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Innovation and excellence in massive-scale communications and information processing

INCOMING (Project No. 856967)

D3.4: Report on 1st Summer School: 5G Technology Fundamentals¹

Abstract: This document presents a report on 1st 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			
ERC	European Research Council			
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			
ΙοΤ	Internet of Things			
NB-IoT	Narrowband IoT			
UNS	University of Novi Sad			
WP	Work Package			

Executive Summary

Among the main H2020 INCOMING activities as part of Work Packages 2 and 3 is to provide expert training programme to ICONIC centre researchers through **summer schools and individual on-site training**. Besides enhancing research excellence via one-to-one collaboration through staff exchanges, as originally planned, an important twinning methodology was intended to use one-to-many trainings, where experts from EU partners are supposed to transfer know-how to ICONIC researchers, in particular ESRs, through training sessions. Training has been carefully designed and timed to complement individual research collaboration effort into a balanced training program.

Training sessions are intended to take two forms: Summer Schools and Expert Trainings. 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. Similarly, expert training will evolve from more 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, the plans for holding training events live as physical events were no longer possible, and both the first Summer School and Expert Training session were done online. Although this certainly could not provide the same effect as the physical events, overall, it appears that the events have been very well organized, with excellent thoroughly planned and designed lectures, and with great benefit to all involved, especially the ESR participants. This report demonstrates the details on the first project Summer School, the first Expert Training sessions and a feedback received from participants in order to improve the overall training experience in the following H2020 INCOMING project years.

1 Introduction and School Agenda

Three annual summer schools are planned to be organized during the course of the project. The schools are intended to gather experts from AAU, CHALMERS, DLR and ICONIC centre providing a set of lectures and tutorials to ICONIC centre ESRs, EU partners' ESRs as well as ESRs external to the project. Each summer school is planned to cover lectures targeting the following two research domains: i) massive IoT track, and ii) large-scale information processing track, i.e., the research areas corresponding to WP2 and WP3. The tracks will gradually shift focus from fundamental topics for the first school, via implementation aspects that will be a focus of the second summer school, to innovation and application aspects of 5G technology that will be covered during the third summer school. Where required, external experts are planned to complement the programme. Summer schools are originally planned to gather ESRs from all involved partners, thus stimulating networking and collaboration between ESRs and staff members.

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. The program is divided into five school days. Each partner institution was responsible for organizing the lectures for one of the school days, and the final day is left reserved for guest lecturers. The partners, and in particular, AAU as a leader, were closely monitoring the selection of lecture topics in order to balance between the two main project topics: massive IoT (WP2) and large-scale information processing (WP3). DLR was responsible for organisation of the first school day (05/11/2020), ICONIC/FTN for the second day (12/11/2020), CHALMERS organized the third day (19/11/2020), AAU was in charge of the fourth day (26/11/2020), while the final day was left to the guest lecturers (04/12/2020).

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

Table 1. INCOMING School Agenda

Thursday (05/11/2020)	Thursday (12/11/2020)	Thursday (19/11/2020)	Thursday (26/11/2020)	Friday (04/12/2020)
Day 1 (DLR)	Day 2 (ICONIC-FTN)	Day 3 (CHALMERS)	Day 4 (AAU)	Day 5 (Guest Lectures)
09:00 – 09:55	09:00 – 09:55	09:00 – 09:55	09:00 – 09:50	09:00 – 09:55
Gianluigi Liva (DLR)	Dusan Jakovetic (UNS)	Alexandre Graell i Amat (CHALMERS)	Sokol Kosta (AAU)	Michele Zorzi (UNIPD)
Channel Coding in the Short	Large Scale and Distributed Convex	«Coding for Distributed and Edge	Mobile Computation Offloading	mmWave and its role in 5G and beyond
Block Length Regime – Part 1	Optimization and Data Analytics – Part 1	Computing – Part 1	for IoT – Part 1	5G networks – Part 1
09:55 – 10:05	09:55 – 10:05	09:55 – 10:05	09:50 – 10:00	09:55 – 10:05
Short 10-min Break	Short 10-min Break	Short 10-min Break	Short 10-min Break	Short 10-min Break
10:05 – 11:00	10:05 – 11:00	10:05–11:00Alexandre Graell i Amat (CHALMERS)Coding for Distributed and EdgeComputing – Part 2	10:00 – 10:50	10:05 – 11:00
Gianluigi Liva (DLR)	Dusan Jakovetic (UNS)		Sokol Kosta (AAU)	Michele Zorzi (UNIPD)
Channel Coding in the Short	Large Scale and Distributed Convex		Mobile Computation Offloading	mmWave and its role in 5G and beyond
Block Length Regime – Part 2	Optimization and Data Analytics – Part 2		for IoT – Part 2	5G networks – Part 2
11:00 – 12:00	11:00 – 12:00	11:00 – 12:00	10:50 – 11:00	11:00 – 12:00
Lunch Break	Lunch Break	Lunch Break	Short 10-min break	Lunch Break
12:00 – 12:55 Mustafa Coskun (DLR) Polar Codes: Basics and Recent Advances – Part 1	12:00 – 12:55 Dejan Vukobratovic (UNS) Detailed View into 3GPP Cellular IoT Standards – Part 1	12:00 – 12:55 Henk Wymeersch (CHALMERS) Basics of radio localization (Part 1): Challenges in 5G localization	11:00 – 12:00 (Virtual) hands-on labs on Mobile Computation Offloading for IoT	12:00 – 12:55 Osvaldo Simeone (KCL): Federated learning in communication systems: Part 1
12:55 – 13:05	12:55 – 13:05	12:55 – 13:05	12:00 – 13:00	12:55 – 13:05
Short 10-min Break	Short 10-min Break	Short 10-min Break	Lunch Break	Short 10-min Break
13:05 – 14:00	13:05 – 14:00	13:05 – 14:00	13:00 – 13:50	13:05 – 14:00
Mustafa Coskun (DLR)	Dejan Vukobratovic (UNS)	Henk Wymeersch (CHALMERS)	Israel Leyva Mayorga (AAU)	Osvaldo Simeone (KCL)
Polar Codes: Basics and Recent	Detailed View into 3GPP Cellular IoT	Basics of radio localization (Part 2):	Random Access in 5G New Radio –	Federated learning in communication
Advances – Part 2	Standards – Part 2	Challenges in Beyond 5G localization	Part 1	systems: Part 2
14:00 – 14:15	14:00 – 14:15	14:00 – 14:15	13:50 – 14:00	The End
Short 15-min Break	Short 15-min Break	Short 15-min Break	Short 10-min Break	
14:15 – 15:30 Marcel Grec (DLR) Implementation of high-speed ML erasure decoders	14:15 – 15:30 Srdjan Sobot (UNS) Hands-on labs on 3GPP NB-IoT technology	14:15 – 15:30 Andreas Buchberger (CHALMERS) Machine-learning and design of error- correction codes	14:00 – 14:50 Israel Leyva Mayorga (AAU) Random Access in 5G New Radio – Part 2	

2 School Day 1 (DLR)

The first school day was organized by DLR. The lecturers were Dr Gianluigi Liva and Mustafa Coskun, while the practical hands-on session is provided by Marcel Grec.

Gianluigi Liva provided a lecture on Channel Coding in Short-Block Length Regime. As a world-renowned expert in the domain of error-correction coding, Dr Liva presented recent problems in information and coding theory related to short-packet error correction which are particularly relevant for massive IoT systems.



Figure 1. Gianluigi Liva lecture (DLR)

Mustafa Coskun is a PhD student at Technical University of Munich and researcher at DLR whose recent research includes significant contributions to the field of design, analysis and decoding methods for polar codes, a class of error correcting codes which is adopted as an error correction mechanism in the latest 3GPP New Radio (5G) standards.



Figure 2. Mustafa Coskun lecture (DLR)

Marcel Grec, a researcher at DLR who's interest is in the domain of implementation of error correction decoders, provided a hands-on lesson about implementation aspects in the area of error correction decoding algorithms.

3 School Day 2 (ICONIC)

The second school day is organized by ICONIC centre, University of Novi Sad. The lecturers were Dr Dusan Jakovetic and Dr Dejan Vukobratovic, while practical hands-on session is provided by Srdjan Sobot.

Dr Dusan Jakovetic presented a lecture on a Large Scale and Distributed Convex Optimization and Data Analytics. Dusan is an Associate Professor at the University of Novi Sad. He is an expert in the domain of distributed optimization, with a PhD degree and best PhD award from Carnegie Mellon University, USA. This talk is based on his recent overview paper in a flagship IEEE journal: Proceedings of the IEEE.

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Figure 3. Dusan Jakovetic lecture (UNS)

Dr Dejan Vukobratovic is a full professor at Faculty of Technical Sciences, University of Novi Sad, and is a director of ICONIC centre and coordinator of H2020 INCOMING project. His talk covered a detailed overview and ICONIC research activities in the domain of 3GPP Cellular IoT technologies.



Figure 4. Dejan Vukobratovic lecture (ICONIC, UNS)

Srdjan Sobot, a PhD researcher at ICONIC, presented a hands-on session, demonstrating various development tasks related to NB-IoT devices, and data that can be collected from the devices for the purpose of real-world experimentation.

4 School Day 3 (CHALMERS)

The third school day is organized by CHALMERS. The lecturers were Dr Alexandre Graell i Amat and Dr Henk Wymeersch, while practical hands-on session is provided by Andreas Buchberger.

Dr Alexandre Graell i Amat is a full professor at CHALMERS and is a scientist in charge for INCOMING project. He is a leading expert in the domain of error-correction coding and applications. This lecture covered modern trends in coding for edge computing.



Figure 5. Alexandre Graell i Amat lecture (CHALMERS)

Dr Henk Wymeersch is a full professor at CHALMERS. His talk covered emerging localization technologies and signal processing methods for beyond 5G networks.



Figure 6. Henk Wymeersch lecture (CHALMERS)

Andreas Buchberger, a PhD researcher at CHALMERS, presented a hands-on session, demonstrating usage of machine learning tools for the design of modern error correcting codes and their optimized data-aided decoders.

5 School Day 4 (AAU)

The fourth school day is organized by AAU. The lecturers were Dr Sokol Kosta and Dr Israel Leyva Mayorga, while practical hands-on session was provided also by Dr Sokol Kosta.

Dr Sokol Kosta is an associate professor at AAU. He is a leading expert in the domain of edge computing. This lecture covered modern trends and tools in edge computing for IoT applications.



Figure 7. Sokol Kosta lecture (AAU)

Dr Israel Leyva Mayorga is a postdoc at AAU, in the connectivity section of Prof. Petar Popovski. His talk covered random access in 5G networks, a fundamental topic about one of the major bottlenecks for realization of massive IoT vision.



Figure 8. Israel Leyva Mayorga lecture (AAU)

Hands-on session, demonstrating usage of edge computing tools, has been presented as part of the lecture by Dr Sokol Kosta.

6 School Day 5 (Guest Lectures)

The fifth school day is organized by AAU, but it involved invitation for lectures to two worldleading lecturers in the domain of 5G wireless communications and machine learning. The lecturers were Dr Michele Zorzi, full professor at University of Padova (Italy) and Dr Osvaldo Simeone, full professor at King's College London (UK).

Dr Michele Zorzi is a full professor at University of Padova, an IEEE Fellow and the IEEE ComSoc Director of Journals. He is a leading expert in the domain of wireless communications. This lecture covered modern trends in mmWave communications for 5G and beyond 5G.



Figure 9. Michele Zorzi lecture (Guest Lecture)

Dr Osvaldo Simeone is a full professor at King's College London, and IEEE Fellow and a holder of ERC consolidator grant. His talk covered recent trends in federated learning and its applications in wireless communication systems.



Figure 8. Osvaldo Simeone lecture (Guest Lecture)

7 Expert Trainings

Expert On-Site Training: Original expert trainings were supposed to be organized during staff exchange visits from EU partner institutions, where each visiting expert should have used the visit opportunity to provide training to ICONIC researchers. The expert training was envisaged in the form of short and intensive courses on a selected topic. However, due to pandemic and impossibility of staff exchange visits, the expert training was held online.

During the first project year, two expert trainings by staff members from DLR and CHALMERS were planned. The expert training by DLR experts Dr Andrea Munari and Dr Federico Clazzer was organized between 28th October and 30th October. The expert training topic was Advanced random access for machine-type communications. Due to a large number of events of H2020 INCOMING organized during the period of October-December 2020., the expert training of CHALMERS is postponed to the period of January-February 2021., and will be held by Prof. Alexandre Graell i Amat. The agreed topic is Statistical Machine Learning with applications in coding theory and wireless communications.

The agenda of the first expert training presented by DLR experts is given below.

Wednesday 28.10	Thursday 29.10	Friday 30.10		
DLR Expert Training on Advanced Random Access for Machine-Type Communications - Day 1 Lecturers: Andrea Munari and Federico Clazzer	DLR Expert Training on Advanced Random Access for Machine-Type Communications - Day 2 Lecturers: Andrea Munari and Federico Clazzer	DLR Expert Training on Advanced Random Access for Machine-Type Communications - Day 3 Lecturers: Andrea Munari and Federico Clazzer		
09:00 – 09:45 Lecture 1: Introduction and fundamentals of random access for IoT applications (ALOHA, SA, stability, diversity slotted ALOHA) – Part 1	09:00 – 09:45 Lecture 1 : CRDSA and IRSA, asymptotic analysis – Part 2	09:00 – 09:45 Lecture 1 : Modern random access from an information freshness perspective – Part 2		
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 2: Introduction and fundamentals of random access for IoT applications (ALOHA, SA, stability, diversity slotted ALOHA) – Part 2	09:55 – 10:40 Lecture 2: The impact of operating over finite frame lengths: error floor analysis	09:55 – 10:40 Lecture 2: Practical considerations and examples of modern random access: asynchronous schemes (E-CRA), DVB-RCS2 and ETSI S- MIM – Part 1		
10:40 – 11:00 Coffee Break	10:40 – 11:00 Coffee break	10:40 – 11:00 Coffee Break		
11:00 – 11:45 Lecture 3: CRDSA and IRSA, asymptotic analysis – Part 1	11:00 – 11:45 Lecture 3: Modern random access from an information freshness perspective – Part 1	11:00 – 11:45 Lecture 3: Practical considerations and examples of modern random access: asynchronous schemes (E-CRA), DVB-RCS2 and ETSI S- MIM – Part 2		
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	11:55 – 12:40 Tutorial Session – Problem Assignments	11:55 – 12:40 Tutorial Session – Problem Assignments		

Table 2. INCOMING Expert Training Agenda

8 School Attendance, Future Schools and Conclusions

The school attracted participants both from the institutions in the project consortium (FTN, AAU, CHALMERS, DLR) and the external institutions (University of Bremen, University of Padova, King's College London, University Lusofona Lisbon etc.).

An online survey was made after the school; in the following, we present the summary of the responses. We also note that the survey was not mandatory. The actual number of participants was higher than what the survey shows. E.g., the lowest number of participants in a session was 13, while the highest was 44.









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 general comments and suggestions are:

13 responses

Solid effort, useful school and material.

Great organization, especially when considering the online format of the school

sadly I was not able to attend as mush as I wanted but the sessions I did was good

Keep up the good work!

Carefully chosen topics and excellently prepared presentations

The topics covered in the school were very much interesting. I am also interested in attending future schools, workshops and guest lectures.

Online is ok, but cannot replace live sessions

It would be nice to add some practical demonstration.

I am satisfied with topics and presenters.

My suggestions for the choice of topics for the next schools:
11 responses
Perhaps exploring technologies for IoT in remote areas, for example, with satellites, would be interesting
Optical communication (VLC and Free space).
More on Ultra Reliable Low Latency in 5G
Large Scale Machine Learning
NB-IoT technology based testbed related topics
A few more lectures and topic about 5G technologies in the core of the network
analysis of latency
Biased by my own interests, in my opinion it would be very interesting to have talks
about the massive random access problem.

Based on the responses, it may be concluded that the first summer school had a very favorable reception by the participants, achieved a great success and set high standards, despite the challenges posed by the current pandemics.

The responses from the survey will be used as an input for the planning of the next schools. The organizers hope that the travel restrictions will be lifted by then, such that the next schools could also provide a stimulating setting for networking and an active exchange of ideas among the participants.