Horizon 2020 Program

WIDESPREAD-03-2018-TWINNING

Innovation and excellence in massive-scale communications and information processing

INCOMING (Project No. 856967)

D3.5: Report on 2nd Summer School: 5G Technology Implementation[1]

Abstract: This document presents a report on 2nd Summer School organized within the framework of the INCOMING project. The school gathered PhD students and researchers from all partner institutions which received training by leading experts in the field coming both from the partner and external institutions.

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List of Abbreviations

AAU	Aalborg University
CHALMERS	Chalmers University of Technology
COVID	Corona Virus Disease
DLR	German Aerospace Centre
ESR	Early Stage Researcher
EU	European Union
FTN	Faculty of Technical Sciences, University of Novi Sad
ICT	Information and Communication Technologies
IEEE	Institute of Electronic and Electrical Engineers
UNS	University of Novi Sad
WP	Work Package

Executive Summary

Work Packages 2 and 3 of H2020 INCOMING project are focused on research and training activities. Among their goals is providing intensive training programme to ICONIC researchers through **summer schools and individual on-site training**. Such activities are intended to complement one-to-one research collaboration via staff exchanges. Expert trainings and summer schools are an important twinning methodology that uses one-to-many trainings, where experts from EU partners transfer know-how to ICONIC researchers, in particular ESRs, through training sessions.

Training sessions are intended to take two forms:

- Summer schools gather ESRs from partner institutions to a week-long event where each day participants are provided with tutorial lectures by experts in the field. Summer schools will start with the first school on fundamentals, and evolve via second school on implementation and the third school on applications of relevant aspects of 5G theory and technology.
- Expert training is a three-day event where an expert lecturer visits the University of Novi Sad and delivers in person traning to ICONIC researchers. Expert trainings evolve from theoretical topics such as finite-length information and coding theory to practical topics of system design and implementation in the context of massive MTC, machine learning or large-scale distributed information processing systems.

Due to COVID-19 pandemic, during the initial stage of the project, the plans for holding training events live as physical events were no longer possible. For this reason, the first Summer School and the first two Expert Training sessions were done online. However, due to improvement of the COVID-19 situation and removal of travel restrictions, the 2nd Summer School and the third and fourth Expert Training sessions are performed in person, as described in more detail in this deliverable. However, all of the events have been delivered with significant delay as compared to the original plans in the project proposal.

This report demonstrates the details on the second project Summer School held in Gothenburg (Sweden) at the Chalmers University of Technology campus during 13th to 17th of June 2022. The report also includes the third and fourth Expert Training sessions held by Prof. Cedomir Stefanovic (AAU) and Prof. Alexandre Graell i Amat (CHALMERS) held in Novi Sad during early 2022. The report also includes a feedback received from participants of the summer school with the goal of improving the overall training experience in the following H2020 INCOMING training events.

1 Introduction and School Agenda

During the course of the project, three annual summer schools are planned to be organized. The schools gather experts from AAU, CHALMERS, DLR, ICONIC centre and external lecturers to provide a tutorial-style lectures to ESRs from ICONIC and EU partners as well as ESRs external to the project. Each summer school targets the two research domains: i) massive IoT track, and ii) large-scale information processing track, i.e., the research areas corresponding to WP2 and WP3.

According to the original Description of Action, the first Summer School was supposed to take place in Copenhagen at AAU Campus Copenhagen in August 2020. However, due to COVID-19 outbreak, it was not possible to organize the school as planned. Due to many involved uncertainties, Project management board decided to postpone the school, accepting some delay in case that it will be possible to organize the school in originally intended face-to-face format. However, as the situation with COVID-19 pandemic did not improve during the Summer of 2020, Project Management Board decided to organize the first project school in online format. Since at that point, it was not possible to avoid overlapping the school with the Autumn/Winter semester at AAU/CHALMERS/FTN, the decision is taken to organize the school's 5 days program distributed over 5 consecutive weeks in November and early December 2020. The school organizer was AAU, under leadership of Prof. Cedomir Stefanovic.

During 2021 the situation with COVID pandemic became gradually more manageable. Project management board decided to wait for a possibility to organise the second Summer school in person as a physical event. That eventually became possible starting from early 2022, when restrictions on travel and gathering have been lifted in most of the EU countries. Suitable slot for the Summer school has been found in June 2022, during the week from 13th to 17th of June. The school is organised by Prof. Alexandre Graell i Amat at the Chalmers University of Technology campus in Gothenburg. During 5 school days, 8 lecturers delivered their tutorials, 2 from CHALMERS, 2 from AAU, 1 from DLR and 1 from ICONIC centre, adjoined with 2 external lecturers: Prof. Olgica Milenkovic from University of Illinois, Urbana-Champaign (USA), and Prof. Enrico Paolini from University of Bologna (Italy). 11 participants from ICONIC, University of Novi Sad, 5 from DLR, and 6 from AAU travelled to CHALMERS to join the school, along with the local staff members, postdocs and PhD students at CHALMERS.

In the following, after the final school agenda is presented in Table 1 on the next page, we present more details on the program of each school day.

H2020 INCOMING Summer School, Chalmers University of Technology, June 13-17, 2022				
Monday (13/06/2022)	**Tuesday (14/06/2022)**	**Wednesday (15/06/2022)**	**Thursday (16/06/2022)**	**Friday (17/06/2022)**
Day 1	**Day 2**	**Day 3**	**Day 4**	**Day 5**
	09:30 – 10:30 Khac-Hoang Ngo (Chalmers) Unsourced multiple access for the internet of things – Part 1	09:30 – 10:30 Olgica Milenkovic (University of Illinois Urbana-Champaign) DNA-Based Data Storage: Implementations and New Coding Theory Challenges – Part 1	10:30 – 11:30 Enrico Paolini (Università di Bologna) Coded Random Access: A Reliable Massive Access Strategy – Part 1	09:30 – 10:30 Petar Popovski (Aalborg University) Ultra-Reliability and Timing for Wireless Connectivity in 5G and Beyond – Part 1
10:30 – 11:00 Coffee break	10:30 – 11:00 Coffee break	10:30 – 11:00 Coffee break	11:30 – 12:00 Coffee break	10:30 – 11:00 Coffee break
11:00 – 12:00 Hossam Mohamed Farag (Aalborg University) Industrial IoT Applications: An Overview of Wireless Communication at the Field Network Level	11:00 – 12:00 Khac-Hoang Ngo (Chalmers) Unsourced multiple access for the internet of things – Part 2	11:00 – 12:00 Olgica Milenkovic (University of Illinois Urbana-Champaign) DNA-Based Data Storage: Implementations and New Coding Theory Challenges – Part 2	12:00 – 13:00 Enrico Paolini (Università di Bologna) Coded Random Access: A Reliable Massive Access Strategy – Part 2	11:00 – 12:00 Petar Popovski (Aalborg University) Ultra-Reliability and Timing for Wireless Connectivity in 5G and Beyond – Part 2
12:00 – 13:15 Lunch break	12:00 – 13:15 Lunch break	12:00 – 13:15 Lunch break	13:00 – 14:15 Lunch break	12:00 – 13:15 Lunch break
13:15 – 14:15 Milica Petkovic (University of Novi Sad) Design of Indoor IoT Through Optical Wireless Communications – Part 1	13:15 – 14:15 Balazs Matuz (German Aerospace Center) Coding for High-Speed Applications – Part 1		14:15 – 15:15 Lennart Svensson (Chalmers) Deep self-supervised land semi-supervised learning – Part 1	
14:15 – 14:45 Coffee break	14:15 – 14:45 Coffee break		15:15 – 15:45 Coffee break	
14:45 – 15:45 Milica Petkovic (University of Novi Sad) Design of Indoor IoT Through Optical Wireless Communications – Part 2	14:45 – 15:45 Balazs Matuz (German Aerospace Center) Coding for High-Speed Applications – Part 2		15:45 – 16:45 Lennart Svensson (Chalmers) Deep self-supervised land semi-supervised learning – Part 2	

2 School Day 1 (13th June 2022)

The first school day was devoted to presentations of postdocs from partner institutions. The general idea was to give floor to young and promising researchers from partner institutions to practice tutorial lecturing activities to a demanding audience. The lecturers were Dr Hossam Mohammed Farag, a postdoc from AAU, and Dr Milica Petkovic, a postdoc from ICONIC centre, UNS.

Dr Farag provided a lecture on Industrial IoT Applications: An Overview of Wireless Communications at the Field Network Level. Dr Farag has a strong experience in the domain of IoT communications in industrial IoT systems, the background he gathered during his PhD work with Prof. Mikael Gidlund at Mid-Sweden University. After he moved to AAU as a postdoc, he became interested in the concept of Age of Information (AoI) which is a relevant metric for IIoT systems.

Dr Milica Petkovic is a postdoc at the ICONIC centre at the University of Novi Sad. Her research interests are in the domain of optical wireless communications (OWC). She has been active in OWC community recently as a work-group chair at COST action NEWFOCUS. Dr Petkovic presented a tutorial lecture on the Design of Indoor IoT Through Optical Wireless Communications.

Figure 1. Dr Milica Petkovic (UNS) – Tutorial lecture on OWC IoT

3 School Day 2 (14th June 2022)

The second school day gradually moved to more senior researchers. The first presenter was Khac-Hoang Ngo, a postdoc at CHALMERS, who presented a tutorial on Unsourced Multiple Access for Internet of Things. Dr Ngo presented a comprehensive account on the recent development of unsourced multiple access schemes, focusing on their progressively better performance and how they approach the theoretical performance bounds.

Dr Balazs Matuz, a senior researcher from DLR, presented a lecture on high-speed implementation of iterative decoders for low-density parity-check (LDPC) codes in 5G standardisation. The tutorial presented an introductory lecture on error correcting codes standardized in 5G and then addressed in detail important issues in LDPC decoder implementation, in particular, extreme throughput required for message passing process inside the decoder and the design options to reduce the internal decoder throughput.

Figure 2. Dr Balazs Matuz (DLR) – Lecture on high-throughput decoder implementation

4 School Day 3 (15th June 2022)

The third school day consisted of a single tutorial lecture presented by Prof. Olgica Milenkovic, University of Ilinois, Urbana-Champaing, USA. Prof. Milenkovic presented a lecture on DNA data storage with emphasis on new challenges in the domain of coding theory.

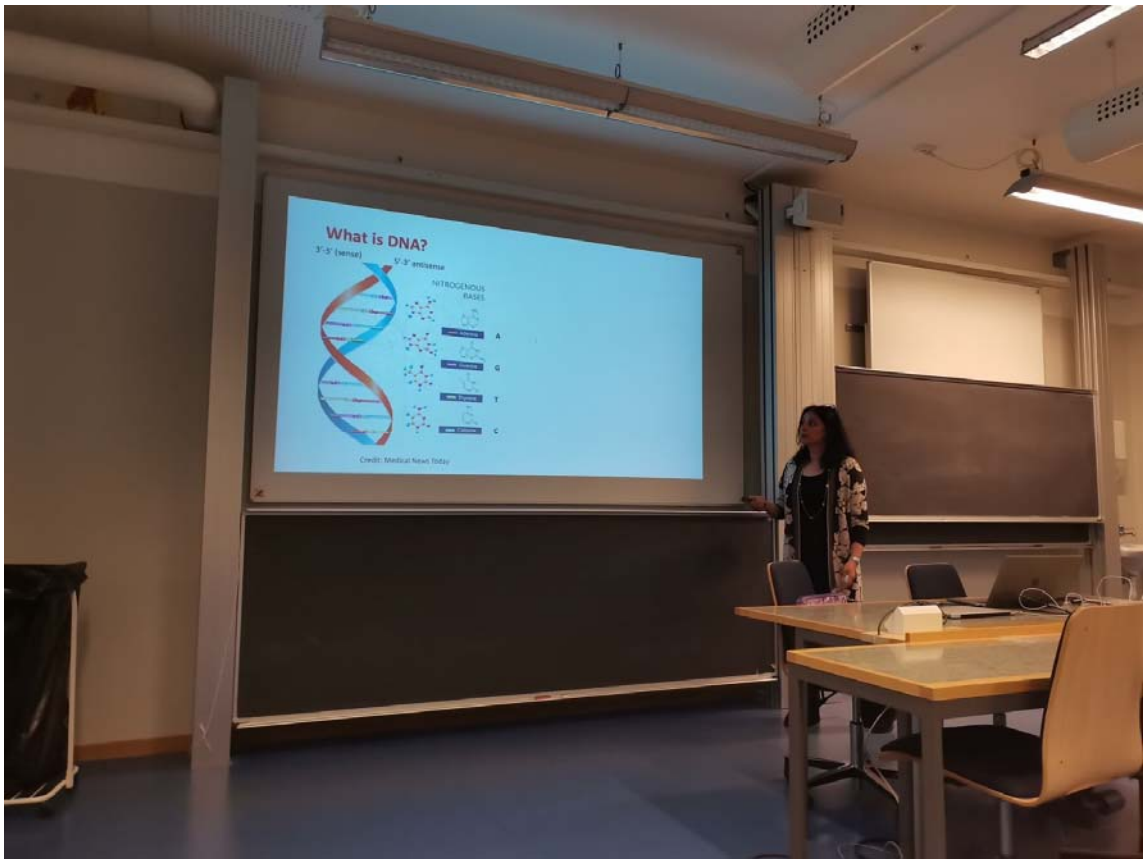


Figure 3. Prof. Olgica Milenkovic (UIUC) – lecture on coding for DNA storage

Wednesday 15th of June afternoon was devoted to sightseeing of Gothenburg and social event.

5 School Day 4 (16th June 2022)

The fourth school day introduced two lecturers, Prof. Enrico Paolini from University of Bologna (Italy) and Prof. Lennart Svennson from Chalmers University of Technology (Sweden).

Prof. Paolini presented a lecture on Coded random access and explained a detailed tutorial on implementing coded random access schemes in practical wireless systems. Lecture also provided introduction on main problems in massive random access in future, beyond 5G cellular systems.

Figure 4. Prof. Enrico Paolini (UniBO) – lecture on coded random access

The second lecture by Prof. Lennart Svennson was a tutorial overview of Deep self-supervised and semi-supervised learning. Prof. Svennson provided a comprehensive overview of this exciting field of machine learning and provided a number of examples of state-of-the-art models deployed on various learning tasks.

Figure 5. Prof. Lennart Svennson (CHALMERS) – tutorial on self- and semi-supervised learning

6 School Day 5 (17th June 2022)

The fifth school day is concluded by a lecture presented by Prof. Petar Popovski (AAU). The lecture covered interesting aspects of Ultra-reliability and Timing for Wireless Connectivity in 5G and Beyond.

Figure 6. Prof. Petar Popovski (AAU) – Lecture on timing and ultra-reliability in 5G

Finally, the last day afternoon, the PhD students from ICONIC centre of UNS have been invited to participate and follow the PhD defense at CHALMERS, as a CHALMERS student of Prof. Alexandre Graell i Amat was defending his thesis. The students from UNS could observe the similarities and differences in the process of PhD thesis defense between CHALMERS and UNS.

7 Expert Trainings

Expert On-Site Training: The expert training is envisaged in the form of short and intensive courses on a selected topic. However, due to pandemic and impossibility of staff exchange visits, the first two expert trainings were held online. Upon lifting the COVID travel restrictions in early 2022, two additional expert trainings have been organised.

During the first project year, two expert trainings were planned. The expert training by DLR experts Dr Andrea Munari and Dr Federico Clazzer was organized between 28th October and 30th October. The training topic was part of WP2 research domain: Advanced random access for machine-type communications and the training was organised online.

The second expert training is provided by Dr Sokol Kosta, an Associate Professor from AAU. He provided expert training on IoT and Mobile Cloud/Edge Computing adjoined with a set of virtual hands-on tasks and activities. The training was integral part of WP3 research domain and was delivered online between 27th and 31st of May 2021.

Thursday, 27/05/2021	Friday, 28/05/2021	Monday, 31/05/2021
Expert Training on IoT and Mobile Cloud/Edge Computing – Day 1 **Lecturers: Sokol Kosta, Aalborg University, Denmark**	**Expert Training on IoT and Mobile Cloud/Edge Computing – Day 2** **Lecturers: Sokol Kosta, Aalborg University, Denmark**	**Expert Training on IoT and Mobile Cloud/Edge Computing – Day 3** **Lecturers: Sokol Kosta, Aalborg University, Denmark**
09:00 – 09:45 **Lecture 1**: Cloud/Edge Computing Fundamentals *Cloud computing concepts, edge computing, etc.*	**09:00 – 09:45** **Lecture 1**: Towards Edge Intelligence (EI) *Describe the path to EI relating to offloading and the need for GPU computation*	**09:00 – 09:45** **Lecture 1**: Mobile applications enabled by edge computing *AR/VR papers from Pan Hui*
09:45 – 09:55 **Short 10-mins Break**	**09:45 – 09:55** **Short 10-mins Break**	**09:45 – 09:55** **Short 10-mins Break**
09:55 – 10:40 **Lecture 2**: Principles of mobile code offloading – Part 1 *Different types of code offloading: method-based, partition-based, etc.* *Describe ThinkAir*	**09:55 – 10:40** **Lecture 2**: GPGPU code offloading – Part 1 *Describe GPU offloading – GVirtuS*	**09:55 – 10:40** **Lecture 2**: Incentive mechanisms for computation offloading *D2D offloading, OpenRp, FlopCoin*
10:40 – 11:00 **Coffee Break**	**10:40 – 11:00** **Coffee break**	**10:40 – 11:00** **Coffee Break**
11:00 – 11:45 **Lecture 3**: Principles of mobile code offloading – Part 2 *Describe 2-3 recent papers, considering mobility e.g..*	**11:00 – 11:45** **Lecture 3**: GPGPU code offloading – Part 2 *Show exercise with GVirtuS offloading* *Other solutions: rCUDA, NVIDIA*	**11:00 – 11:45** **Lecture 3**: Distributed Ledger Technologies for IoT *IOTA*
11:45 – 11:55 **Short 10-mins Break**	**11:45 – 11:55** **Short 10-mins Break**	**11:45 – 11:55** **Short 10-mins Break**
11:55 – 12:40 Tutorial Session – Problem Assignments *Idea1: Read the ThinkAir paper and find limitations* *Idea2: Follow one tutorial from Azure IoT Edge*	**11:55 – 12:40** Tutorial Session – Problem Assignments *Ask students to do the exercise with GPU offloading*	**11:55 – 12:40** Tutorial Session – Problem Assignments *Use 20 minutes to come up with ideas how IOTA can be used for computation offloading + presentations*

Table 2. 2nd Expert Training Agenda (Prof. Sokol Kosta - AAU)

Figure 7. Prof. Sokol Kosta (AAU) – 2nd Expert Training on IoT and Edge/Cloud Computing

The third and fourth expert training are agreed to be delivered during late 2021 in online form. However, due to improvement with COVID-19 and rise of a milder Omicron strain, travel and work restrictions around Europe became more relaxed. Project management board decided to postpone these trainings to early 2022 with the goal of delivering these trainings as physical events at the UNS premises in Novi Sad, Serbia.

The first in-person expert training is provided by Prof. Cedomir Stefanovic (AAU) in the domain of WP2 activities on Uplink cellular communications. The training took place between 11th and 14th of April 2022 at the University of Novi Sad.

Table 3. 3rd Expert Training Agenda (Prof. Cedomir Stefanovic - AAU)

Monday 11.04	Tuesday 12.04	Thursday 14.04
AAU Expert Training on Uplink cellular communications - Day 1	**AAU Expert Training on Uplink cellular communications - Day 2**	**AAU Expert Training on Uplink cellular communications - Day 3**
09:00 – 09:45 Lecture: Uplink cellular communications ▪ Information theoretic models ▪ Fundamental results	**09:00 – 09:45** Lecture: Slotted Aloha ▪ Basic models and results	**09:00 – 09:45** Lecture: Tree algorithms ▪ Basic models and results
09:55 – 09:55 **Short 10-mins Break**	**09:55 – 09:55** **Short 10-mins Break**	**09:55 – 09:55** **Short 10-mins Break**
09:55 – 10:40 Lecture: Uplink cellular communications ▪ Communication theoretic approaches ▪ Fundamental results	**09:55 – 10:40** Lecture: Slotted Aloha ▪ Coded slotted ALOHA part 1	**09:55 – 10:40** Lecture: Tree algorithms ▪ Gated and windowed access ▪ Enhancements
10:40 – 11:00 **Coffee Break**	**10:40 – 11:00** **Coffee break**	**10:40 – 11:00** **Coffee Break**
11:00 – 11:45 Lecture: Uplink cellular communications ▪ Communication protocols for random access	**11:00 – 11:45** Lecture: Slotted Aloha ▪ Coded slotted ALOHA part 2	**11:00 – 11:45** Lecture: Tree algorithms ▪ Free access ▪ Enhancements

Figure 8. Prof. Cedomir Stefanovic (AAU) – 3rd Expert Training on uplink cellular communications

The fourth expert training was provided in person by Prof. Alexandre Graell i Amat. The topic was Statistical Machine Learning and it covered important aspects of WP3 research, including probabilistic graphical models and variational and Monte Carlo inference methods.

Table 4. 4th Expert Training Agenda (Prof. Alexandre Graell i Amat - CHALMERS)

Tuesday 26.04	Wednesday 27.04	Thursday 28.04	Friday 29.04
CHALMERS Expert Training on Statistical Machine Learning - Day 1	**CHALMERS Expert Training on Statistical Machine Learning - Day 2**	**CHALMERS Expert Training on Statistical Machine Learning - Day 3**	**CHALMERS Expert Training on Statistical Machine Learning - Day 4**
09:00 – 09:45 Lecture: Bayesian Linear Regression	**09:00 – 09:45** Lecture: Linear Models for Classification	**09:00 – 09:45** Lecture: Graphical Models	**09:00 – 09:45** Lecture: Monte Carlo Inference
09:45 – 09:55 **Short 10-mins Break**	**09:45 – 09:55** **Short 10-mins Break**	**09:45 – 09:55** **Short 10-mins Break**	**09:55 – 04:55** **Short 10-mins Break**
09:55 – 10:40 Lecture: Bayesian Linear Regression	**09:55 – 10:40** Lecture: Linear Models for Classification	**09:55 – 10:40** Lecture: Graphical Models	**09:55 – 10:40** Lecture: Monte Carlo Inference
10:40 – 11:00 **Coffee Break**	**10:40 – 11:00** **Coffee break**		**10:40 – 11:00** **Coffee Break**
11:00 – 11:45 Lecture: Bayesian Linear Regression	**11:00 – 11:45** Lecture: Linear Models for Classification	**11:00 – 11:45** Lecture: Graphical Models	**11:00 – 11:45** Lecture: Variational Inference
11:00 – 11:10 **Short 10-mins Break**	**11:00 – 11:10** **Short 10-mins Break**	**11:00 – 11:10** **Short 10-mins Break**	**11:00 – 11:10** **Short 10-mins Break**
11:10 – 11:55 Lecture: Bayesian Linear Regression	**11:10 – 11:55** Lecture: Linear Models for Classification	**11:10 – 11:55** Lecture: Graphical Models	**11:10 – 11:55** Lecture: Variational Inference

The training was held on the UNS premises between 26th and 29th of April 2022 and attracted attention of many ICONIC staff members, but also final year BSc and MSc students.

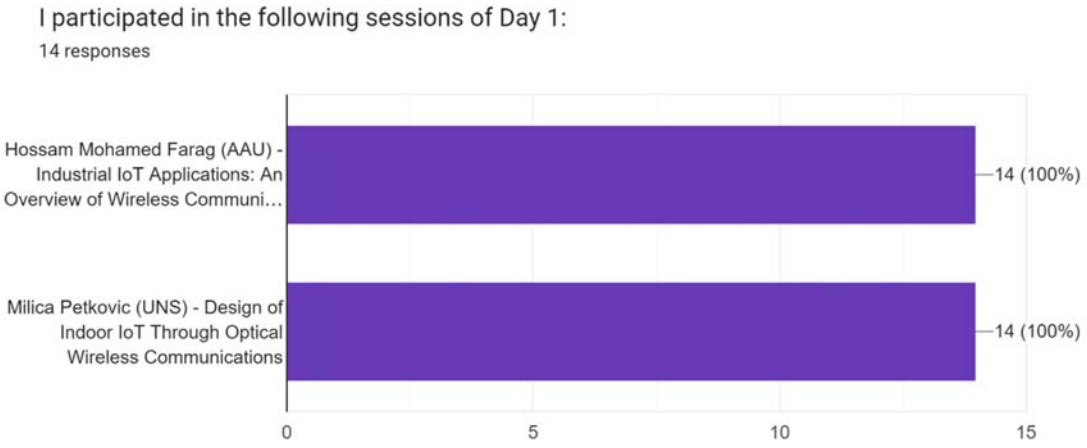
Figure 9. Prof. Alexandre Graell i Amat (AAU) – 4th Expert Training on probabilistic machine learning

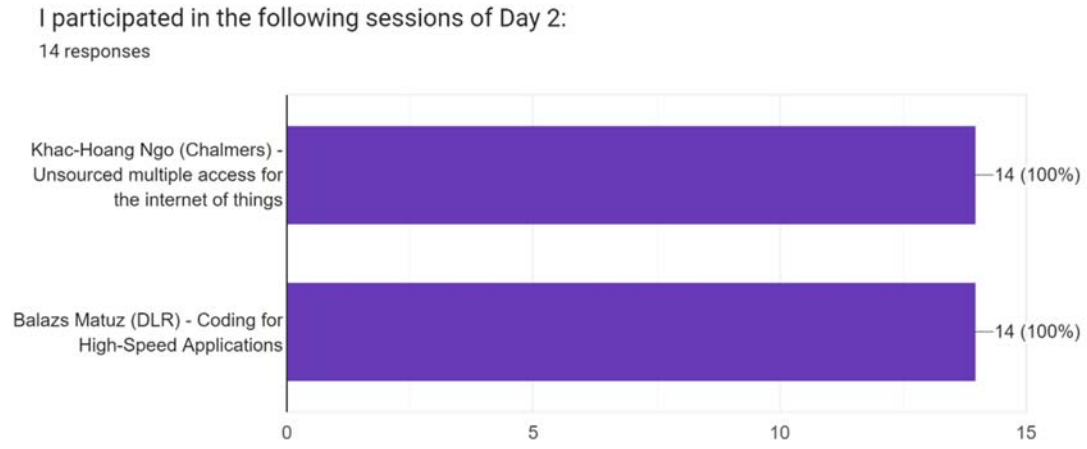
8 School Attendance, Future Schools and Conclusions

The ICONIC summer school attracted participants both from the institutions in the project consortium (FTN, AAU, CHALMERS, DLR) and the external institutions (University of Illinois Urbana-Champaign, Università di Bologna).

In order to keep track of overall performance, an online and anonymous survey was made after the summer school. In the following, we present the summary of the responses.

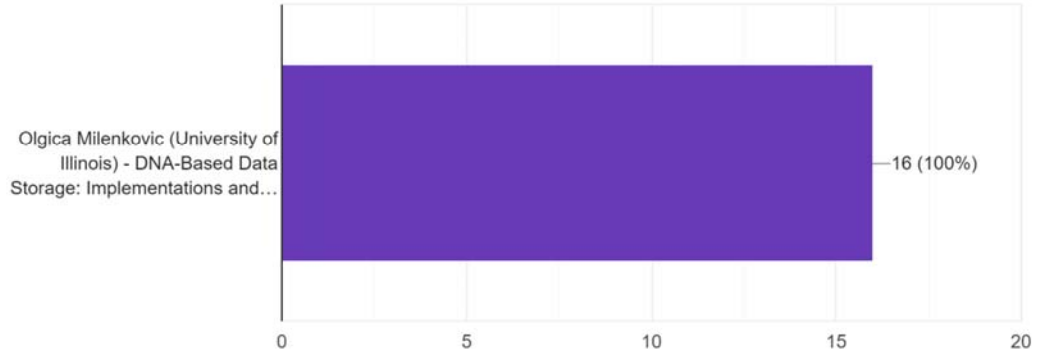
- Note that the actual number of participants was higher than what the survey shows since online survey was not obligatory.





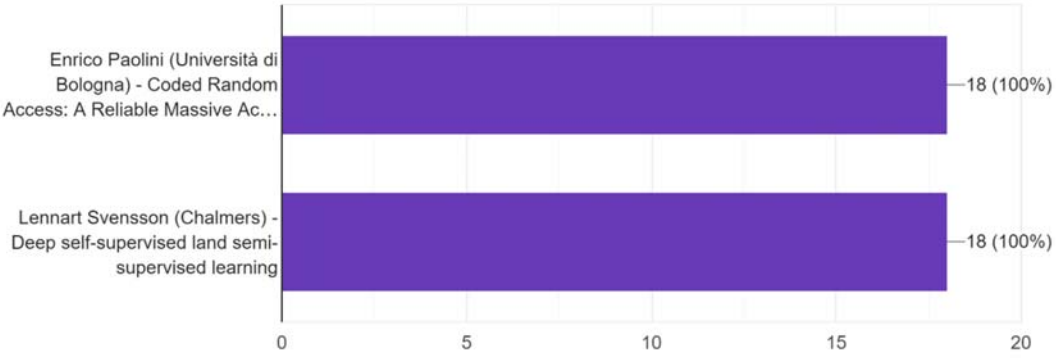
I participated in the following sessions of Day 3:

16 responses



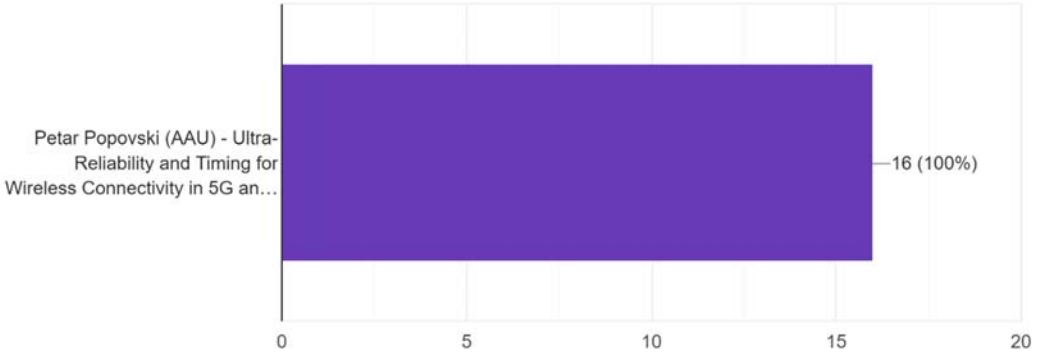
I participated in the following sessions of Day 4:

18 responses



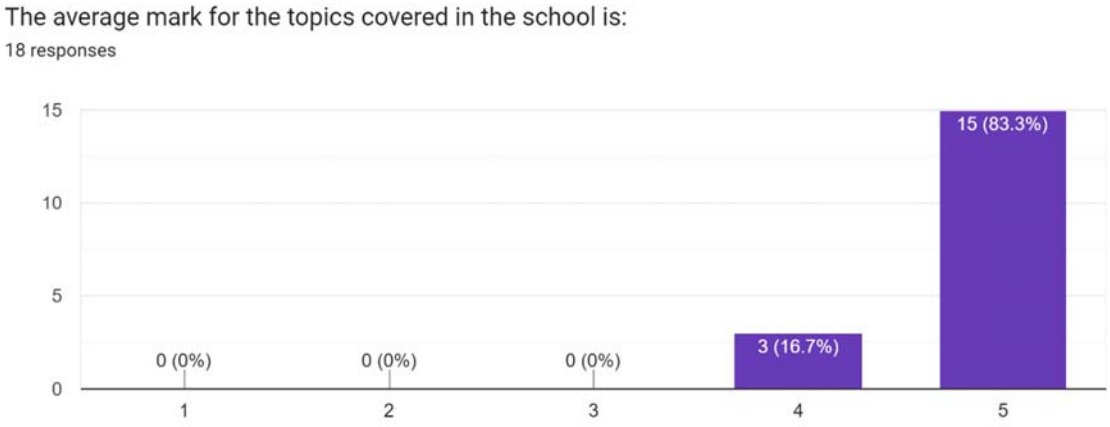
I participated in the following sessions of Day 5:

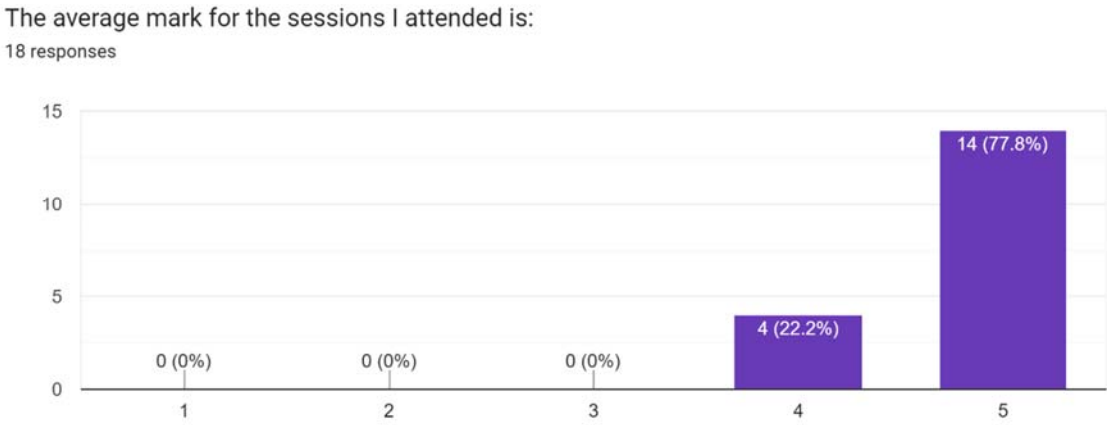
16 responses

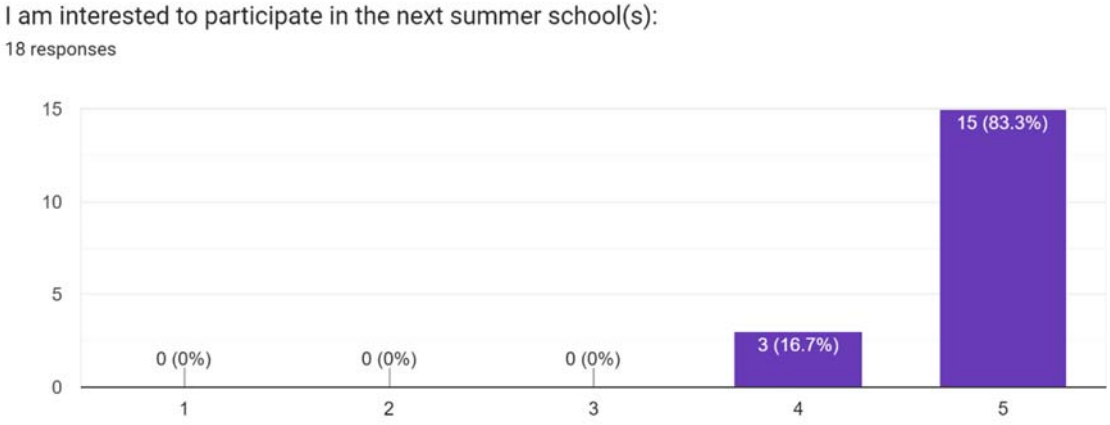


- The respondents were also asked to provide a score on the scale from 1 to 5 on the following:
  - The quality of the covered topics (1: “unsatisfactory” - 5: “excellent”).
  - The quality of the lectures (1: “unsatisfactory” -5: “excellent”).
  - The level of personal interest for the participation in the next schools (1: “definitely not likely” - 5: “definitely likely”).

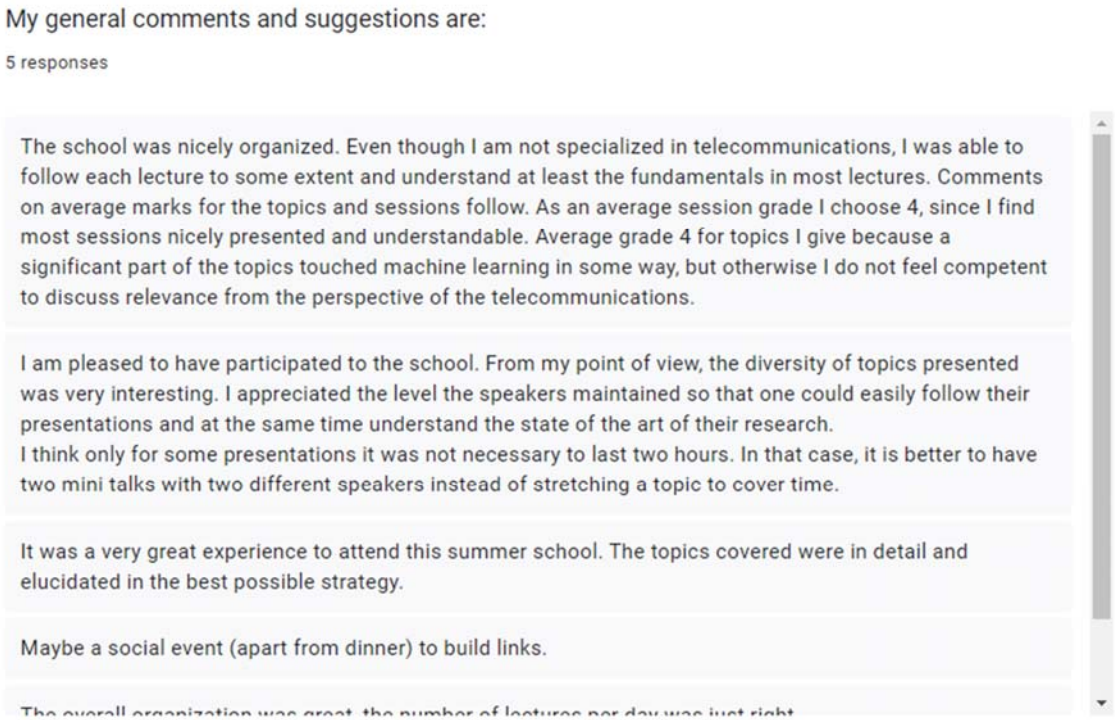
The responses are summarized in the following:

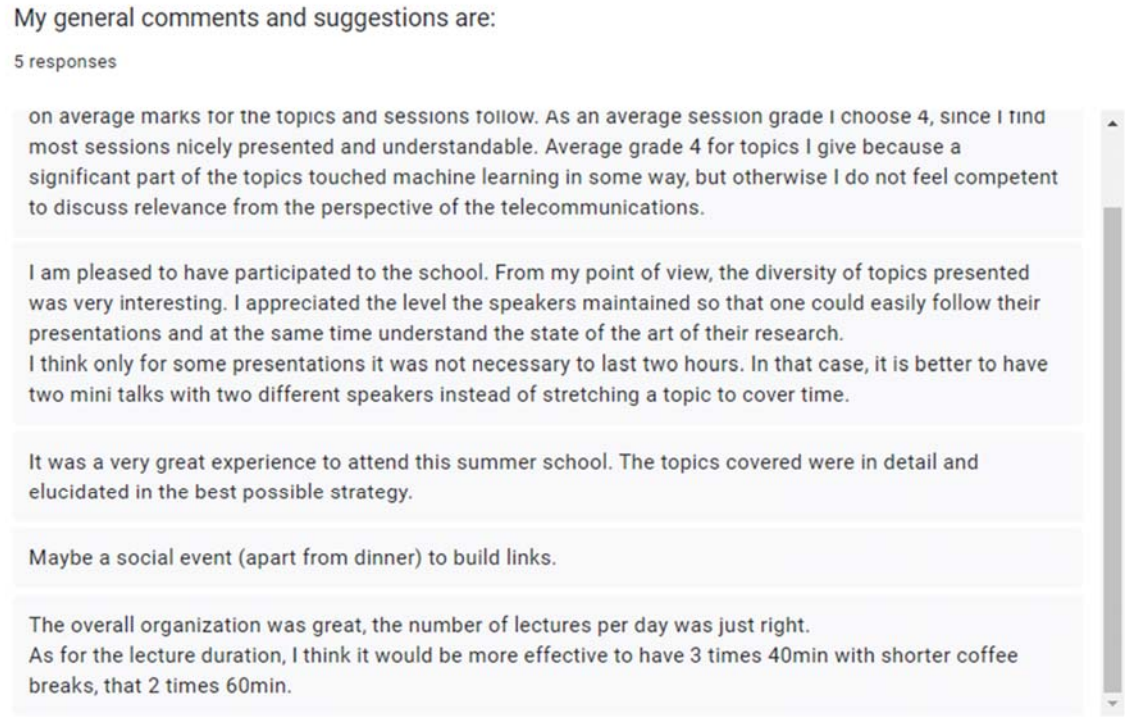






- Finally, the respondents had the opportunity leave some comments and suggestions regarding the next schools, as presented below.





My suggestions for the choice of topics and/or lecturers for the next school:

7 responses

I have no certain topic suggestion, but as a general direction, I suggest continuing to include machine learning aspects in the sessions where possible. The reason is that ML is and it seems that it will be widely used in the future as a tool to solve different problems in different domains.
I think diversity of topics should be maintained
Quantum information/coding theory
Mission Critical Communications for access networking
quantum comms
All fine. Maybe focus on basics/ general introduction to topic, rather than details (as in a paper).
Large scale and distributed machine learning, big data topics

Based on the presented responses of attendees, it may be concluded that the second summer school had a very satisfactory reception by the participants. Since the travel restrictions were lifted and the school was hold in person, a stimulating environment for networking and an active exchange of ideas among the participants was establish, which can boost more active collaboration between ESRs and project partners. The last responses from the survey will be used as an input for the planning of the next school.