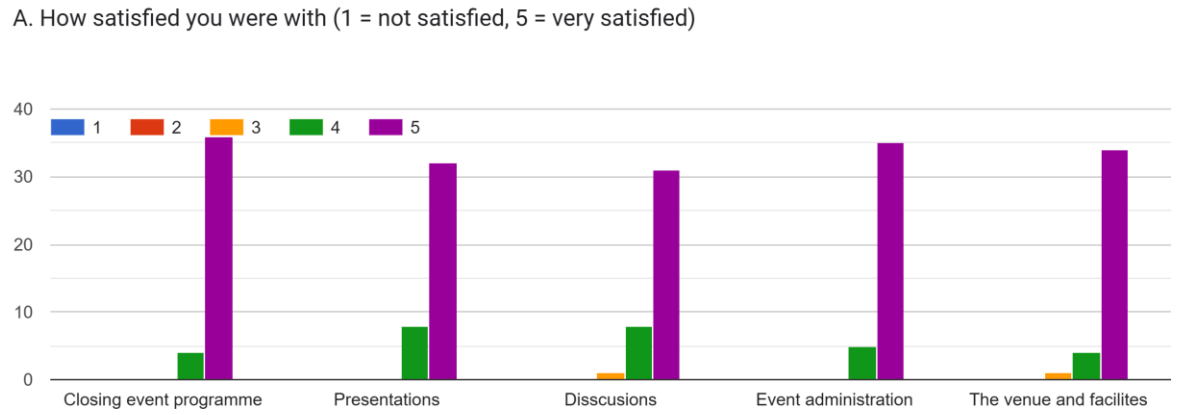

Figure 3. Results for the attendees satisfaction from

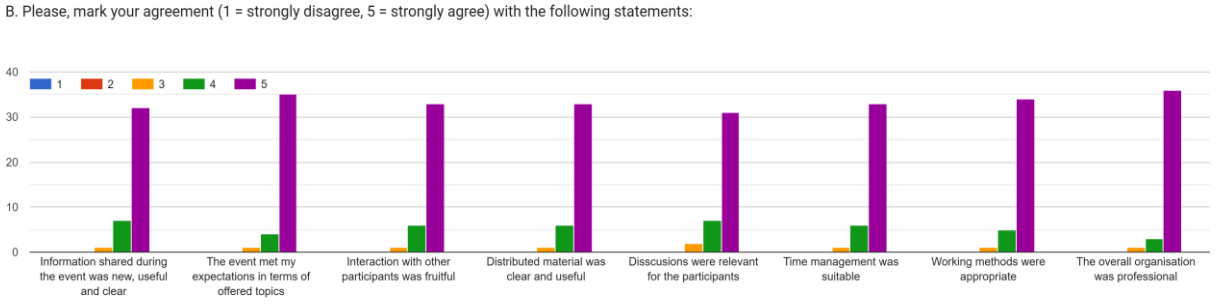

Figure 4. Results for the agreement of the attendees with different statements

The participants were asked for additional inputs/comments/suggestions/remarks related to closing event.
The following comments are received:

All activities on the framework of this project have been very beneficial
Perfect
The closing event was well organized, with good interaction between participants and organizers, and professional overall organization. It was a pleasure to participate in this event.
The overall organization was very professional, the time schedule was convinient, the presentations were interesting and raised positive discussions.
Very good organisation. It was a pleasure to be a part of such event
Everything perfectly arranged.
Also learnt a lot about smart city
Great event!
We had a very pleasant time! We learned a lot about IoT and the history of Bulgaria, the places we visited were fascinating and the guides were really sweet and kind, thank you for everything!

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Good job!
A huge congratulations to everyone involved in bringing this project to a successful close! The dedication, collaboration, and hard work from the entire team were truly inspiring. This closing event is not just the end of a project, but a celebration of what we can achieve together. Looking forward to future opportunities to build on this success!
It was extremely well organized and realized event indeed
Really friendly organisation team, congrats to all
The closing event was well organized, and project results were summarized.I liked very much the students presentations.
The event was well organized, informative, and provided useful discussions and materials.
Great team work!
The entire project was very well organized and also met all expectations in terms of new knowledge and experiences.
What I liked the most about the event was the interactive aspect of the work
I was surprised how good the project closing event was!
Everything was perfect
Everything was as it was supposed to be.
Thank you for your hard work on making this event happened.
The IoT Eco project has served as a valuable guide to better understand technologies such as digital twins and the opportunities they offer for improving efficiency in various fields, including energy, security, engineering, manufacturing, environment, healthcare, smart cities, government, and many more. Furthermore, this project has enabled networking among universities, students, and professors, fostering collaboration and innovation. We sincerely thank you for the opportunity you have given us.
The event was well organised!
No comment
10/10
Everything was organized in perfection
Well organized closing event
No comments
Best closing project ever!
Everything was conducted with professionalism. Great collaboration
The event was managed very professionally
The event was perfectly organised. The presentations and discussions were insightful.
It was my pleasure participating in the closing event, also I'm so glad I could meet other students and professors from different countries, thank you for having us there :)))
The project work group was excellent.
The closing event was very helpful and informative for the PHD students.
Wonderful experience

9. **Conclusion**

The closing event of the IoT-ECO Project marked a highly successful culmination of a collaborative and educational initiative. Participant feedback highlights the event's exceptional organization, engaging content, and meaningful interactions. The professional execution of the schedule, the quality of presentations, and the interactive nature of the sessions contributed to a dynamic and enriching experience for all attendees.

The project's framework proved to be highly beneficial, offering participants valuable insights into emerging technologies such as IoT, smart cities, and digital twins. These topics were not only well presented but also sparked thoughtful discussions, demonstrating the project's effectiveness in fostering intellectual curiosity and innovation. The inclusion of cultural elements, such as visits to historical sites in Bulgaria, added depth to the experience, promoting cross-cultural understanding and appreciation.

A key strength of the event was its ability to facilitate networking among students, professors, and institutions. This collaborative environment encouraged the exchange of ideas and laid the groundwork for future partnerships. The involvement of bachelor, master and PhD students and the emphasis on academic contributions further underscored the project's commitment to advancing research and education.

In conclusion, the IoT Eco Project and its closing event stand as a model of excellence in international collaboration, technological education, and event management. The success of this initiative offers a strong foundation for future projects and continued innovation in the field.

ANNEX

Presentations at the Closing event

IoT ECO

IoT Green Transformation for Academic Society and Business Oriented Ecosystem in Western Balkans

https://iot-eco.eu/

1

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IoT Green Transformation for Academic Society and Business Oriented Ecosystem in Western Balkans

Project number: 101083018 – IoT-ECO – ERASMUS-EDU-2022-CBHE-STRAND-2

Welcome to the IoT- ECO Closing Event 2025

Assoc. Prof. DR. Galia Marinova - IoT-ECO Project Coordinator
gim@tu-sofia.bg

Technical University of Sofia,
25.09.2025

2

IoT ECO — Erasmus+ CBHE Framework and Partners

Erasmus+ CBHE

Consortium

3

IoT ECO — Erasmus+ CBHE Framework and Partners

Associate Partners

Innovation Fund of Montenegro

Autoriteti Portual Durrës
DURRËS PORT AUTHORITY

CL69-KO

4

IoT ECO

IoT Green Transformation for Academic Society
and Business Oriented Ecosystem in Western Balkans

https://iot-eco.eu/

01.12.2022 to 01.12.2025

101083018 – IoT-ECO – ERASMUS-EDU-2022-CBHE-STRAND-2

5

IoT ECO — Two and a half years we worked a lot

- **Meetings in Sofia, Tirana, Graz and Patras. Virtual meetings.**
- **IoT-ECO Summer School, UBT, Pristina, Kosovo**
- **Visits, meetings and presentations from companies and associate partners.**
- **Exchange of experience and training courses for students, teachers and staff.**
- **Development of the IoT-ECO Hub. Training.**
- **Development of teaching materials.**
- **Development of Virtual models, digitals twins and demonstrators.**
- **Development, accreditation and probation of new and updated courses.**
- **Development of new modules.**
- **Feedback from the pilot courses. Analysis, adjustment, improvement.**

6

Achievements of the IoT-ECO project

Report of needs analysis.

IoT-ECO Hub.

New teaching materials - more than 30 new lectures, 20 new practical assignments, 5 tutorials.

10 new courses and 3 updated courses.

3 new modules.

3 Virtual models - Digital Twins- Demonstrators: Port of Durres (UAMD, UPT), UBT Campus (UBT, UP) and UoM Campus (UoM, UNIMED)

9 Invited guest lecturers from companies and associate partners.

More than 100 students/ teachers and staff took part of the exchange of experience.
231 students (84F, 147 M) followed the new and updated courses in the academic year 2024/2025.
More than 670 students will have studied them by the completion of the project.

300 students attended the IoT-ECO Summer School

7

Dissemination of the IoT-ECO project Achievements

The IoT-ECO Consortium dissemination events:

- Dissemination at International Conferences - more than 5
- Dissemination at International Weeks - more than 5
- Dissemination at Fairs and other events
- Scientific papers - more than 10
- Articles in newspapers and university sites - more than 10
- Open days
- Webinars

Our target groups:

- Academia - teachers, students, staff
- Researchers
- Schools
- People with disabilities
- Companies
- Society
- Administration, Politicians, Decision makers

8

IoT-ECO Summer School in UBT - the greatest dissemination event

The Consortium presented:

- The new courses and modules in IoT-ECO
- The new teaching in IoT-ECO
- The virtual models-demonstrators in IoT-ECO

Round tables:

- To disseminate the project to business, administration and society
- To plan further cooperation, training and internships
- To plan the sustainability of the IoT-ECO project results
- To plan further development
- To sign MoUs - 9 MoUs are signed

We expect your feedback!

9

We provided instruments with IoT-ECO

- To support the Green transformation of the Western Balkans.
- The Green Future of the WB will need the efforts of all of us.

Enjoy the Closing Event in TU-Sofia!

Provide us your feedback!

Stay connected with us to go forward together!

10

Thank you!

Contact: gim@tu-sofia.bg

Project web site: https://iot-eco.eu/

11

IoT ECO

IoT Green Transformation for Academic Society and Business Oriented Ecosystem in Western Balkans

https://iot-eco.eu/

1

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STARS EU

IoT Green Transformation for Academic Society and Business Oriented Ecosystem in Western Balkans

Project number: 101083018 – IoT-ECO – ERASMUS-EDU-2022-CBHE-STRAND-2

Closing event 2025 – TU-Sofia & IoT-ECO Project

Tutorial:

Part 1: Constructing a virtual prototype in a port environment with Microsoft Azure for Durres Port Authority.

Part 2: Constructing virtual prototypes in a port environment with ADOBE AEREO

Introduction to the Internet of Things

Prepared by: Manjola Zeneli
Uendi Cerma

September 2025

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2

IoT ECO

Constructing a virtual prototype in a port environment with Microsoft Azure Digital Twin

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- Azure Digital Twin
- Azure Digital Twin Components
- Smart Digital Twin Definition Language (DTDL)
- Azure Digital Twin Interfaces
- Azure Digital Twin features
- Azure Digital Twin subscription
- Azure Digital Twin configuration
- Azure Digital Twin portal
- Azure Digital Twin logic
- Azure Digital Twin/ DTDL/JSON configuration models that have been developed
- Azure Digital Twin/ uploading models JSON configuration models
- Azure Digital Twin configuration/Model Graph
- Azure Digital Twin configuration/Building Scenario
- Azure Digital Twin configuration/Export Building Scenario/Twin Graph
- Azure Digital Twin/ View of Twin Graph
- Azure Digital Twin /3D model photos of port
- Azure Digital Twin configuration/Real Port View
- Adobe Aero examples

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3

IoT ECO

Azure Digital Twin

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- Azure Digital Twins is an IoT platform, integrated with other Azure services like Azure IoT Hub, Azure Stream Analytics, and Azure Data Explorer.
- It enables you to create a digital representation of real-world things, places, business processes and people.
- Digital models can be used to get better insights of real models for the future, optimize operation, reduce costs and improve customer experience.
- It models every environment
- This can make it easier to connect digital twin models to physical devices and systems, and to analyze and visualize data from those devices and systems.
- Azure Digital Twins includes a set of pre-built templates and sample models that can be used as starting points for creating digital twin models. This can help developers get started quickly and reduce the time and effort required to create a digital twin from scratch.
- Azure Digital Twins is designed to be highly scalable and can handle large numbers of digital twin models and devices. This makes it suitable for use in large-scale IoT projects and for use in industries such as smart buildings and smart cities.
- Azure Digital Twins allows for multiuser access and collaboration, this provides for different teams to work on different parts of the model and also permits to different stakeholders to access the same model with different level of permissions.

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4

IoT ECO

Azure Digital Twin Components

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- **Components of Azure Digital Twin**:
  - **Digital Twin Definition Language (DTDL)**: The modeling language used to describe twins.
  - **Azure IoT Hub**: Integrates IoT data with Azure Digital Twin.
  - **Time Series Insights**: Helps visualize and analyze the time-series data.
  - **Azure Functions**: Used for custom logic and event-driven processing.

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5

IoT ECO

Digital Twin Definition Language (DTDL):

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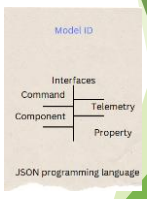
The modeling language used to describe twins.
Open modelling language.
Each device model has a unique ID **Digital Twin Model ID(DTMI)**
Each device model consists of a set of **interface**
Interfaces describe attribute of devices telemetry, property command, component
DTDL may contain 0,1 or many of each of the following fields.



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6

Azure Digital Twin Interfaces

Properties are data fields that represent the state of an entity.
Telemetry represent measurements or events and describe device sensor readings
Component-allows you to build your model interface as an assembly of other interfaces. It is an integral part of a solution.
Relationships-Shows how a digital twin can be involved with other digital twins. A solution can offer a graph of connected elements thanks to relationships.

7

Azure Digital Twin features

- Digital Twins creates graphs based on digital models of the physical environment .
- Creates twins.
- Creates relationship between twins.
- Enriches twins by adding attributes and metadata.

8

Azure Digital Twin subscription

1.Go to the link: https://azure.microsoft.com/en-us
2.Click on tab Get started with Azure
3.Click on Try Azure for Free
4.Sign up
5.For students there are 200 $ credits Free

9

Azure Digital Twin configuration

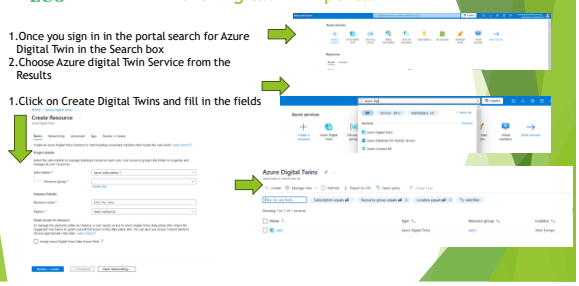
Step 1 - Setting up Azure Digital Twin Instance
- **Create Resource Group:**
  1. Navigate to Azure Portal
  2. Create a new resource group for the project.
- **Deploy Azure Digital Twin:**
  1. Search for "Azure Digital Twin" in the Azure Marketplace.
  2. Follow the steps to create an Azure Digital Twin instance in your resource group.
  3. Configure permissions for the Digital Twin instance.

10

Azure Digital Twin portal

1.Once you sign in in the portal search for Azure Digital Twin in the Search box
2.Choose Azure digital Twin Service from the Results

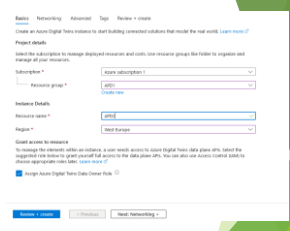
1.Click on Create Digital Twins and fill in the fields



11

Azure Digital Twin portal

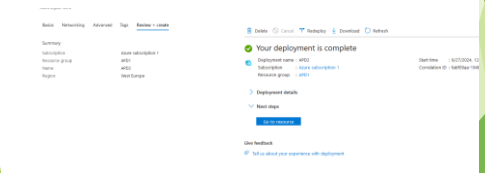
1.Fill in the field on the basic of setup including Subscription and Resource Group
2.Fill in the other field , check the Assign Azure Digital Twin Data Owner role in order to have the possibility to manage the azure digital twin.
3.Click the tab **Review and Create**



12

Azure Digital Twin portal

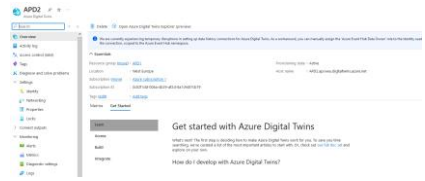
1. In the box are shown the details of the resource, Confirm the creation by selecting Create
2. In the second picture is shown the resource created called APD2
3. Then go to "Go to resource " button to navigate in the instance in the portal



13

Azure Digital Twin portal

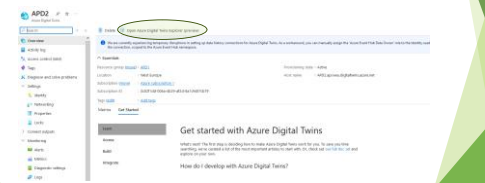
1. The view of the resource APD2 is shown in the picture below



14

Azure Digital Twin portal

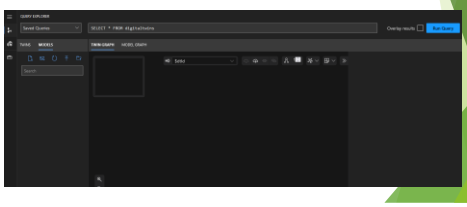
1. The view is shown in the picture below
2. Select Open Azure Digital Twin Explorer



15

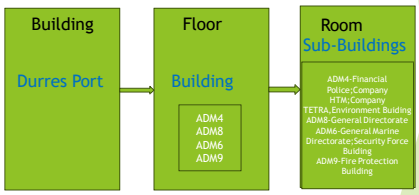
Azure Digital Twin portal

1. Select Open Azure Digital Twin Explorer
2. This will open Azure Digital Twin Explorer in a new tab as shown below
3. Azure Digital Twin Explorer will connect automatically to the instance
4. We will use Azure Digital Twin Explorer to set up the MODELS and TWIN GRAPHS



16

Azure Digital Twin logic



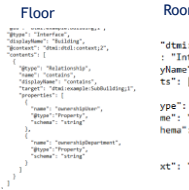
Digital twins represent digital entities into the rooms.

17

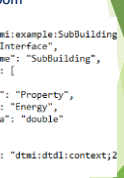
Azure Digital Twin/ DTDL/JSON configuratio models that have been developed

Building

Floor



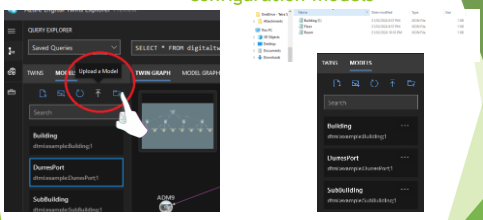
Room



Azure Digital Twin uses programming language DTDL version 2.Each model defines what a building is ,what a floor is and what a room is. Later we create digital twins that are instances of these models representing building floors and rooms. Models are written in DTDL a similar language to JSON. Each model describes a single type of entity.

18

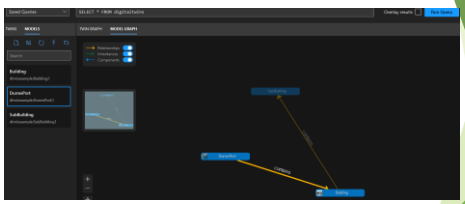
Azure Digital Twin/ uploading models JSON configuration models



The procedure for starting uploading a model is shown in the figure above, just click in the arrow pointing up inside the red circle. In the open window that appears select the three files and then click open to upload them all.

19

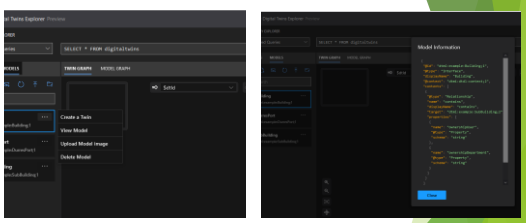
Azure Digital Twin configuration/Model Graph



The files will be uploaded in digital twin instance as is shown in the picture. They are shown in the **Model** panel and display their name.

20

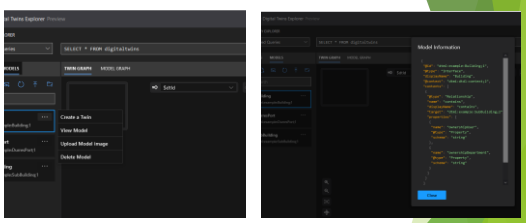
Azure Digital Twin configuration



If there is clicked in building View Model we can see the model code in DTDL. If we click in Upload Model Image we can insert an image to the model. The same logic is for each of the models uploaded.

21

Azure Digital Twin configuration



From these models we can create twins where they are necessary second the facility environment and buildings. Here is uploaded a pre-create graph that contains

22

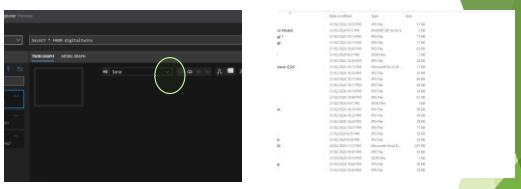
Azure Digital Twin configuration /Building Scenario 1/3

ModelID	ID (must be unique)	Relationship (From)	Relationship Name	Init Data
dtmi:example:DurresPort;1	DurresPort1			{"Date": 2024}
dtmi:example:Building;1	ADM8	DurresPort1	contains	
dtmi:example:Building;1	ADM4	DurresPort1	contains	
dtmi:example:Building;1	ADM6	DurresPort1	contains	
dtmi:example:Building;1	ADM9	DurresPort1	contains	
dtmi:example:Subbuilding;1	GeneralDirectorate	ADM8	contains	{"Energy": 7449}
dtmi:example:Subbuilding;1	FinancialGuard	ADM4	contains	{"Energy": 2771}
dtmi:example:Subbuilding;1	CompanyHTM	ADM4	contains	{"Energy": 412}
dtmi:example:Subbuilding;1	CompanyTetra	ADM4	contains	{"Energy": 633}
dtmi:example:Subbuilding;1	EnvironmentBuilding	ADM6	contains	{"Energy": 8494}
dtmi:example:Subbuilding;1	GeneralMarineDirectorate	ADM6	contains	{"Energy": 4283}
dtmi:example:Subbuilding;1	SecurityForceBuilding	ADM6	contains	{"Energy": 2998}
dtmi:example:Subbuilding;1	FireProtectionBuilding	ADM9	contains	{"Energy": 2424}

This is building scenario for the Durres Port Authority and some of the main building and sub-buildings named as in the photo with the energy measured in each of them for a certain month.

23

Azure Digital Twin configuration /Import Building Scenario 2/3



In the Twin Graph tab select the up arrow pointing into a cloud inside the green circle and from the shown table select the file *"building scenario" in* excel format and then Open.

24

Azure Digital Twin configuration/ Import Building Scenario 3/3

To finish importing the graph click on Save icon inside the green circle in the right upper corner. Azure digital Twin explorer will use the uploaded file to create the requested twins and relationships between them. To confirm the import process will show an "import successful" dialog box.

25

Azure Digital Twin configuration/Export Building Scenario/Twin Graph

To export the twin graph click on down arrow in cloud icon inside the green circle. The graph will be exported with the format **Exported Graph.json.** It can be used for modifications or for importing it In future projects.

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Azure Digital Twin configuration

From Azure Digital Twin platform we can run different queries with sql commands as in the example:
Query: SELECT * FROM digital twins
To see the graph select the Run Query button.

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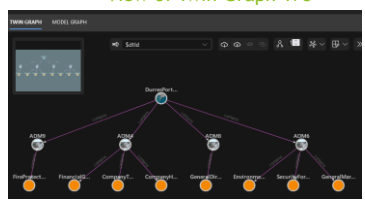
Azure Digital Twin/ View of Twin Graph 1/5



Azure Digital Twin Explorer retrieves all the twins and the relationships from the service. The circles represent digital twins and the lines represent relationships.
Durres Port Facility contains 4 buildings In the scenario and each of the buildings contains a certain number of sub-buildings.

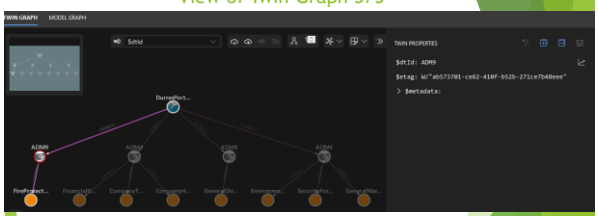
28

Azure Digital Twin/ View of Twin Graph 2/5

We can select a twin to see the properties and the values for scenario of Durres Port that highlights the relationship with the buildings.

29

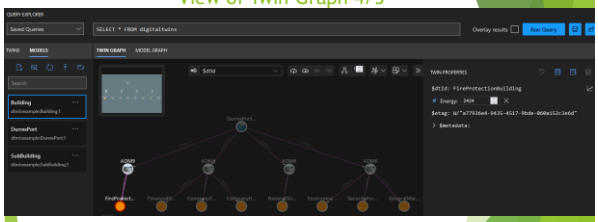
Azure Digital Twin/ View of Twin Graph 3/5



We can select a twin to see the properties and the values for example if we click in ADM 9 there are shown the relationship with the buildings and sub-buidings.

30

Azure Digital Twin/ View of Twin Graph 4/5



A twin can be selected to see the properties and the values for example if the Fire Protection Building is clicked there are shown the relationship with the building and the proper value of energy in the TWIN PROPERTIES Panel in the right part of the photo. The energy in this example is 2424 kWh.

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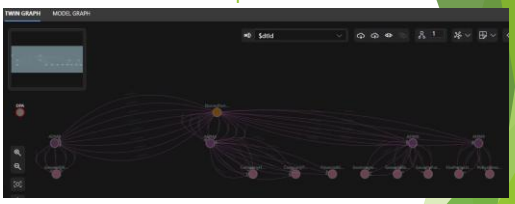
Azure Digital Twin configuration /Twin Graph View 5/5



The Other model of Twin Graph.

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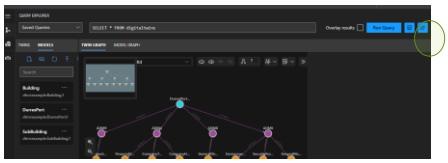
Azure Digital Twin configuration /Twin Graph View



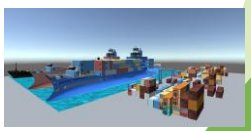
The Configuration can be shared by clicking in the icon in the upper right part of the Azure platform. When we click a tab **Linkcopied** is shown and we have the possibility to paste he link and then share for accessing it.The link is as follow:
https://explorer.digitaltwins.azure.net/?query=SELECT%20*%20FROM%20digitaltwins&tid=1bfe871c-aed0-4e7a-8065-0d258e17f499&eid=APD.api.weu.digitaltwins.azure.net

33

Azure Digital Twin configuration /Real Port View

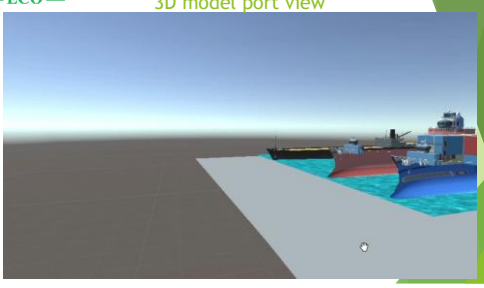
34

Azure Digital Twin / 3D model photos of port



35

Azure Digital Twin / 3D model port view



36

Azure Digital Twin configuration /Real Port View

A Picture of the integration of the 3D Model , digital twin Prototype and real Port View.

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37

Part 2: Constructing virtual prototypes in a port environment with ADOBE AEREO

Adobe Aero offers innovative solutions for creating captivating augmented reality (AR) experiences, making it a valuable tool for digital twinning projects. Let's explore two examples showcasing how Adobe Aero can enhance real-world environments with digital overlays.

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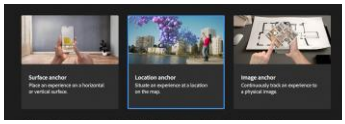

Example 1: In the first scenario, Adobe Aero integrates with **Google Maps** to create an AR experience based on a real-world location. By overlaying digital content onto the physical environment, users can explore detailed 3D models or relevant information anchored to the actual location. Imagine standing in front of a building or landmark, and through your device, you see interactive data and graphics come to life, providing in-depth insights about the area.

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Our digital augmented twin will be the Port of Durrres, so we choose it as our prime location.

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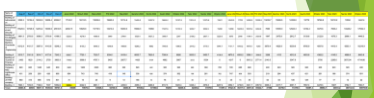
The next step after gathering all the energy consumption data from three years we are going to design the graphics.



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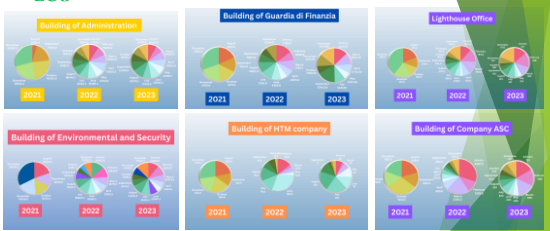

The infographics are organized in piecharts and saved as PNG files.

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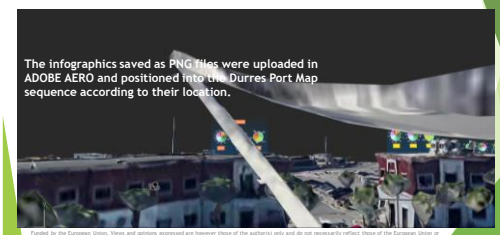

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Final step beta testing through the ADOBE AERO APP

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Example 2: Scanning a Photo to Gain AR Data In this case, Adobe Aero uses the power of AR to extract data from a simple photo. By scanning an image, users can trigger augmented content that enhances the visual information in the photo. In this case, scanning a port photo could bring to life detailed data of passangers and cars.

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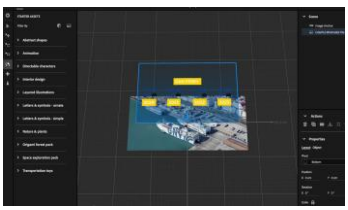

Same as the first example we import infographics into the ADOBE AERO in horizontal mode, according XY. After positioning the infographic we share the link for the beta testing.

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Final step beta testing throught the ADOBE AERO APP

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Thank you for your attention !

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"Implementation of the IoT hub and Digital Twins at the UBT smart and self-sustainable city"

http://iot.ubt-uni.net/

IoT Green Transformation for Academic Society and Business Oriented Ecosystem in Western Balkans
https://iot-eco.eu/

1

IoT Green Transformation for Academic Society and Business Oriented Ecosystem in Western Balkans

"Implementation of the IoT hub and Digital Twins at the UBT smart and self-sustainable city"

President of UBT
Prof. Dr Edmond Hajrizi
Dean of Computer Science and Engineering Faculty
Assoc. Prof Dr. Besnik Qehaja

Closing Event IoT-Eco 24-28/09/2025

2

AGENDA

CURRENT SITUATION
Explore the existing state of the UBT campus, shedding light on current conditions, infrastructure, and landscape.

MODEL PROPOSAL
We ideate innovative solutions in the Inception phase, visually refine ideas with the Virtual Model, and outline detailed implementation plans.

CONCLUSIONS
Our proposed solutions signal a significant step towards fostering and setting the foundation for a resilient academic environment at UBT.

3

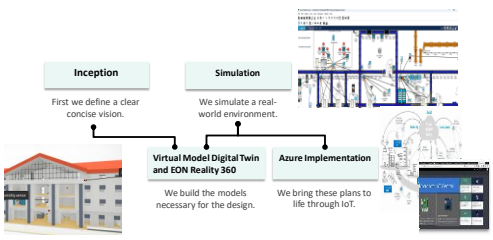
CURRENT SITUATION

4

Current Situation

5

MODEL PROPOSAL



6

INCEPTION

- Strategic Integration of IoT for Green Transformation
- Cross-Border Collaboration and Knowledge Exchange
- IoT-ECO Hub for Practical Solutions
- Inclusive Educational Approach for Sustainable Impact

7

VIRTUAL MODEL

- **Pre-Implementation Insights:** Virtual models provide a virtual playground for our academic community to gain insights into proposed solutions before physical implementation.
- **Curriculum Enhancement:** Integrate virtual models into the curriculum to expose students to cutting-edge technologies.
- **Cross-Border Collaboration:** Engage in collaborative projects with institutions in the Western Balkans and EU partners for knowledge exchange.

8

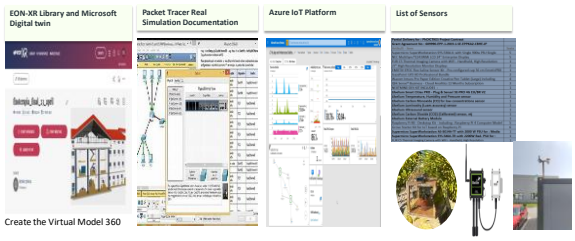
EXAMPLE: The Implementation scope from the UBT Staff and Students

9

EXAMPLE: The Implementation in Agriculture from the UBT Staff and Students

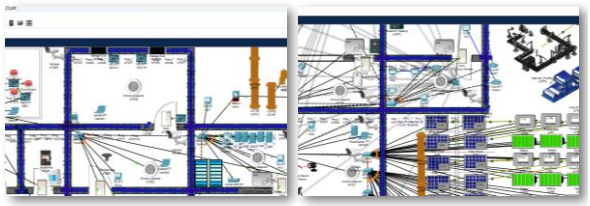
10

Our infrastructure for the implementation of this IoT Virtual HUB



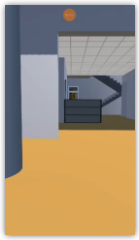
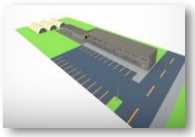
11

THE SIMULATION MODEL



12

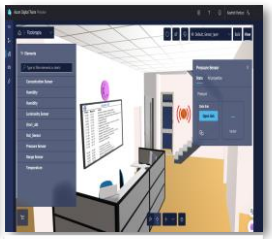
THE VIRTUAL MODEL


13

3D representation of campus on Azure Digital Twins


Azure Digital Twins Preview

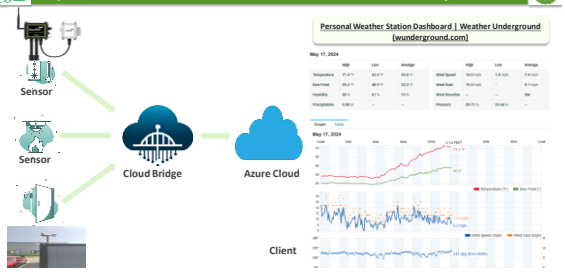

Sensor behavior

14

Implementation: Main Architecture UBT-Smart City

15

Implementation: Main Architecture UBT-Smart City



16

3D representation of campus on Azure Digital Twins

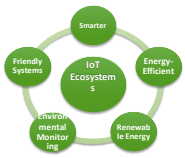
Data access via external link


17

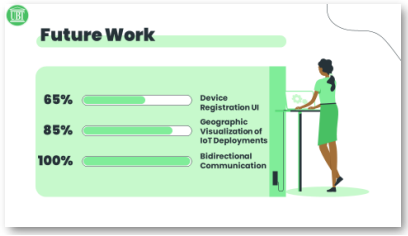
CONCLUSIONS

Implementation of IoT Ecosystems

- Environmental Sustainability
- Ecological Responsibility



18


Future Work
65%
Device Registration UI
85%
Geographic Visualization of IoT Deployments
100%
Bidirectional Communication

19


Thank You!
Do you have any questions?


SCAN ME

20

Co-funded by
the European Union

IoT Layer: Valve Control System

The valve control system consists of a soil humidity sensor, air temperature and humidity sensor, field controller, valve controller and sprinklers.

The valve control system collects and processes soil humidity, as well as, air temperature and humidity. It is managed through an all-digital network platform, and the data collected can be sent back to the control center and each monitoring center through the wireless network to realize the distributed monitoring and centralized control.

The valve controller communicates with the field controller through Node-Red, and the collected data are uploaded to the monitoring center by the field controller through the wireless network.

IoT Green Transformation for Academic Society
and Business Oriented Ecosystem in Western Balkans
https://iot-eco.eu/

IoT Green Transformation for Academic Society and Business Oriented Ecosystem in Western Balkans
Project number: 101083018 – IoT-ECO – ERASMUS-EDU-2022-CBHE-STRAND-2

Presentation title: „Towards an IoT Eco Futures: Sustainable Optical Communication and Hybrid Networks "

Erich Leitgeb and Pasha Bekhrad

Sofia , 24. 09. – 28. 09. 2025

IoT-ECO 2025

TU Graz in the Closing event at
TU-Sofia

September 24 - 28, 2025

Institute for Microwave and Photonic Engineering

Towards an IoT Eco Futures: Sustainable Optical Communication and Hybrid Networks

ihf Institut für Hochfrequenztechnik

Towards an IoT Eco Futures: Sustainable Optical Communication and Hybrid Networks

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Towards an IoT Eco Futures: Sustainable Optical Communication and Hybrid Networks

- Introduction, Motivation, Principles and Basics
- Wireless Technologies / RF compared to FSO (propagation effects on Free Space Optics (FSO), WLAN, DVB-T, Satellite Communications, LMDS)
- Applications / Different Scenarios / Broadband Access
- Results, Proposals and Further Work

1 Introduction / Motivation for Combining RF and Optical Wireless

- To increase the **Data Rates** of the Transmission System (Broadband Access and Backbone)
- To improve the **Reliability and Availability** of the Transmission System (including Redundancy and Site Diversity); for 5G the Network Infrastructure is an important fact!!!
- To increase the **Cost Efficiency** of the Transmission System
- Achievable by Combination, because of
  - Different Propagation Behaviour
  - Different Weather Influences

1 Introduction

Advantages (FSO, compared to other Communication Techniques)

- large Bandwidth …. high Data Rates
- Focusing / Narrow Beam
- Electromagnetic Compatibility
- minimising ‚electromagnetic Pollution'
- protection of ‚wiretapping'

- Disadvantage of FSO: **Reliability is** mainly **determined by** local weather **(and not only by electrical and optical components or network infrastructure)**
- **Bad weather conditions - attenuation - limited range**
- **Leads to usage of FSO for the Last Mile Access mainly!!!**

2 Considered Technologies

Optical Wireless compared to RF Wireless and "Wireless Technologies" used in the different scenarios

- Propagation effects on FSO and differences to common Wireless Technologies
- FSO systems and first combinations with LMDS
- Digital Video Broadcasting-Terrestrial (DVB-T)
- Wireless LAN (WLAN)
- Satellite Communications
- Combination with **5G and LTE** (!Autonomous Driving!)

!!!! Combinations in parallel and serial setups !!!!

2.1 FSO – Channel

Reliability of Optical Wireless – the FSO Channel

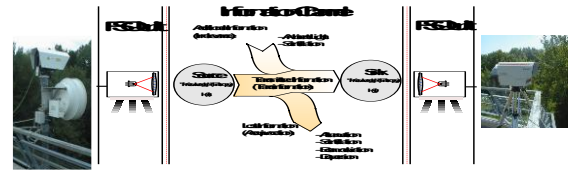
Attenuation mainly caused by:

- Molecular absorption (always the same value depending on height and molecules in the air
- Scattering on particles (molecules, aerosols, fog, clouds, rain, etc.)
- Atmospheric turbulences (scintillations, variation (change) of the refractive index)

2.1 Weather Influence on FSO

The optical channel is significantly different from the RF channel!

Fog, Clouds and Snow mainly affect the reliability of Optical Wireless links



Type 2 FSO-System **Type 3 FSO-System**

2.1 Scattering on particles

- **Rayleigh-Scattering (only Rayleigh-Scattering results in a visibility of 350 km); proportional f^4 – important for very small particles only** (much smaller than the used wavelength)
- **Visibility is mainly influenced by additional Scattering (Mie-Scattering) – important for the larger particles in clouds and fog** (particles of the same size like the used wavelength)

2.1 Comparison of FSO and µW - Mie Scattering

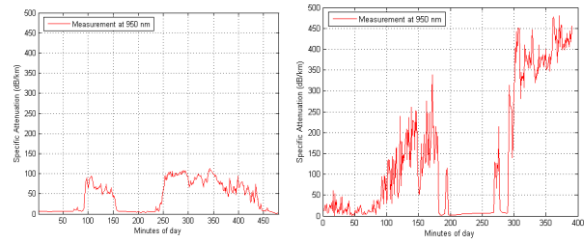
- **For a stand-alone FSO system, fog can cause attenuation of up to 100 dB/km in the climate around Graz (800 dB/km in some regions), while rain can cause attenuation up to 25 dB/km in a heavy thunderstorm at a rain rate of 150 mm/h, which is comparatively less important.**
- **The same rain rate can cause up to 50 dB/km attenuation for a microwave link (up to 35 dB/km for 40 GHz), while fog does not particularly matter, and increased humidity causes less than 5 dB/km.**

2.1 Micro-physics of fog

- **Radiation fog (continental / city fog); like spec. Attenuation in Graz: 100 dB/km (slow changes)**
  - **particle diameter ~ 4 µm,**
  - **liquid water content between 0.01 and 0.1 g/m³**
- **Advection fog (maritime fog); like spec. Attenuation in Nice: 300 dB/km (fast changes)**
  - **particle diameter ~ 20 µm,**
  - **liquid water content 0.2 g/m³**

2.1 Specific attenuation of fog

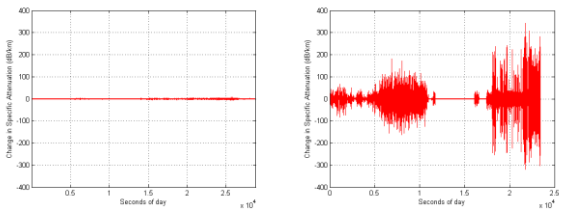
Graz Nice



Max. Attenuation measured in Graz (120 – 150 dB/km)
Max. Attenuation measured in Nice (up to 780 dB/km)

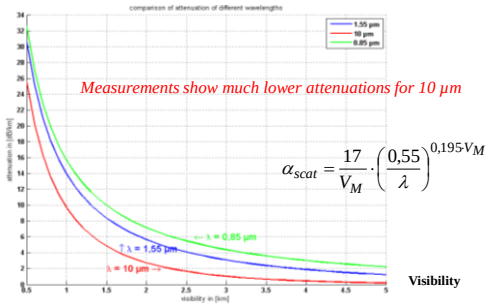
2.1 Changes in specific attenuation of fog

Graz Nice



Time Behaviour

2.2 Wavelength Comparison – Attenuation and Visibility

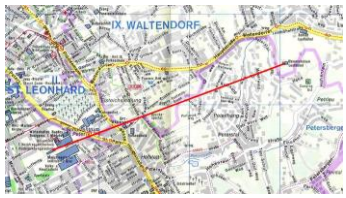


Empirical Equation as Figure: for λ = 0.85 µm (green) and λ = 1.55 µm (blue) [33], including 10 µm (red);
[33] Lentke H., *Connection of data networks (LAN) directly through the atmosphere using infrared light*, CBL GmbH (Dietburg, D)

2.3 FSO and RF links

First experiments started in 2001 / 2002 with Directional Radio Systems and LMDS

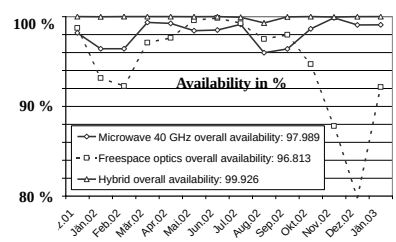
Optical links between Graz Inffeldgasse 10 and Observatory Lustbühel (2.7 km)



FSO and directional radio

2.3 Experiment

Combined / Hybrid Systems



December 2001 – January 2003

LMDS and FSO in parallel

Local Multipoint Distribution Service (LMDS) - a broad-band wireless access technology - planned for digital television trans-mission (DTV)

as a fixed wireless, point-to-multipoint technology for last mile

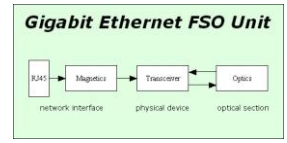
a 40 GHz Microwave system installed at TU Graz

2.3 FSO - well suited for Broadband Access Networks

- **Quick installation of optical short distance links in urban areas (Point-to-Point / Point-to-Multipoint Systems)**
- **Broadband link for railway, highway or river crossings**
- **Links between buildings of companies or institutions (no ‚wire-tapping')**
- **Rapid replacement of broken cable-links in emergency situations**
- **Short term installation for mobile / nomadic use (e.g. seminars, meetings, events)**
- **Connections to subsidiaries, storage depots (outposts) of companies or other institutions**
- **For Disaster Management, Disaster Recovery and CIMIC purpose**
- **Quick communication connection to Broadband Backbone**

2.3 GBit/s Free Space Optics Systems for Last Mile

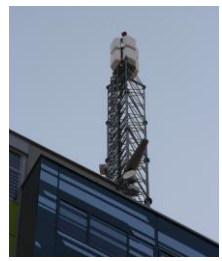
- Multi-Beam design concept, 8 Transmitters, 1 Receiver (in 2004)
- **GBit Ethernet (in 2004 very expensive)!!!**



- Next Generation of GBit Ethernet
- FSO NG (in modules), as Broadband Access to 5G etc.

2.4 DVB-T

- **In 2005 relatively new and widespread technology, initiatives from local governments to establish additional DVB-T channels**
- **Bandwidth per channel from 5 to 23Mbit/s**
- **IP over DVB standard is already existing (MPE Multi Protocol Encapsulation)**
- **Outstanding advantages regarding wave propagation and reflections on metallic surfaces or armoured concrete**
- **Set Top Box needed / Ideas of Combinations with other communications technologies**



Digital Video Broadcasting-Terrestrial (DVB-T)

2.4 DVB-T

In 2015 an international project "SEE TV-WEB" for using DVB-T for Internet-Access were finalized

Tackling the "Digital Divide" in SEE by using the capacity of DTT networks

Acronym: SEE TV-WEB

TU Graz was involved in this **S**outh **E**ast **E**urope Programme

2.5 WLAN

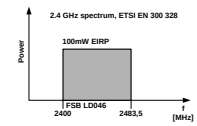
- License free **Wireless LAN / first ideas of combinations with FSO (long time before 5G)**

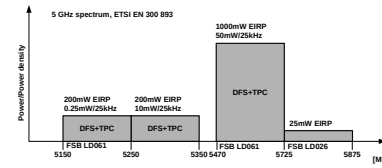
WLAN
-Free to use for everyone
-Possible interferences
-Limited EIRP
-2.4GHz and 5GHz spectra

Spectra and allowed EIRP
(Equivalent Isotropically Radiated Power)

2.5 ETSI WLAN

(European Telecommunications Standards Institute)





TPC: Transmit Power Control DFS: Dynamic Frequency Selection

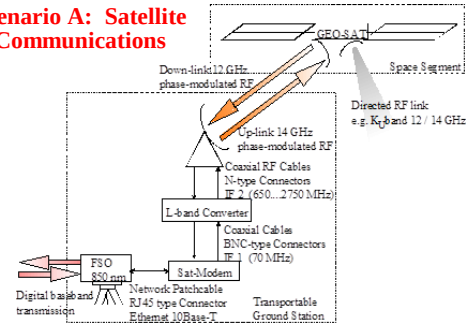
3 Applications / Different Scenarios Combination Experiments

- FSO systems and first combinations with LMDS (shown)
- Satellite Communications
- Wireless LAN (WLAN) (in CIMIC exercise)
- Digital Video Broadcasting-Terrestrial (DVB-T)
- New ideas with Optical Feeder Links and Visible Light Communications
- Autonomous Driving and Hybrid Deep Space Links

Green Photonics

Pasha Bekhrad and Erich Leitgeb

Scenario A: Satellite Communications



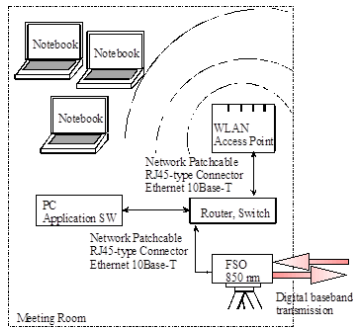
As example a usual K_U-Band Satellite Ground Station

Pasha Bekhrad and Erich Leitgeb

Scenario A: SatCom (RF) with FSO and / or WLAN

A typical K_U-Band Satellite Ground Station is connected with FSO or / and WLAN to a conference- or meeting room

Scenario A: Satellite Communications (RF) in combination with FSO and / or WLAN



Pasha Bekhrad and Erich Leitgeb

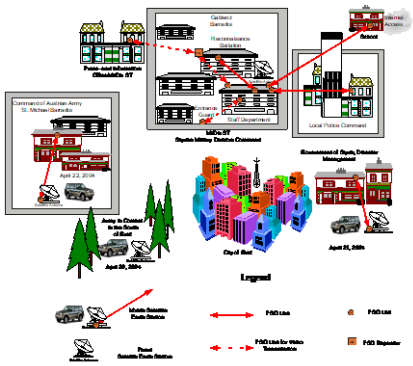
Scenario A: Satellite Communications (RF) in combination with FSO and / or WLAN

Video conference and data transmission for the Mil Div ST at the combat in south of Graz

Mobile satellite earth station

also used in combination with Scenario B: CIMIC Exercise

Pasha Bekhrad and Erich Leitgeb



Scenario B: CIMIC Exercise

CIMIC

Installation of FSO and Satellites in Civil-Military-Cooperation

Exercise in Styria

Pasha Bekhrad and Erich Leitgeb

Scenario C: DVB-T in combination with FSO and WLAN

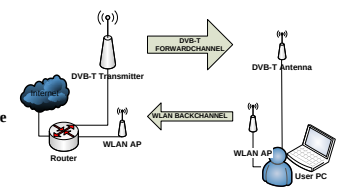
A.) Direct connection

- **Using DVB-T as a forward channel (like downlink)**
- **Using WLAN/FSO as a back channel**

B.) Local WLAN relay

- **Users in a community area are connected to a WLAN cloud which is concentrated to location with LOS to the core network**

Applications and Method



Provided services: http; email; VoIP; VoD; VPN

Pasha Bekhrad and Erich Leitgeb

4 Outlook

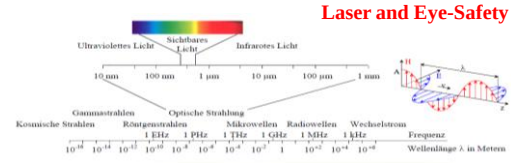
Future Scenarios in Green Photonics

- Further tests with Internet services like http, email, VoIP and multimedia services will be demonstrated and evaluated
- Proposals for Optical Feeder Links and Visible Light Communications
- Combination of FSO and RF technologies (including Site Diversity / Redundancy); for 5G of main interest
- Combination scenarios for Autonomous Driving (with special interest on 5G and Deep Space Communications

4 Optical Communications (Fiber and FSO)

High Carrier-Frequency, high Bandwidth and high Data Rate

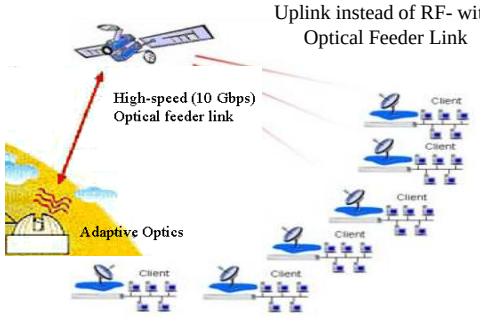
Laser and Eye-Safety

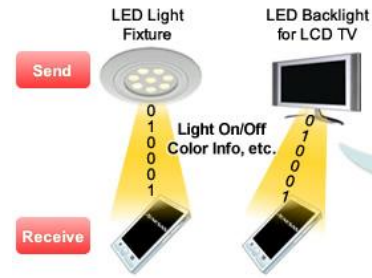


Bezeichnung	Spektralbereich
UV-C	100 nm ..... 280 nm
UV-B	280 nm ..... 315 nm
UV-A	315 nm ..... 380 nm
Sichtbares Licht	380 nm ..... 780 nm
IR-A	780 nm ..... 1400 nm
IR-B	1400 nm ..... 3000 nm
IR-C	3000 nm ..... 1 mm

4.1 FSO as uplink for Broadcast Satellites

Uplink instead of RF- with Optical Feeder Link



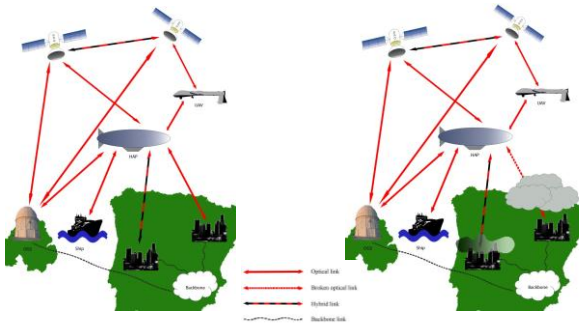


4.2 VLC

Visible Light Communications

Backchannel with RF, WLAN, IR etc.

4.3 Site Diversity and Redundancy

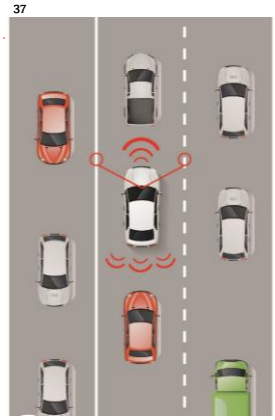


The Austrian RDI Roadmap for Automated Vehicles serves several purposes:

4.4 Vehicle to X Communication

!!!!!! in-Car and Car to X Communication !!!!!

5G as an important technology, but for Base-Stations the nec. Broadband Access!!!



4.4 Vehicle to X Communication

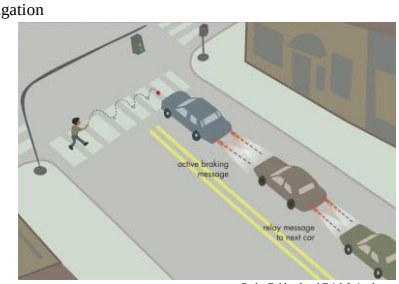
Austrian Research, Development & Innovation Roadmap for Automated Vehicles

!!!!!! Communication is an important factor in-Car and Car to X Communication !!!!!

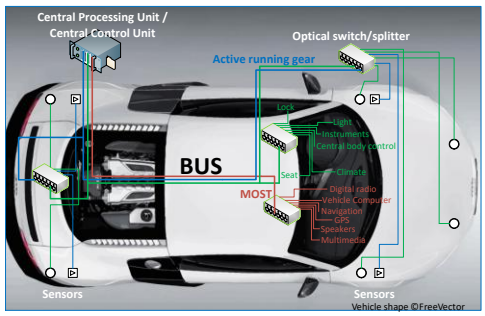
4.4 VLC (Visible Light Communication) in Traffic

- LED as Transmitter at the automobile headlight
- Light for Communications at traffic lights or other Infrastructure will be detected
- In tunnels etc. also for navigation

Communication Car to X (Car / Infrastructure)

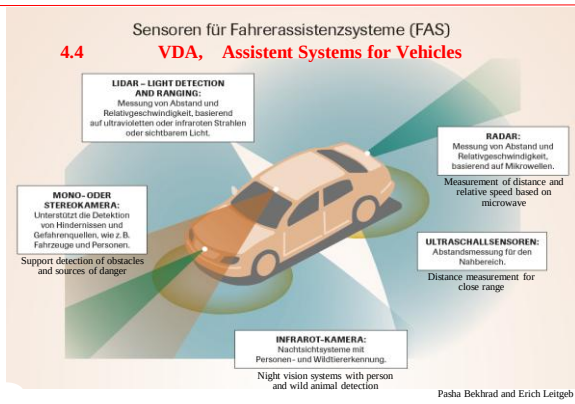


4.4 Car Networks



4.4 Vehicle to X Communication

- **In-Car (Fixed or Wireless) with Sensors and Electronics (incl. NFC and RFID)**
- **Car to X Communication** (5G and OWC in combinations)
- **Traffic and Car Sensors** (including Radar, Lidar and cameras)
- **Main Aspects 1) Costs / Power Consumption / Energy; 2) Efficiency / Innovation; 3) Reliability / Availability; 4) Safety / Security**



5 Final Conclusions and further work

To increase the link reliability and cost efficiency by

- **Combination of FSO and RF technologies (planning with 5G)**
- **Site Diversity / Redundancy (also relevant with 5G)**
- **10 µm wavelength and other high bitrate technologies**
- **Alternative Modulation and Coding Techniques**
- **Possible Combinations of RF and Optics also in Sensor and Navigation Technologies**

Green Photonics

THANK YOU

FOR

YOUR ATTENTION!

IoT — ECO

Distributed signal processing and machine learning for IoT: Main concepts and recent developments

1

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

UNIVERSITY OF PATRAS
ΠΑΝΕΠΙΣΤΗΜΙΟ ΠΑΤΡΩΝ

IoT Green Transformation for Academic Society and Business Oriented Ecosystem in Western Balkans
Project number: 101083018 – IoT-ECO – ERASMUS-EDU-2022-CBHE-STRAND-2

University of Patras Team:
- Kostas Berberidis
- Christos Mavrokefalidis
- Periklis Theodoropoulos
- Evangelos Georgatos

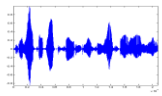
2

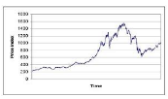
Outline

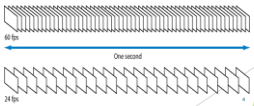
- Part I: Main concepts
  - Evolutions in Data and Processing
  - Computing on the Edge of the Network
  - Centralized, Distributed and fully Decentralized Architectures
  - Recap
- Part II: A selection of new developments
  - Distributionally Robust Optimization
  - Conditional Value-at-Risk (CVaR) in Federated Learning
  - Sharpness Aware Minimization: a means to improve generalization in Deep Learning
  - Sharpness Aware Minimization for Federated Learning
  - What to Take With You

3

Data evolution: from Conventional Signals …

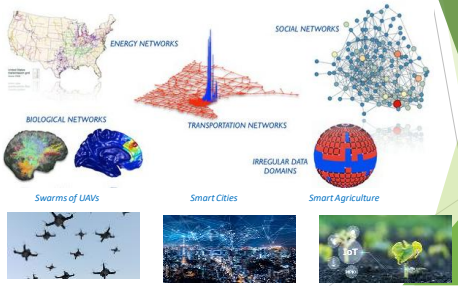






4

Data evolution: … to Unconventional Signals



5

More on the new Data

- Data generation is becoming:
  - Massive (and sparse)
    - New means of exploring the physical world
  - Unstructured and Irregular
  - Often collected in a distributed manner
    - Nature-to-Machine Communication (and interaction)
    - M2M communication and cooperation
- New challenges for sciences related to data gathering and processing e.g.
  - Signal Processing, Machine Learning, IoT, Communication Networks,
  - Applied Statistics, Scientific and High Performance Computing

6

Valuable property: The underlying sparsity of Data

"…systems produced by Nature and by the Art of man are seldom as complex […] as their size and number of components might lead us to expect them to be. Fortunately for our prospects of understanding complex systems, it is not common for each element in such systems to interact strongly with each other element. On the contrary, the world is mostly empty".

Foreword by Herbert Simon* in the book:

"Decomposability: Queueing and Computer System Applications", by P. J. Courtois, Academic Press, 1977.

* One of the Fathers of Artificial Intelligence

7

7

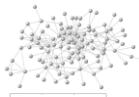
Sparse World (SparseLand): examples

- If our whole solar system was compressed (leaving no space between sub-atomic particles) it would be a sphere with a diameter of about 20 km.
- One set of human chromosomes contains about 3 billion base pairs (A, C, G, T) → an incredibly high number of combinations. However, the human genes are estimated to be only ~20000.
- A human can utter thousands of different phonems. However, every single language may be composed by only a few tens of them.
- A 5-years engineering curriculum consists of 50-60 courses with thousands of different things to learn and remember. However, the essential constituent concepts may not be more than a few hundreds (this is just a conjecture ☺).

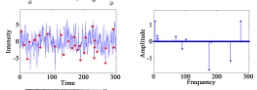
8

8

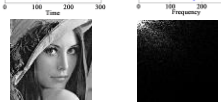
SparseLand: Technical examples



A network may comprise a huge number of nodes where the maximum number of links is O(N^2), however, the actual number of links is commonly O(N). So, the so-called "Adjacency matrix" is sparse.



Left: A time-domain signal
Right: Its Fourier spectrum



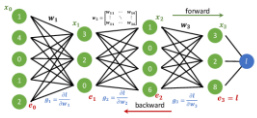
Left: LENNA image
Right: Its DCT transform

9

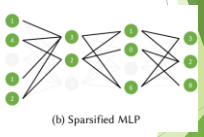
9

SparseLand: Technical examples (Cont.)

Sparsity in Deep Neural Networks



(a) Dense MLP training example



(b) Sparsified MLP

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Massive data → New processing paradigm

❑ Massive data + Very high computational power → Data-driven processing

❑ From Model-based techniques to Data-driven techniques (Deep Learning)

❑ New trend: Model-based Deep Learning (e.g. Deep Unrolling)

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From Centralized processing:

to Distributed Processing

and to Decentralized Processing

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Computing (and Learning) on the Edge*

- In many cases, **immense amounts of data** are available, but at different spatial locations.
  - **Exchanging** data can **be prohibitive** because of
    - Inefficient **communication resources**
    - **Privacy** considerations
- Other problems of Edge Computing:
  - **Different nodes** (spread in space) observe the **same** phenomenon, or
  - Several **subsets of nodes** observe **different** phenomena, or
  - **Different nodes** observe different **views** of the same phenomenon.

Edge: the part of the network which is close to where data is generated. Edge devices: smartphones, IoT sensors, cameras, drones, wearables, embedded system etc.

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Computing on the Edge

- The above problems are challenging because we have to establish a **cooperation** between the nodes so as to Estimate/Detect/Learn **using all that data**, dealing with
  - the node inconsistency, and
  - the Communication Overhead and Latency

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Applications(1)

In **automotive** domain, **connected** and autonomous **vehicles** may collaborate

- They employ cameras, LiDAR and GPS sensors
- They aim for, e.g.,
  - (a) vehicle and pedestrian recognition, and
  - (b) improving they localization information (positioning of themselves and the surrounding vehicles)

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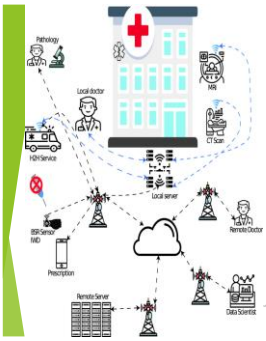

Applications(2)

- In the **medicine field**, especially during **pandemic outbreaks or other massive emergency situations**
  - Many patients remain at home due to **hospitals reaching full capacity quickly**
  - **Medical IoT devices** (such as oxymeters, ECG Monitors) **collect patients data remotely.**
  - These **devices enable collaboration among healthcare providers** for coordinated patient care.

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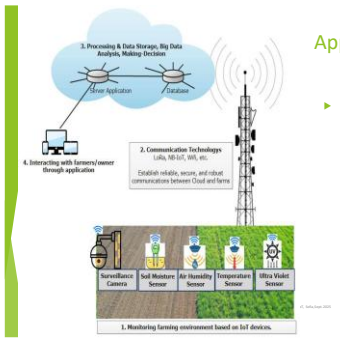

Applications(3)

- In the **environmental domain**, devices in an IoT network may collaborate
  - The **devices sense the environmental** quantities in an area of interest
  - They aim for **forcasting future values** in the short or long term

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How do we approach these applications

- Under the **decentralized** setting
  - Assuming K agents with sensing, processing and communication capabilities and a **common task.**
  - The agents may or may not **collaborate** with each other. In the case of collaboration, each agent k can communicate with its **neighborhood** N_k or with a **centralized server**.
  - All agents are designed to estimate/detect/learn a common unknown variable x using **available local data**.
  - This is accomplished by **minimizing a local cost-function** $f_k(x)$.

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How do we approach these applications

- Mathematically speaking, we use the **stochastic optimization**
- The global **empirical loss function** to be minimized can be written as

$$\min_{x \in \mathcal{X}} \frac{1}{K} \sum_{k=1}^{K} \left[f_k(x, Z_k) \right]$$

- Each local cost function is given by

$$f_k(x, Z_k) = \mathbb{E}_{Z_k \sim P_i} \left[l(x, Z_k) \right]$$

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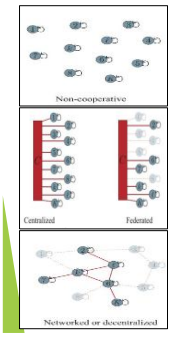

Basic decentralized architectures

- **Non-cooperative** topologies
  - Each agent operates **individually**
- **Centralized** topologies
  - All data are sent to a central server which performs all processing
- **Federated** topologies
  - **Local processing** is employed by **agents** and exchange of models takes place with the central server
- **Decentralized** topologies
  - All **participating entities** are **peers** and **collaborate.**

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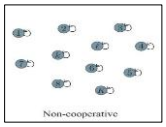

Decentralized protocols: The non-cooperative case

- Each agent operates in a **stand-alone fashion** and solves its **local minimization problem** with respect to its local data using gradient descent.

$$x_{k,i+1} = x_{k,i} - \mu \nabla f_k(x_{k,i})$$

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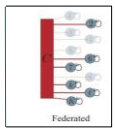

Distributed protocols: Federated case

$$x_{k,i+1} = x_{k,i} - \mu \nabla f_k(x_{k,i})$$

$$x_{i+1} = \frac{1}{K} \sum_{k}^{K} x_{k,i+1}$$

- Here, the **minimization** is performed following a **two-step** iterative procedure to achieve consensus.
- **First Step (Local Step):** Each agent adapts it model parameters with respect to its local data,
- **Second Step (Consensus Step):** The fusion center aggregates the received results

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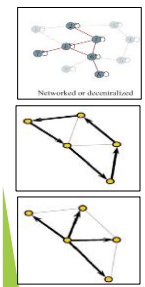

Basic decentralized architectures

- **Incremental**:
  - **Cyclic structure**, each node knows its upstream and downstream neighbor
  - Each note sends its estimate to **one neighbor**
  - **NP-hard** problem
  - It may converge to the centralized solution
- **Diffusion**:
  - Each node communicates with **(all) its neighbors**
  - Amount of communications is higher / More data to process
  - May even outperform the centralized solution

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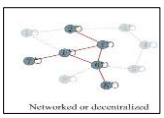

Diffusion: Adapt–then–Combine

$$\psi_{k,i+1} = x_{k,i} - \mu \nabla f_k(x_{k,i})$$

$$x_{i+1} = \sum_{n \in N_k} a_{k,n} \psi_{n,i+1}$$

- Each agent computes a new **local intermediate estimate**, given current local estimate and local data.
- Each agent **receives the local intermediate estimates** of neighbors, and computes the new local estimate.

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What we have seen so far

- Nowadays, we have **immense amount** of **available data** received by edge (e.g. **IoT)** sensor **devices**.
- **Edge Computing is an emerging paradigm**
- We seek for **collaborative solutions** dealing with data **heterogeneity** and **communication network barriers,** preserving data **privacy.**
- Mathematically we model these problems under **Standard** Stochastic Optimization Techniques.

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Part II: A selection of new developments

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Distributionally robust optimization in FL (1)

- Traditional FL (e.g., using FedAvg) has convergence or instability issues due to
  - non-iid data among users (known as "client-drift"),
  - non-uniform user availability (network outages, battery savings, user inactivity)
- The non-iid case has been studied in current literature by weighted averaging rules, gradient corrections, etc.
- The non-uniform availability of users is less considered in current literature, however, poses an interesting challenge in FL
  - How can we take into account users that, although infrequent, they have useful data to contribute?

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Distributionally robust optimization in FL (2)

- Let us assume that there are three users that participate in an FL process
- Let us assume that their loss functions are $f_1(w), f_2(w), f_3(w)$
- Let us assume that the third user actually participates very rarely, namely,
  - $p_3 \ll p_1, p_2$ holds for the probabilities of participation
- Under traditional FL aggregation rules like FedAvg, the following cost function holds

$$G_{FL}(w) = p_1 f_1(w) + p_2 f_2(w) + p_3 f_3(w) \simeq p_1 f_1(w) + p_2 f_2(w)$$

- How can we take into account also the cost function of the "useful" but infrequent third user?

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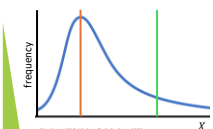
Distributionally robust optimization in FL (3)

- Mean value of X

$$E[X]$$

- Conditional Value-at-Risk (CVAR) of a random variable X

$$CVaR^{a}[X] = \inf_{t \in R} \{ t + \frac{1}{a} \mathbb{E}\,[X - t]_{+} \}$$



- Consider X being $G_{FL}(w)$
- Under $p_3 \ll p_1, p_2$, as FL progresses, $f_1, f_2 < f_3$
  - $E[G_{FL}(w)]$ mainly due to f_1, f_2
  - $CVaR^{a}[G_{FL}(w)]$ mainly due to f_3
- Thus,
  - $G_{FL}^{R}(w) = \gamma\, CVaR^{a}[G_{FL}(w)] + (1-\gamma)\, E[G_{FL}(w)]$
    $\gamma \in [0, 1]$

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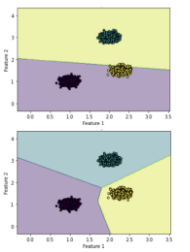
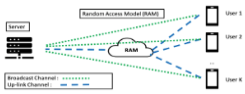
Motivation Example: CVaR in Federated Learning (1)[1]





- We have distributed to 3 agents each pattern class.
- The server samples
  - the **green** agent with probability **0.5**,
  - the **purple** agent with probability **0.4**,
  - the **yellow** agent with probability **0.1**,

[1] P. Theodoropoulos et al., "FEDERATED LEARNING UNDER RESTRICTED USER AVAILABILITY", ICASSP'23

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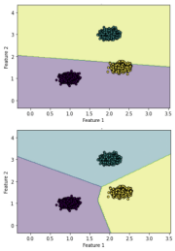
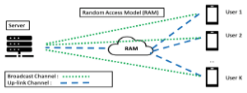
Motivation Example: CVaR in Federated Learning (2)





- ***Risk-Neutral** Case:*

$$\sum_{k=1}^{3} p_k f_k(x) = p_1 f_1(x) + p_2 f_2(x) + p_3 f_3(x)$$

- ***Risk-Aware** Case:*

$$(1-\gamma)\max\{f_1(x), f_2(x), f_3(x)\} + \gamma(p_1 f_1(x) + p_2 f_2(x) + p_3 f_3(x))$$

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Sharpness Aware Minimization:

A successful way to improve generalization in Deep Learning models

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Traditional Optimization for deep learning

Deep Neural Networks (DNNs) have remarkedly exhibited superior performance across **vision** and **language** applications.

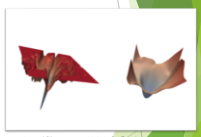
Traditionally, DNNs "**learn from data**" via solving the following the Empirical Risk Minimization (ERM) objective:

$$\min_{w} f(w), \qquad f(w) = \mathbb{E}_{\xi_i \sim P}[Q(w;\xi_i)]. \quad (1)$$

The problem with conventional ERM:

- **Generalization Gap**: Difference between performance on **training** (known) data and **testing** (unknown) data.
- Conventional optimizers of ERM, like SGD and ADAM, often converge to **sharp minima**.

Sharp minima problem: Small change in model parameters, can lead to huge loss increase.



Foret, Pierre, et al. "Sharpness-aware Minimization for Efficiently Improving Generalization." *International Conference on Learning Representations*, 2021.

33

Sharpness Aware minimization (SAM)

Sharpness Aware Minimization (SAM) aims at improving the generalization gap via:

- jointly optimizing **Empirical Risk** and
- seeking **flat minima** solutions.

Formally this idea is described via a min-max problem:

$$\min_{w} \max_{\|\epsilon\| \le \rho} f(w+\epsilon).$$

This measure denotes **the worst case** (max) possible loss at an ρ-ball neighbourhood around w and tries to minimize it.

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SAM STEPS

- SAM objective is approximately solved via an iterative **2-step** procedure

(**alternatively** solve the max, min problems)

- At iteration t:
  1. Solve approximately the **inner maximization** (compute the perturbation ϵ).

$$\epsilon_t = \rho \frac{\|\nabla f(w_t)\|}{\|\nabla f(w_t)\|}.$$

  2. Solve the **minimization** step, by computing the stochastic gradient $g_t = \nabla f(w_t + \epsilon_t)$.

$$w_{t+1} = w_t - \mu g_t.$$

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Characteristics of SAM

- The **good news** for SAM:

SAM solution follows a **simple** two-step iterative process.

Currently, SAM facilitates **state-of-the-art** generalization performance in both **centralized** and **distributed** (federated, decentralized) learning settings.

- The **bad news** for SAM:

Double computational cost: Requires **2** gradient computations (**double the cost** versus SGD, ADAM optimizers).

This cost "inflation" is even greater in distributed learning.

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Currently Active Research directions in SAM

- Improve generalization performance.

Kwon, J., et al. "Asam: Adaptive sharpness-aware minimization for scale-invariant learning of deep neural networks." *International conference on machine learning*. 2021.

Li, B., and G. Giannakis. "Enhancing sharpness-aware optimization through variance suppression." *Advances in Neural Information Processing Systems*, 2023.

Oikonomou, D., and N. Loizou. "Sharpness-Aware Minimization: General Analysis and Improved Rates." *The Thirteenth International Conference on Learning Representations*. 2025.

- Decrease computational cost.

L., Yong, et al. "Towards efficient and scalable sharpness-aware minimization." *Proceedings of the IEEE/CVF Conference on Computer Vision and Pattern Recognition*. 2022.

Du, Jiawei, et al. "Sharpness-aware training for free." *Advances in Neural Information Processing Systems* 35, 2022.

Du, Jiawei, et al. "Efficient Sharpness-aware Minimization for Improved Training of Neural Networks." *International Conference on Learning Representations, 2022*.

- Implement distributed solutions for SAM (Federated & Distributed Learning).

Li, Y., et al. "One Arrow, Two Hawks: Sharpness-aware Minimization for Federated Learning via Global Model Trajectory." *Forty-second International Conference on Machine Learning, 2025*.

Sun, Y., et al. "Dynamic regularized sharpness aware minimization in federated learning: Approaching global consistency and smooth landscape." *International conference on machine learning*, 2023.

Li, Q., et al. "Dfedsammν: Dual constraint controlled model inconsistency for decentralize federated learning." *IEEE Transactions on Pattern Analysis and Machine Intelligence, 2025*.

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What to Take With You

- Nowadays, we have **immense amount** of **available data** received by **IoT** sensor **devices**.
- There exist great need for **Edge Computing.**
- We seek for **collaborative solutions** dealing with data **heterogeneity** and **communication network barriers,** preserving data **privacy.**
- Mathematically we model these problems under **Standard** Stochastic Optimization Techniques, but it faces some **challenges under uncertainty.**
- So, an interesting tool for training under uncertain environments is to use more **Robust Methods**, like **Risk and Sharpness measures**

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Basic Literature

- **A. H. Sayed, "Adaptation, learning, and optimization over networks", Foundations and Trends® in Machine Learning, 7(4-5), pp. 311-801, 2014.**
- **S. Vlaski, S. Kar, A. H. Sayed, and Jose M. F. Moura, "Networked Signal and Information Processing: Learning by multiagent systems", IEEE Signal Processing Magazine, 2023.**
- **Alexander Shapiro, Darinka Dentcheva, and Andrzej Ruszczynski, Lectures on Stochastic Programming: Modeling and Theory, MOS-SIAM Series on Optimization. SIAM & Mathematical Optimization Society, Philadelphia, 2014.**
- **Li, M., Sutter, T. and Kuhn, D., 2021, July. Distributionally robust optimization with Markovian data. In *International Conference on Machine Learning* (pp. 6493-6503). PMLR.**
- **J Plata-Chaves, N Bogdanović, K Berberidis, "Distributed diffusion-based LMS for node-specific adaptive parameter estimation", IEEE Transactions on Signal Processing 63 (13), 3448-3460, 2015.**
- **P. Foret, A. Kleiner, H. Mobahi, and B. Neyshabur, "Sharpness-aware minimization for efficiently improving generalization," in International Conference on Learning Representations, 2021.**
- **E Georgatos, C Mavrokefalidis, K Berberidis, "Fully distributed federated learning with efficient local cooperations", 2023 IEEE International Conference on Acoustics, Speech and Signal Processing, ICASSP 2023, Rhodes, Greece, June 2023.**
- **P. Theodoropoulos, C. Mavrokefalidis, K. Berberidis, "Risk-Aware Decentralized Federated Learning with Intermittent Communications", EUSIPCO 2025, Palermo, Italy, Sept. 2025.**

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Thanks for your attention!!!

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IoT ECO

IoT Green Transformation for Academic Society and Business Oriented Ecosystem in Western Balkans

https://iot-eco.eu/

1

Co-funded by the European Union

STARS EU

IoT Green Transformation for Academic Society and Business Oriented Ecosystem in Western Balkans

Project number: 101083018 – IoT-ECO – ERASMUS-EDU-2022-CBHE-STRAND-2

Closing Event 2025-TU-Sofia & IoT-ECO Project

The applications of IoT in industry, academy and more

Introduction to the Internet of Things

Frida Gjermeni & Manjola Zeneli

September 2025

2

The applications of IoT in industry, academy and more.

3

Exploring the Impact of IoT in Key Sectors Why IoT Matters:

- **Efficiency and Automation:**
  - IoT streamlines processes, reduces human error, and increases operational efficiency across various sectors.
- **Data-Driven Decision-Making:**
  - The vast amounts of data generated by IoT devices provide valuable insights, enabling informed decision-making and strategic planning
- **Innovation and Competitiveness:**
  - Companies and institutions that leverage IoT are at the forefront of innovation, gaining a competitive edge in their respective fields

4

IoT in Industry

- **Industrial IoT (IIoT) Explained**
  - Integration of IoT into manufacturing and industrial processes
  - Key enablers: sensors, cloud platforms, automation
  - Role of IIoT in industry
  - Use Cases of IIoT:Smart Factories; Energy Management; Remote Monitoring; Industrial Robotics

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Applications of IoT in Manufacturing

•**Smart Factories:-**
•Smart factories support IoT technologies to automate and optimize manufacturing processes. By integrating IoT devices with robotics, smart factories achieve higher efficiency, precision, and flexibility in production lines.

- **IoT-enabled automation** -IoT devices enable real-time data collection from various stages of the manufacturing process. This data is used to automate tasks such as material handling, assembly, and quality control, reducing the need for manual labor and minimizing human error.
- **Robotics**-Robots equipped with IoT sensors can perform complex tasks such as welding, painting, and assembly with high precision and consistency. These robots are connected to central control systems that monitor their performance and adjust operations as needed to maintain optimal efficiency.
- **Flexibility in Production:** IoT-enabled robots can be reprogrammed and reconfigured quickly to accommodate changes in production requirements, such as shifting from one product line to another or adjusting for customized orders. This flexibility allows smart factories to respond rapidly to market demands.
- **Real-Time Decision-Making:** IoT devices provide real-time data on production metrics, allowing factory managers to make informed decisions on the fly. For example, if a bottleneck is detected in one part of the production line, the system can automatically reroute tasks to other areas to maintain overall productivity.

❖ **Predictive Maintenance:** IoT sensors collect and analyze data over time to identify patterns and trends that indicate potential equipment failures. Predictive maintenance uses machine learning algorithms to predict when a machine is likely to fail based on historical data and current operating conditions.

- Using IoT sensors to predict machine failures reducing downtime and repair costs

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Applications of IoT in Manufacturing

- **Minimizing Unplanned Downtime:** By predicting when a machine is likely to fail, maintenance can be scheduled during planned downtime, such as shift changes or scheduled breaks. This approach minimizes unplanned downtime, ensuring that production lines remain operational as much as possible.
- **Extending Equipment Lifespan:** Regular, data-driven maintenance helps extend the lifespan of equipment by preventing catastrophic failures that can cause significant damage. Well-maintained equipment operates more efficiently and has a longer service life, reducing the need for frequent replacements.
- **Cost Savings:** Predictive maintenance reduces repair costs by preventing major breakdowns that require expensive emergency repairs. Additionally, by avoiding unnecessary maintenance, factories save on labor and spare parts, further reducing operational costs.
- **Improved Resource Allocation:** Maintenance teams can prioritize their efforts based on predictive maintenance insights, focusing on the equipment that needs attention most. This targeted approach improves resource allocation and reduces the overall maintenance workload.

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IoT in Supply Chain Management

- **IoT for Logistics and Tracking:**
  - Real-time monitoring of goods in transit
  - RFID, GPS, and connected sensors for tracking
- **Inventory Management:** Automated inventory tracking using IoT-enabled systems- Inventory tracking is a critical aspect of supply chain management, ensuring that products and materials are available when needed and reducing the risk of stockouts or overstocking. IoT-enabled systems revolutionize inventory tracking by providing real-time visibility, accuracy, and automation.
- **RFID (Radio Frequency Identification):** RFID tags are small electronic devices that can be attached to items or pallets. These tags store product information and can be read by RFID readers, enabling automated and accurate inventory tracking
- **IoT Sensors:** Sensors embedded in storage facilities, warehouses, and transport vehicles monitor environmental conditions, such as temperature and humidity, and track the location and status of inventory items in real-time.
- **Connectivity:** IoT devices are connected via networks such as Wi-Fi, LPWAN (Low Power Wide Area Network), or 5G, facilitating seamless communication and data exchange between inventory items, tracking systems, and central databases
- **Cloud-Based Platforms:** Data collected by IoT devices is transmitted to cloud-based platforms where it is processed, analyzed, and stored. This data is accessible to stakeholders through dashboards and mobile apps, providing real-time insights into inventory levels and movements.

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IoT in Supply Chain Management Use Cases

- Automated: Warehouse Management
- Stock Counting
- Dynamic Storage Allocation
- Retail Supply Chains
- Smart Shelves
- Real-Time Stock Monitoring
- Cold Chain Management
- Temperature-Sensitive Inventory

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Energy Management and IoT

- **Energy Efficiency in Industrial Settings:**
  - Smart energy grids and real-time energy monitoring
  - Optimizing energy consumption in industrial equipment

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10

Energy Management and IoT Case Studies

- **Case Studies:**
  - Companies successfully implemented IoT for energy management
- **General Electric (GE)-Smart Energy Solutions:**
  - GE has implemented IoT solutions in its operations and for its customers, focusing on optimizing energy consumption across industrial and commercial sectors.
- **Siemens**-Siemens is a leader in smart building technology, integrating IoT systems for energy management in commercial and industrial buildings worldwide.
- **Schneider Electric-Energy Efficiency in Industrial Facilities:**-Schneider Electric is a global leader in energy management and automation, offering IoT-enabled solutions to optimize energy use in industrial facilities.
- **Tesla-Energy Management in Giga factories:**
  - Tesla has integrated IoT technologies into its Giga factories, which produce batteries and electric vehicles. The company focuses on optimizing energy use to reduce costs and increase sustainability.
- **Nestlé-Energy Efficiency in Food Processing:**
  - Nestlé has implemented IoT solutions in its food processing facilities to optimize energy use and reduce the environmental impact of its operations.

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IoT in Smart Cities and Urban Planning

- **Smart City Infrastructure: A smart city uses IoT and other digital technologies to improve the quality of life for its citizens, enhance urban services, and optimize the efficiency of city operations. By integrating IoT into city infrastructure, municipalities can address challenges such as traffic congestion, waste management, and public safety.**
- **IoT's Role in Smart Cities:**
- **IoT devices and sensors are embedded throughout urban environments, collecting real-time data that informs decision-making, resource allocation, and the delivery of public services.**
  - IoT in urban traffic management, waste management, and public safety-
  - Traffic Flow Optimization : Smart Traffic Lights: Adaptive Traffic Control Systems: Connected Vehicles
  - Real-Time Traffic Monitoring
  - Real-time data collection for improved decision-making-Data-Driven Governance
  - Centralized Data Platforms
- **Smart City Solutions in Industry:**
  - Industry-specific applications, including construction and utilities

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IoT in Academia

- **How IoT is Reshaping Education and Research:**
Smart classrooms and IoT-enabled learning environments-The integration of Internet of Things (IoT) devices into educational environments is revolutionizing how learning and teaching occur.
Smart classrooms, enhanced by IoT technologies, are creating connected and interactive spaces that promote engagement, personalized learning, and efficient classroom management.

Key IoT devices in smart classrooms

- Interactive whiteboards
- Smart lighting systems
- Smart HVAC systems
- Wearable devices
- Smart desks and chairs
- Audio-visual equipment
- IoT in academic research for data collection and experimentation

- **The Role of IoT in STEM Education**-The Internet of Things (IoT) refers to devices that are able to collect information and then exchange that data with other devices online. For example, a fitness watch is part of the IoT because it detects your pulse, sleep, and more and can send that information to your smartphone.

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Smart Campuses with IoT 1/3

- **Smart Campuses**-Universities are embracing the Internet of Things (IoT) to create smart campuses that offer a more efficient, sustainable, and enriching experience for students, faculty, and staff. Here are a few ways they're doing it.
- **Connected Classrooms:**
  - IoT-enabled devices for interactive learning and student engagement. **Smart Classrooms: Many** universities have adopted IoT-enabled smart classrooms that feature connected devices, interactive displays, and sensors that enhance teaching and learning.
- **Campus Security:**
  - IoT solutions for monitoring and enhancing campus safety-IoT-powered surveillance systems can keep the campus community informed during critical situations.
  - Automated access control, CCTV integration, and real-time alerts -Purdue University and University of Washington employ IoT-based security solutions, including video surveillance, access control, and emergency response systems, to capture and analyze real-time data and send out alerts
- user frustration..

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Smart Campuses with IoT 2/3

Risks and challenges

- Security Concerns
- Privacy Issues
- Technical Challenges
- Reliability
- Financial Costs
- Educational Challenges
- Energy and environmental issues.
- Legal and compliance issues.

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Smart Campuses with IoT 3/3

Benefits

- Agility,
- Cost efficiencies,
- Flexibility,
- Interaction,
- Scalability,
- Resilience,
- The creation of intelligent classrooms, and the stimulation of creativity to support
- Personalized learning

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IoT in Education Management 1/2

- **Administrative Applications:**
  - IoT for tracking attendance, student engagement, and resource management
  - Smart scheduling and campus facility management

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IoT in Education Management 2/2

- **Case Study:**
  - Universities using IoT for optimizing operations:
- **Sustainable Infrastructure:** IoT sensors are being used to optimize energy usage, reduce emissions, and manage sewer systems.
- **Campus Transportation:** Arizona State University and University of Michigan are using IoT to optimize transportation services. Shuttle tracking, real-time bus schedules, and smart parking systems guide drivers to open spots and improve campus mobility.
- **Streamlining Operations:** Georgia State University and University of Texas at Arlington are among those using IoT for library management. RFID tags and sensors track books, manage inventory, and enhance resource use. Predictive maintenance based on sensor data ensures equipment is functioning properly, while smart asset tracking systems are helping universities manage valuable equipment and prevent loss.
- **Boosting Research and Innovation:** Universities like MIT have equipped labs with sensors to collect data on experiments, monitor environmental conditions, and enhance scientific investigations. This is also allowing some researchers to run experiments remotely, which is streamlining research processes and making cross-institutional collaborations easier.
- **Data-Driven Insights:** Universities can analyze data collected through IoT devices to gain valuable insights into student performance, resource allocation, and event crowd management. This allows for data-driven decision-making to improve efficiency, personalize learning, and enhance overall campus life.

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IoT in Smart Ports

- **IoT Revolutionizing Port Operations:**
  - Definition of Smart Ports and their role in global trade-**Smart Ports** are modernized seaports that leverage advanced technologies such as the Internet of Things (IoT), Artificial Intelligence (AI), Big Data, and automation to enhance the efficiency, safety, and sustainability of port operations. These technologies are integrated to optimize the movement of goods, improve operational decision-making, and reduce environmental impacts.
  - Key IoT technologies: sensors, data analytics, automation-IoT and Sensor Networks: Enable real-time monitoring of cargo, equipment, and environmental conditions.
  - Automation: Use of automated cranes, guided vehicles, and drones for efficient handling and surveillance.
  - AI & Big Data Analytics: Enhance predictive maintenance, optimize logistics, and improve decision-making processes.
  - Blockchain & Cybersecurity: Ensure secure and transparent transactions, and protect port infrastructure from cyber threats.
  - Sustainable Practices: Focus on reducing carbon emissions and improving energy efficiency through green technologies.
- **Importance of Digital Transformation in Ports**-Digital transformation in ports involves the adoption of digital technologies to revolutionize traditional port operations. This transformation is crucial for modernizing ports to meet the increasing demands of global trade, improving efficiency, and ensuring competitiveness in a rapidly evolving industry.

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IoT in Port Automation

- **Automation of Port Processes:**
  - Autonomous cranes and vehicles in port operations-Autonomous cranes and vehicles are revolutionizing port operations by automating the handling, transportation, and storage of cargo. These technologies leverage advanced robotics, artificial intelligence (AI), and sensors to operate with minimal human intervention, enhancing efficiency, safety, and reliability in ports.
  - Automated logistics and cargo handling systems- Automated logistics and cargo handling systems are transforming port operations by streamlining the movement, storage, and management of goods. These systems utilize advanced technologies such as robotics, artificial intelligence (AI), the Internet of Things (IoT), and automated guided vehicles (AGVs) to enhance efficiency, reduce costs, and improve the overall productivity of ports.
- **Real-Time Data Collection and Analysis:**
  - IoT-enabled sensors for monitoring cargo movement and container status-IoT-enabled sensors are transforming the way ports monitor cargo movement and container status. These sensors provide real-time data on the location, condition, and security of cargo, enabling ports to enhance operational efficiency, improve safety, and ensure the integrity of goods throughout the supply chain.

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IoT for Smart Port Security

- **Security Challenges in Ports:**
- **Use of AI and Machine Learning for Threat Detection-**
  - Artificial Intelligence (AI) and Machine Learning (ML) are transforming threat detection in port security by enabling faster, more accurate identification of potential risks. These technologies analyze vast amounts of data in real-time, learning from patterns and improving their detection capabilities over time. By automating threat detection processes, AI and ML help ports respond more quickly to security incidents, reduce human error, and enhance overall safety.

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IoT in Port Energy Management

- **Energy Efficiency in Smart Ports:**
  - IoT sensors for monitoring energy usage in ports
  - Smart energy grids and renewable energy integration
- **Case Study:**
  - A port utilizing IoT for energy efficiency improvements-Durres Port Authority
  - Usage of Smart energy Meters
  - Application of solar panels for reducing hydro energy usage and prioritizing renewable energy

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IoT in Logistics and Supply Chain for Ports

- **Smart Supply Chain Management:**
  - Real-time cargo tracking and monitoring in ports
  - RFID and GPS for optimizing cargo movements
- **Fleet and Asset Management:**
  - IoT solutions for managing port vehicles and equipment

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Data Analytics and Decision-Making in Smart Ports

- **IoT-Enabled Analytics in Ports:**
  - Role of data analytics in optimizing port operations
  - Predictive analytics for maintenance and resource allocation
- **Case Study:**
  - A port using real-time data for operational efficiency-Durres Port authority is using video analyzing in CCTV system to monitor all the pedestrian and auto operations in port
  - Temperature is being monitored in server room I Durres Port by the data generated from the sensors of temperature incorporated in the network and storage devices

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Smart Ports and Environmental Sustainability

- **IoT for Sustainable Port Operations:**
  - Monitoring air and water quality using IoT sensors
  - Waste management and recycling automation
- **Green Ports:**
  - Integrating IoT for eco-friendly port operations

Use cases: In Durres Port are installed air and water sensors to monitor the situation appropriately and take all the measures second the results regarding the scenarios that have been established.

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Challenges and Future of IoT in Industry, Academia, and Smart Ports

- **Challenges:**
  - Security, data privacy, and network scalability issues
  - Power consumption and resource management
- **Future Trends:**
  - 5G integration, edge computing, AI, and blockchain in IoT

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The difficulties of deploying IoT technologies 1/3

In Integration

- Inherently distributed elements
- Deep heterogeneity
- Data management
- Application maintenance
- Human factor, human-object synergy
- Application inter-dependency
- Multiple stakeholder concerns
- Quality Evaluation

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The difficulties of deploying IoT technologies 2/3

In Cybersecurity threats

- The issue of default passwords
- Unsafe communication and unsecure personal information
- The deployment of automation and AI management when is not configured properly
- IoT traffic unencrypted
- Insufficient security support to battle threats

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The difficulties of deploying IoT technologies 3/3

In legacy system Integration

- **Communication Protocol Gaps**
- **Data Overload and Processing Bottlenecks**
- **Lack of Flexibility and Scalability**
- **High Costs of Integration**
- **Security Vulnerabilities**
- **Regulatory concerns**

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The benefits of deploying IoT technologies

- **Automation**
- **Predictive Maintenance**
- **Process Improvement**
- **Cost Reduction**
- **Improved Insights**
- **Adaptability**
- **Compliance**
- **Mobility**

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Conclusions

- **Summary of Key Points:**
  - IoT's transformative impact on industry, academia, and smart ports
  - Opportunities for growth and innovation
- **Closing Remarks:**
  - The potential of IoT to drive efficiency, sustainability, and innovation

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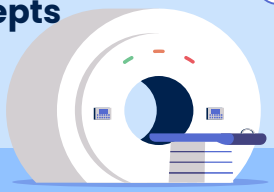
Implementation of IoT concepts via Azure services



UP, Prishtina, 2025

1

Contents

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2

Overview

This presentation outlines a centralized system designed for monitoring healthcare devices, specifically focusing on MRI and EKG technologies.
By leveraging Azure Digital Twin technology, this system aims to predict maintenance requirements and detect defects in a timely manner. The ultimate goal is to enhance healthcare outcomes, ensuring that medical equipment remains reliable and efficient in supporting patient care.

3

Kosovo's Healthcare System

The healthcare system in Kosovo faces several challenges, particularly in managing medical equipment, predicting failures, and providing timely services in high-demand hospital departments.

This project proposes the development of a Smart Healthcare Center model that leverages Microsoft Azure Digital Twins integrated with Artificial Intelligence (AI) to improve predictive maintenance and assist medical personnel with intelligent diagnostics.

4

Introduction to Healthcare Monitoring

01

Importance of Monitoring
Continuous monitoring of healthcare devices ensures optimal performance and patient safety, reducing downtime in critical medical settings.

02

Focus on MRI and EKG
MRI and EKG machines are essential in diagnostics; their efficient operation is crucial for timely patient care and accurate results.

03

Challenges faced
Healthcare facilities often face issues with device malfunctions, leading to operational delays and increased costs, making predictive maintenance vital.

5

Overview of Azure Digital Twin

What is ADT?
A digital representation of physical systems for real-time monitoring and simulation.

Benefits of Azure Utilization
Enhances predictive maintenance and reduces operating costs.

Integration Capabilities
Seamlessly integrates with existing healthcare infrastructures.

6

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Cybersecurity Challenges in Modern Smart Grids

Cyber digital security of the energy infrastructure

Asst. Prof. Velimir Strugar, Ph.D.
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Closing Event of the project 101083018 – IoT-ECO, Erasmus+ LS, ERASMUS-EDU-2022-CBHE, ERASMUS-EDU-2022-CBHE-STRAND-2
Technical University of Sofia 24-28 September 2025

1

Topics:

❑ **WE ARE GOING TO DISCUSS ABOUT**:

2

2

IoT and Green Transformation

IoT
plays a crucial role in the Green Transformation, which involves shifting toward sustainable technologies and processes that **reduce carbon emissions, improve energy efficiency, and protect the environment.**

Smart Grids
- IoT devices enable smart grids to **balance electricity supply and demand in real-time.**
- **Smart sensors and meters** continuously collect data on consumption, allowing dynamic energy management, thus reducing losses and emissions.

Smart Cities
- **IoT sensors monitor** air quality, water quality, and noise levels.
- **Intelligent traffic management** (smart traffic lights, parking sensors) reduces emissions and fuel consumption.
- **Smart waste management** optimizes waste collection and recycling.

Renewables (RES)
- IoT enables **remote monitoring and optimization** of solar panels, wind turbines, and hydropower plants.
- **Predictive maintenance** through IoT technologies reduces maintenance costs and downtime.

Building Energy Efficiency
- **Smart thermostats, motion and lighting sensors**, and automated **HVAC systems** reduce building energy consumption.
- IoT systems provide detailed **insights into energy and water consumption,** enabling continuous optimization.

Agriculture
-**IoT sensors monitor soil conditions,** plant health, and climate, facilitating precision agriculture.
- **IoT reduces the usage of water,** fertilizers, and pesticides significantly.

Industry 4.0 Sustainable Manufacturing
- **IoT in manufacturing processes reduces energy consumption** by optimizing machinery and processes.
- Smart factories use IoT for **monitoring gas emissions and reducing waste.**

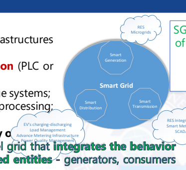
E-Mobility
- IoT allows for **monitoring** and managing EV **charging infrastructure.**
- **Smart vehicle-charging management reduces grid load and enables better integration** of renewable energy sources.

Environmental Protection
- **IoT devices monitor and report on air, water, and soil pollution,** enabling timely reactions to ecological incidents.
- **Drones and sensors are used for monitoring forests, waters,** and endangered areas to protect them effectively.

3

SMART GRID ARHITECTURE

❑ **The smart grid is based on:**
- advanced metering infrastructures (AMI);
- **two-way communication** (PLC or some other);
- advanced energy storage systems;
- data management and processing; **Big data**
- **cyber-physical security o**



❑ **A smart grid is an electrical grid that integrates the behavior and actions of all connected entities - generators, consumers and prosumers**

SG is an electricity network that consists of a system of infrastructural, HW and SW solutions that enable two-way communication between all system entities and provide power generation and distribution in the supply chain in an efficient manner.

- SG is a self-sufficient power system.
- It can provide energy from different power sources, including renewables and storage, allowing suppliers and consumers much broader control and management capabilities.

❑ Prominent features of SG are:
- Two-way energy flow, full RESs, ESs and EVs integration
- Increased energy efficiency – high level
- The changed role of the consumer
- **Integration of ICT**
- New ways of trading, new energy market entities
- **Sensor technology and IoT** (consumer and network equipment)
- Smart houses

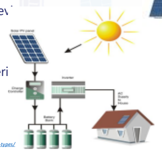
Source: https://www.digiteum.com/

4

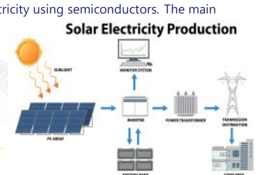
PV / RES Power Systems: Key Principles

Photovoltaic (PV) systems transform sunlight into electricity using semiconductors. The main parts of a typical PV system are:
- PV panels
- Inverters (DC to AC conversion)
- Mounting structures
- Communication and monitoring systems
- Cabling and protection dev

Types of installations:
- Grid-connected
- Hybrid systems (grid + batteri
- Fully off-grid



Source: https://be-cis.com/solar-power-system-types/



Key Related Standards:
- IEC 61215 – PV module performance tests (2021)
- IEC 61730 – Safety for PV modules (2023)
- IEC 62109 – Safety of inverters (2022)
- ISO 9488 – Solar energy terminology (2020)

5

5

Smart Inverters and IoT Integration

❑ Modern inverters have many smart functions:
- Connect to cloud systems
- Measure and optimize energy flows in real time
- Support grid stability with reactive power control
- Work with energy storage and electric vehicles

❑ IoT enables:
- Remote monitoring and updates
- Communication through Wi-Fi, Ethernet, or GSM
- Data transfer to analytical platforms

❑ But IoT also increases cybersecurity risks for

Source: https://www.sourcenergy.com/solar-energy-news/leading-inverter-brands-products-compatible-210-ultra-high-power-modules

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6

IoT based PV Systems = Smart Grid

- IoT transforms PV systems into smart grids enabling:
  - Remote monitoring and diagnostics
  - Predictive maintenance
  - Optimizing power flows
  - Managing energy storage and demand
  - Detecting failures early
- Smart grids decide:
  - When to store or release energy
  - When to export power to the grid
  - How to shift loads to cheaper periods
- However, IoT systems collect user data, raising privacy concerns about household habits and energy use.

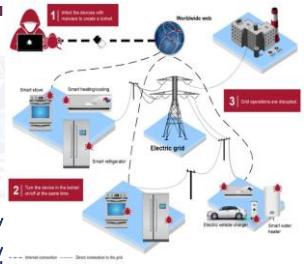
- A Smart Grid is unthinkable without smart metering
- The architecture of the AMI system implies the:
  - Smart meters;
  - data concentrators (optional);
  - communication network;
  - communication center with server;
  - workstations;

7

7

Cybersecurity Risks in PV / RES Power Systems

- **Modern PV / RES systems are critical infrastructure.**
- Cyber-attacks could:
  - Steal/compromise energy production data
  - Manipulate the inverter settings
  - Send false grid signals
  - Shut down PV generation
  - Demand ransom payments
- **Privacy risks include:**
  - Knowing when people are at home
  - Learning daily routines
  - Tracking EV charging times
  - Using data for stalking or burglary planning
- Inverters are the most risky component of a PV system, because they may contain untested



source: https://wepower.com/

8

8

Usual and most common vulnerabilities of PV systems

- "Cyber event" **is a disruption** to **electrical or communication** systems **caused by unauthorized access** to hardware, software or communications networks. (according definition provided by **USA Department of Energy**)
- In practice, several issues make PV systems vulnerable:
  - Many solar web dashboards are exposed to the Internet without proper login protection.
  - Default admin passwords often remain unchanged after installation.
  - Some inverters lack secure firmware update mechanisms, leaving known bugs unpatched.
  - Cloud APIs sometimes leak sensitive data if improperly secured.
  - Wi-Fi encryption can be outdated or weak.
- For example, in 2023, a simple search on Shodan found thousands of inverters accessible directly from the Internet, many with factory-default credentials. *(SHODAN - Sentient Hyper-Optimized Data Access Network)*

source: https://www.vais.com

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What can be the target of Cyber attack?

- Attackers can target **inverters, SCADA systems, networks, and cloud-based components** to disrupt **operations, steal data, or manipulate energy flows.**
- Inverters are often directly connected to the internet for monitoring and management, making them a potential target. Attackers could exploit vulnerabilities in the inverter's software or communication protocols to manipulate power output, disrupt operations, or even spread malware.
- PV Systems often use SCADA (Supervisory Control and Data Acquisition) systems, which are designed to be user-friendly but can be vulnerable to attacks. Exploiting these vulnerabilities could allow attackers to gain control of the system and disrupt operations.
- Hackers can target PV installations through network attacks by exploiting open ports, introducing malware, or intercepting unencrypted communication.
- Cloud-based systems used for monitoring and managing PV installations can be vulnerable to attacks. Attackers can exploit login credentials or intercept communications to gain unauthorized access.
- **PV systems rely on various third-party service providers, including software and hardware vendors. Exploiting vulnerabilities in these providers' systems can provide attackers with access to the PV installation.**
- Attackers could inject false data into the system, potentially leading to miscalculations, inaccurate readings, and compromised control of the system. Types of DIAs include False Data Injection Attacks (FDIAs), Covert Attacks (CAs), and Replay Attacks (RAs).

10

10

Consequences of Cyber Attacks

- Cyber attacks on PV systems can:
  - Stop power production
  - Damage equipment by voltage spikes
  - Leak private user data
  - Cause financial losses
  - Influence electricity market prices
  - Reduce public trust in renewable energy
- Example:
  - In 2023, an attack attempted to overload solar inverters in a U.S. utility, but safety systems prevented major damage.
- A compromised smart system might:
  - Keep batteries charged but refuse discharge
  - Feed power into the grid at the wrong times
  - Shut down healthy systems with false error codes

if the storage system is already under attack, which is less harmful:
- disabled charging
- disabled discharging

???

Source: https://www.nrel.gov/

11

11

Real Cyber Attacks on Energy Sector – some Case Studies

- Some real attacks show risks for PV and energy systems:
  - **sPower DoS (Denial-of Service) Attack (USA, 2019)** - Attackers disrupted communication between control centers and multiple PV and wind plants by exploiting firewall vulnerabilities. https://nsarchive.gwu.edu/sites/default/files/media_mentions/2019-10-31_cyberscoop.com-utah_renewables_company_was_hit_by_rare_cyberattack_in_march.pdf
  - **Hacktivist attack on Lithuanian Solar Park (2024)** - Pro-Russian hacktivists compromised monitoring systems, briefly gaining control over multiple PV installations. https://cyble.com/blog/solar-monitoring-solutions-in-hacktivists-crosshairs/
  - **Solarman & Deye Cloud Platform Vulnerabilities (2024)** - Security flaws exposed over 195 GW of global PV capacity to potential remote manipulation. https://www.bitdefender.com/en-us/blog/labs/60-hurts-per-second-how-we-got-access-to-enough-solar-power-to-run-the-united-states
  - **Hidden Remote Shutdown Modules in Inverters (2024)** - Undisclosed remote-control features in Chinese-made inverters were remotely activated, disabling units in multiple countries. https://industrialcyber.co/reports/forescout-sundown-research-uncovers-critical-vulnerabilities-in-solar-inverters-that-threaten-power-grid-stability/
  - **SUN:DOWN – Multiple Vulnerabilities in Popular Inverters (2025)** - Over 40 serious vulnerabilities found in Sungrow, Growatt, and SMA inverters, potentially allowing attackers to destabilize grids. https://www.forescout.com/press-releases/forescout-vedere-labs-uncovers-severe-systemic-security-risks-in-global-solar-power-infrastructure/ https://thehackernews.com/2025/03/researchers-uncover-46-critical-flaws.html
  - **SolarView Compact Exploits in Japan (2024)** - Hackers accessed publicly exposed solar data loggers, stealing sensitive financial data and threatening system integrity. https://www.forescout.com/blog/the-security-risks-of-internet-exposed-solar-power-systems/https://dersec.io/reports/DERSec_Solar_Vulnerability_Summary_11-15-24.pdf

12

12

Improving Cybersecurity and Privacy

- How to improve security in PV and EV systems:
  - **Change** default **passwords**
  - Use **strong encryption** for remote connectio[n] VPN)
  - **Install firmware updates** regularly
  - **Segment networks** to isolate devices
  - **Monitor logs** for strange activity
  - **Validate** sensor data
  - **Secure communication** between inverters, EV chargers, and cloud systems
  - **Test smart systems** against cyber mani[pulation]
- For privacy:
  - Collect only necessary data
  - Anonymize data if possible
  - Inform users about data use
  - Follow regulations like GDPR

Source: https://www.slideserve.com, https://www.investopedia.com

ISO 27001 ISO IEC

13

13

Standards and Regulations

- International standards and regulations help keep PV and EV systems secure:
  - **Cybersecurity Standards:**
    - IEC 62443 – Cybersecurity for industrial systems
    - ISO/IEC 27001 – Information security management
    - EU NIS2 Directive (Directive (EU) 2022/2555)– obligations for critical infrastructure
    - IEC 62351 – Security for power grid protocols
    - ISO/IEC 27019 – Security for energy utilities
    - UL 2900 – Cybersecurity for IoT devices
  - **PV Technology Standards:**
    - IEC 61215 – PV module performance
    - IEC 61730 – PV module safety
    - IEC 62109 – Inverter safety
  - **EV and Charging Standards:**
    - ISO 15118 – Communication between EVs and chargers
    - IEC 61851 – EV charging systems
    - CCS Protocol – Combined Charging System for fast charging
  - **Data Privacy Regulation:**

Source: https://nvlpubs.nist.gov/nistpubs/CSWP/NIST.CSWP.29.pdf

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Risk Assessment in PV Systems

- Risk assessment helps secure PV systems. Steps include:
  - **Identifying assets:**
    - Inverters
    - Sensors
    - Cloud services
    - User data
  - **Identifying threats:**
    - Hackers
    - Insider threats
    - Physical damage
  - **Checking vulnerabilities:**
    - Default passwords
    - Open ports
    - Unencrypted traffic
  - **Evaluating consequences:**
    - Financial losses
    - Service disruptions
    - Privacy breaches

Risk probabilities	Risk Severity				
	Catastrophic (A)	Major (B)	Moderate (C)	Minor (D)	Insignificant (E)
Certain (5)	5A	5B	5C	5D	5E
Likely (4)	4A	4B	4C	4D	4E
Possible (3)	3A	3B	3C	3D	3E
Unlikely (2)	2A	2B	2C	2D	2E
Exceptional (1)	1A	1B	1C	1D	1E

Source: https://doi.org/10.1016/j.eiar.2020.106418

Source: https://medium.com/@solar.dao/risk-management-in-re...

- **Calculating risk level:**
  - Catastrophic
  - Major
  - Moderate
  - Minor
  - Insignificant
- **Planning mitigation measures**

Risk=Probability*Severity

Examples of high risks:
- Public inverter panels online without passwords
- Cloud services without multi-factor authentication
- Logs with personal user data in plain text

15

EVs and Charging Stations as IoT Cyber-Physical Entities

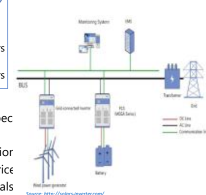
Electric Vehicles (EVs) are part of

Energy networks:
- Dynamic loads connected to the grid
- Participate in grid services (V2G – vehicle-to-grid)
- Affect grid balance during mass charging

Communication networks: Constantly exchange data with:
- Charging Point Operators (CPO)
- Mobility Service Providers (MSP)
- Aggregators
- Grid Operators

- Information exchanged includes:
  - Vehicle identity
  - User profiles
  - State-of-charge (SoC)
  - Charging location and time
  - Pricing and billing data

- Cybersecurity is essential bec[ause]
  - Hackers might:
    - ✓ Block charging sessio[ns]
    - ✓ Change charging price[s]
    - ✓ Send false grid signals
    - ✓ Steal user identities
  - EVs can become attack points into grid systems



Source: http://solars-inverter.com/

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16

Documented Cyber Incidents in EV Infrastructure

Have there been cybersecurity incidents involving EVs so far? **Unfortunately, YES.**

Examples:

2015 – Security Short Take: Hackers remotely take control of Jeep, https://www.csoonline.com/article/552175/hackers-remotely-take-control-of-jeep.html

2021 – Tesla Hackers demonstrated remote control over Tesla features via vulnerabilities in third-party apps https://edition.cnn.com/2022/02/02/cars/tesla-teen-hack

2025 – Detection of cyber attacks in electric vehicle charging systems using a remaining useful life generative adversarial network https://www.nature.com/articles/s41598-025-92895-9

Last year saw a 39% increase in the number of cyber-attacks against the automotive and smart mobility ecosystem and products. Thus, a total of 409 incidents were recorded in 2024.

- **These incidents prove:**
  - **EVs and chargers are networked cyber-physical systems.**
  - **Attacks can disrupt the energy grid and user privacy.**
  - **Security is crucial for safe EV adoption**

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Conclusion

Key messages:
- Smart grids are essential for sustainable energy
- Cybersecurity risks are growing as systems become more digital
- Privacy protection is essential because energy systems collect personal data
- Real cyber attacks show threats are not theoretical
- Smart grid security = national and societal security
- **Cybersecurity MUST BE integrated in early planning phase** (from the conceptual design stage)

In any economy, PV/RES infrastructure can reach secure and sustainable operation only through cyber resilience, grounded in clear regulation, strong technical expertise, and effective inter-institutional coordination.

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THANK YOU

"Security is a process, not a product." – Bruce Schneier, 2000.

Bruce Schneier is an American cryptographer, computer security professional, privacy specialist, and writer.

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1

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Project number: 101083018 – IoT-ECO – ERASMUS-EDU-2022-CBHE-STRAND-2

Quality Assurance and Evaluation

Mimoza Ibrani

TU Sofia, September 2025

2

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Project number: 101083018 – IoT-ECO – ERASMUS-EDU-2022-CBHE-STRAND-2

Work package WP7 – Quality assurance and evaluation

Start Month 1 **End Month** 36

Objectives

- Developing the Project Quality Plan
- Conducting evaluation forms about the activities and feedback analysis
- Developing Quality Assurance policies for the common IoT-ECO hub and teaching materials

All project-planned work package activities have been completed, and the objectives have been successfully achieved.

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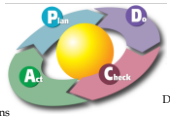
Project Quality Board

Event Quality Assessment Reports
Yearly Quality Report I
Yearly Quality Report II
Yearly Quality Report III
IoT pilot course evaluations



Peer review for IoT courses
ToR for External Quality Evaluator
External Evaluation Quality Midterm Report
External Evaluation Final Quality Report
Deliverable assessment and approval by PO

Project Quality Plan

4

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Project Quality Assurance Plan

Quality management roles, tasks and mechanisms
- Project Management Board and Project Quality Board
- Roles of project coordinator, partners, task and work package leader
- External quality evaluation

Quality assurance of project expectations
- Quality of project document-based deliverables
- Quality of events
- Quality Assurance policies for the IoT-ECO hub and teaching materials
- Yearly quality report

Potential risks and mitigation measures

Internal quality

External quality

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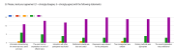
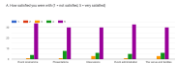
Event Quality Assessment Reports

- For each project event, quality evaluation forms were distributed to participants to gather their feedback and inform improvements for future events
- The response rate was satisfactory



- Event Quality Assessment Reports were prepared, shared, and discussed among project partners and structures
- The results of the quality surveys served as valuable inputs for the Yearly Quality Reports and for tracking the implementation of the project



I was impressed with the students work for the IoT-Eco project. The technical organization was perfect. We learned and shared a lot of ideas. We cannot wait for the next meeting to come with projects and idea related to IoT echo.

Very clear and useful

Overall the workshop and meetings were good, I would like to have more real case scenarios presented during the workshops and not only presentations, we went to the Patnos…..

Great opportunities are offered from both sides and different perspectives are shared amongst students and teachers

6

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Yearly Quality Reports I,II,III

Yearly Quality Report I and II are prepared, approved as deliverables and shared with external quality evaluator

Yearly Quality Report III is almost finalized and will be submitted on time

Quality evaluation per work package deliverables with recommendations for improvements

Quality aspects of project reporting, exploitation, and dissemination with recommendations for improvements

Impact of project activities at the institutional, national, and regional levels

Student and industry involvement in project activities

Recommendations for improvements

7

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IoT Hub and pilot courses

Course materials are prepared as per the guidelines

Peer review form for developed materials

Student feedbacks for pilot courses are received

Student thesis, research projects and prototypes: quality as per institutional guidelines and framework

8

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External Quality Evaluation

The External Quality Evaluator was contracted following a public call, in accordance with the project's Terms of Reference

The Midterm External Quality Report (covering months M1–M18) was delivered and shared with the consortium. The recommendations provided were duly considered by the consortium

The Final External Quality Report is expected towards the end of the project

Most project deliverables (25) have been assessed and approved by the EU Project Officer, while a few (5) deliverables were improved based on given recommendations

9

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Thank you for your attention!

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Presantation on the Project Dissemination

3 years of visibility, engagement, and impact.

Prepared by: Manjola Zeneli, Uendi Cerma

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Objectives of dissemination and communication

- Raise awareness of IoT-ECO's mission and relevance for sustainability and digital transition.
- Disseminate results, best practices, and lessons learned to academia, industry, and policymakers.
- Build a strong project identity, increase collaboration, and ensure lasting impact beyond the project's lifetime.

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Newsletters

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Event posters

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- Website
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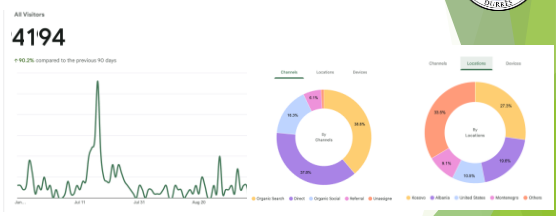

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Social media (Facebook)

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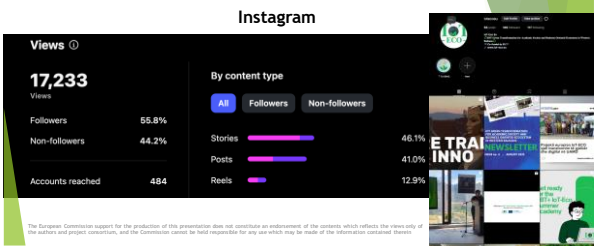
Instagram



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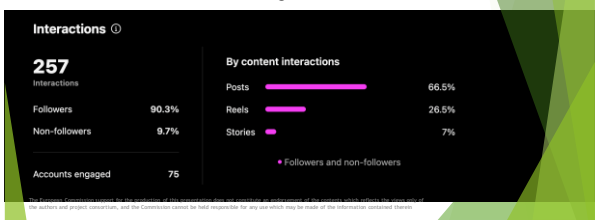

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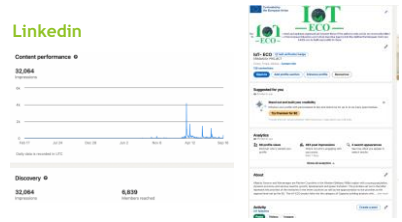

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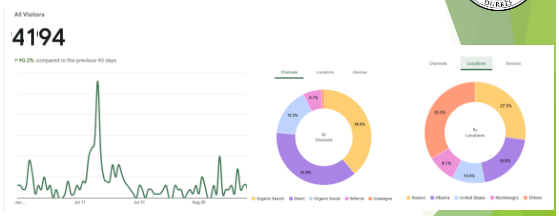

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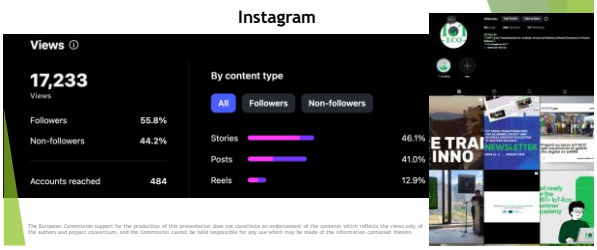

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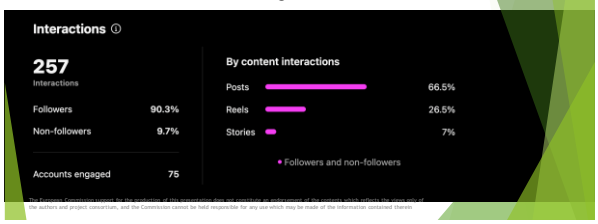

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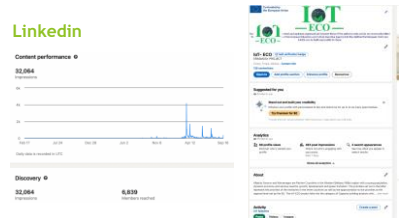

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UNIVERSITY OF PATRAS

Presentation of the IoT-ECO Hub

University of Patras Team:
- Kostas Berberidis
- Christos Mavrokefalidis
- Periklis Theodoropoulos
- Evangelos Georgatos

Technical University of Sofia

27 September 2025

2

Outline

- General concept of the IoT-ECO hub
- Structure of the educational part
- Services to the students
- Administration and guides
- Highlights

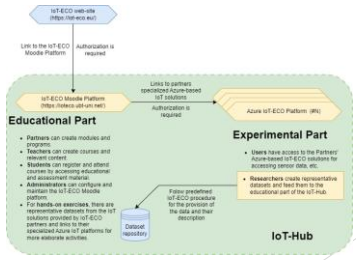
3

General concept of the IoT-ECO hub (1/2)

- The general concept for the hub relies on the principles of modularity to allow each partner to develop and deploy their respective courses as they see fit.
- The IoT-ECO hub consists of the educational and experimental parts.
- In the **educational part**, the users will have access to the educational content produced in the frame of the IoT-ECO project.
  - Centralized, deployed at the premises of UBT.
- In the **experimental part**, the users will have access to the Azure-based IoT solutions provided by the IoT-ECO partners.
  - Decentralized, provided via the partners that develop the digital twins
- These choices made for a sustainable IoT-ECO hub solution, remaining operational after the completion of the project

4

General concept of the IoT-ECO hub (2/2)



5

Structure of the Educational Part (1/2)

- The structure of the educational part aims at:
  - Accommodate several courses (it has been discussed that **6 courses** will be created in the frame of IoT-Hub).
  - For each digital twin developed within IoT-Hub , there will be also a **laboratory course**, providing a representative dataset as well as links to the actual digital prototypes to enable students to elaborate further in data collection and analysis depending on their interests.
  - **Access to students** will be granted by teachers in a per course/dataset fashion. This way, each teacher will have the flexibility to allow a student to attend and use a specific number of courses and datasets, thus, **defining a module.**
  - A **module** is defined as **a collection of courses/datasets** that cover a particular thematic area. For example, a module on "Signal processing over IoT" may consist of three courses on "Fundamentals of Signal Processing", "Statistical Signal Processing" and "Distributed Estimation & Learning over an IoT network" plus any of the available datasets for supporting laboratory exercises.

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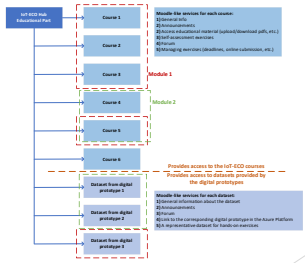
Structure of the Educational Part (2/2)



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Services to the students - Courses

- Course outline: objectives, learning outcomes, syllabus, teaching and evaluation methods, etc.
- Course announcements.
- Educational material (e.g., pdfs, docx or relevant, ppt or relevant, etc.).
- Projects and assignments.
- Self-assessment mechanisms.
- Forum for enabling interactions among involved parties.
- A mechanism for managing exercise assignments.
- Experimental data: representative datasets

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Services to the students – Lab courses

- General description of the dataset, its structure, usage-related information, etc.
- Announcements.
- Forum for enabling interactions between involved parters.
- The **link to any of the available digital prototypes** for further experimentation
  - Access to the digital prototype - being part of the Experimental Part of the IoT-ECO hub - is expected to be managed independently by corresponding partner.
- Access to representative datasets for allowing teachers devise **laboratory exercises** and students to gain experience by studying the datasets and developing data processing and analysis techniques.

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Administration and guides

- The IoT-ECO hub supports several user roles:
  - Managers (administrative privileges)
  - Content creators (create courses and can manage them)
    - This will be used for the time being
  - Teachers (manage courses)
- Students need to have an account to the platform
  - Self-registration may give rise to potential security risks (e.g., spammers)
  - The teachers define whether enrollment to a course can be done by them or by the students themselves
- More detailed information can be found, e.g., here (i.e., @moodle.org)

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Highlights of the IoT-ECO hub

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Access to the IoT-ECO hub

- IoT-ECO hub can be accessed via the IoT-ECO web-site

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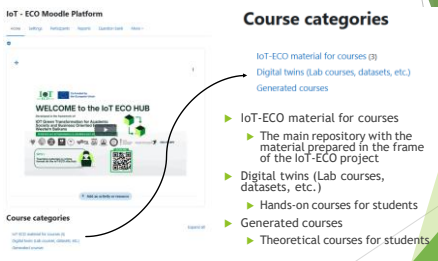
IoT-ECO course related material



- IoT-ECO material for courses
  - The main repository with the material prepared in the frame of the IoT-ECO project
- Digital twins (Lab courses, datasets, etc.)
  - Hands-on courses for students
- Generated courses
  - Theoretical courses for students

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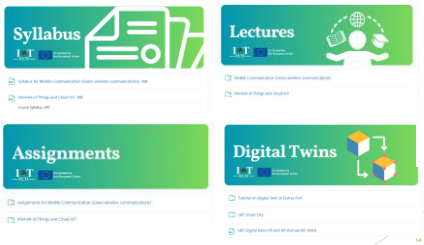
IoT-ECO material for courses



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IoT-ECO material for courses

- Detail syllabus for six topics in the general area of IoT and green transformation
- For each topic, there are:
  - Several lectures slides with the required information covering both theory and applications
  - Three assignments that can be adopted by professors in the frame of their courses
- Information about the IoT-ECO digital twins
  - Manuals, datasets, etc.
- It is important to keep updating the content as well as adapting the structure of the courses to new requirements as they appear

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Highlights of the IoT-ECO hub

- Flexible educational platform based on Moodle
- Contains material for creating new courses and laboratories in the general area of IoT and green transformation
- The digital twins provide a rich playground for students as well as seasoned researchers

The IoT-ECO material for courses can be utilized by professors and adapted to the specific requirements of **new** courses

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Thanks!!!

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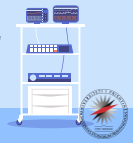
Challenges & Limitations

While the system offers major benefits, several challenges need to be addressed for real-world implementation:

- **Data Privacy & Security** – Handling sensitive patient and device data requires strict compliance with health data regulations.
- **Initial Costs** – Setting up IoT infrastructure, cloud services, and training personnel requires significant investment.
- **Technical Training** – Medical staff and engineers need training to properly use and maintain the system.
- **Infrastructure Gaps** – Not all hospitals currently have reliable internet or IT infrastructure to support continuous monitoring.
- **Integration with Legacy Systems** – Many healthcare facilities use outdated devices that may not easily connect with IoT or cloud platforms.



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Real-Case Story

Imagine a scenario:

A **doctor** is about to schedule an MRI scan late at night.
The system dashboard shows a **red alert** – indicating the MRI is unsafe for use due to a critical maintenance issue.
Instead of risking patient safety, the doctor immediately reschedules the scan and reports the alert.

Meanwhile, the **biomedical engineer** receives the same alert remotely, checks the logs, and arranges urgent maintenance before the machine can be used again.
This simple use case demonstrates how real-time monitoring can **prevent medical errors, save costs, and ensure patient safety**.

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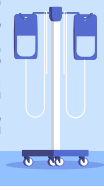
Potential for Expansion

The framework developed in this project is highly adaptable and scalable, allowing for expansion far beyond the initial hospital department simulation. In the next phases, the system can be extended to:

- **Multiple Healthcare Facilities**: By replicating the digital twin infrastructure, hospitals across Kosovo and the region can interconnect their device monitoring systems.
- **National Health Infrastructure Integration**: At a larger scale, the system can form the backbone of a national digital health strategy.
- **Real-Time Patient Data Synchronization**: Data integration can provide doctors with real-time insights into both device performance and patient status.
- **AI-Enhanced Diagnostics**: Future integration with advanced AI models can assist with diagnostic imaging and personalized treatment recommendations.
- **Regional and Cross-Border Cooperation**: The framework could be adapted for cross-border healthcare initiatives, allowing shared data standards and collaborative healthcare monitoring.



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Conclusion & Key Takeaways

By integrating **real-time monitoring, predictive maintenance, and AI-driven insights**, this project directly addresses the challenges of medical equipment failures and operational inefficiencies.

Key outcomes highlighted by this project include:

- **Enhanced Patient Safety** → Automated alerts and predictive monitoring reduce risks linked to malfunctioning equipment.
- **Operational Efficiency** → Hospitals can minimize downtime, optimize maintenance schedules, and ensure device availability.
- **Cost Reduction** → Preventive maintenance lowers emergency repair costs and resource waste.
- **Data-Driven Management** → Centralized, structured data supports evidence-based decisions.
- **Scalable Impact** → From a single department, the framework can grow into a **national and regional model of healthcare digitalization**.

In short, this project demonstrates how combining **IoT, AI, and digital twins** can pave the way for the **next generation of smart hospitals**.

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Thank you!

Do you have any questions?

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