HORIZON 2020

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D6.4 Report of educational outreach

Acronym	SLICES-SC
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Authors	Stavroula Maglavera, Kostas Choumas, Nikos Makris, Thanasis Korakis (UTH), Esa Posio (UOULU), Damien Saucez (INRIA), Raymond Knopp (Eurecom), Konstantinos Filis (OTE)
Reviewers	Barbara Toth (SCZAKI), Peter van Daele (imec)

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Scientific Large-scale Infrastructure for Computing Communication Experimental Studies **Starting Communities**

www.slices-sc.eu

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Executive summary

This deliverable reports on the outreach of the educations activities of SLICES including the SLICES Academy, the Networking Channel, the SLICES Hackathons, the SLICES Workshops and the SLICES Summer Schools that organised within the whole duration of the project. The outreach of the educational activities was organised in collaboration with communications activities that they have always been kept under control, monitored, and refitted according to the needs of the project, and the objective results are encouraging. These activities have been constantly monitored to ensure the correct outreach actions are in place and producing results as presented in this deliverable. In the final year of the project, the SLICES Academy entered the mature phase with its online publication, which will be continued its development and enhancement through the SLICES-PP and other new initiatives. In addition, the Networking Channel, the SLICES Hackathons, the SLICES Summer schools will be sustained through collaboration and other initiatives.

1. SLICES Academy

1.1. SLICES Academy

SLICES Academy[1] is an ecosystem that supports the community towards the engagement of people to the new technologies of the future Internet. Through its services, it focuses on enhancing the knowledge of researchers, continuous learning workers in the business and developers of testbed facilities in the most innovative fields of technology. Areas as networking, cloud computing, wireless connectivity and AI/ML, are covered by the SLICES academy platform. The main service of SLICES Academy is this platform, which is supported by the Moodle[2] software. SLICES partners have accessed this platform and can publish their own online courses, which cover a range of topics including 5G and 6G technologies, AI/ML, IoT, SDN, Cloud/Edge computing, Hypercomputing, and more. In addition, we offer a broad portfolio of webinars and training events, specifically emphasizing SLICES-RI and its application. A significant number of these recordings have been generated through documenting our involvement at major events and conferences, as well as the tutorials we have conducted regarding SLICES. Moreover, SLICES Academy provides a direct link to the Networking Channel[3], which is a twice-a-month online activity to maintain and build a research and education community, by organizing a series of lectures. Finally, we also provide a code repository for all software developments of SLICES. More details of the SLICES Academy are provided in Deliverable 4.2.

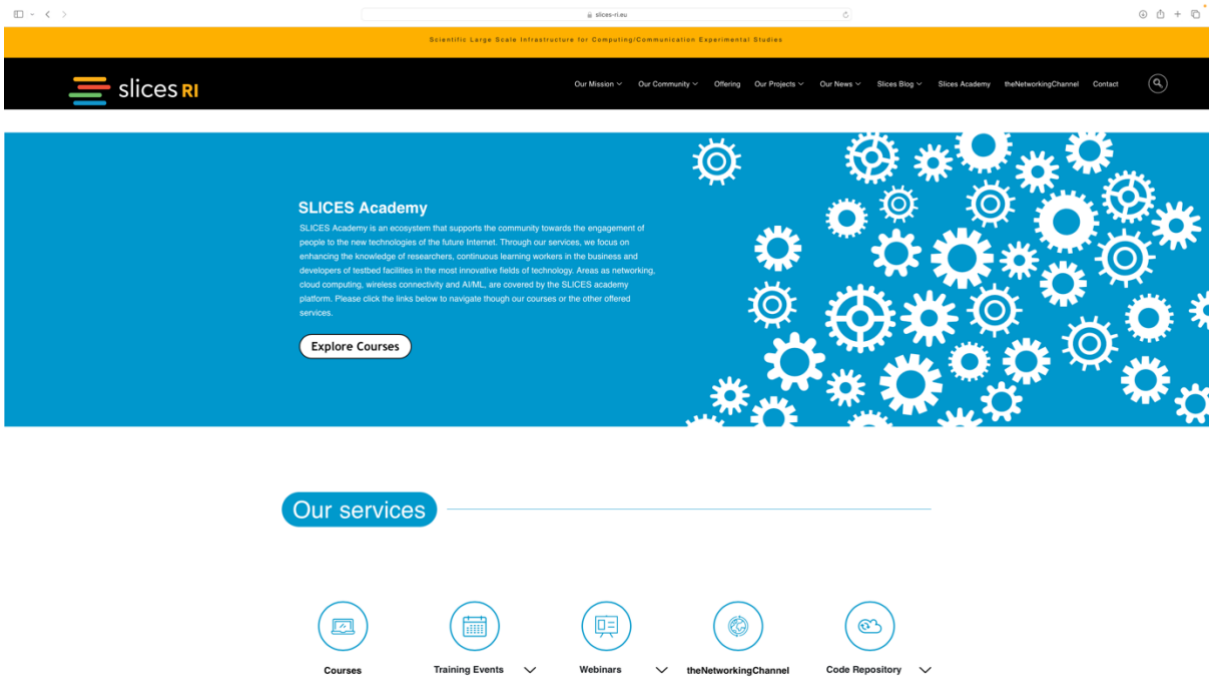


Figure 1. SLICES Academy portal

We defined the following three target groups of potential students and users of SLICES-RI:

- testbed developers,
- experimental researchers,

[1] SLICES Academy website, https://www.slices-ri.eu/slices-academy/ [Last accessed 26 August 2024]

[2] Moodle Software, https://moodle.org/?lang=el [Last accessed 26 August 2024]

[3] TheNetworkingChannel, https://networkingchannel.eu [Last accessed 26 August 2024]

- industrial engineers.

Potentially in the future, the three target groups may be extended with the public authorities, but for now, we believe that these users can be treated as industrial engineers. Under online courses students have the possibility to select one of the three roles depicted below, to see a filtered set of the available courses for the respective role. The three roles are the following:

- **Testbed developers:** users interested in deploying a testbed like the ones provided by SLICES. They are offered a range of courses that teach them how to reproduce one or more of the SLICES testbeds in their own facilities. These courses also provide the methodology for extending the replicated testbeds to support a wider range of experimentation tools.
- **Experimental researchers:** users that want to use a SLICES testbed for their research. They can enroll in various courses that instruct them on how to effectively utilize the SLICES testbeds for their experiments involving protocols, software tools, and hardware resources. These courses allow researchers to become acquainted with SLICES and its facilities, introducing them to the SLICES community.
- I**ndustrial engineers:** users that want to be familiar with the technologies supported by SLICES. They can pick from a range of courses that teach them how to efficiently use the SLICES testbeds to become familiar with new protocols, software tools, and hardware resources.

The SLICES Academy students, apart from defining their role are also prompted to mention which areas of expertise they wish to expand or begin developing their knowledge in. More specifically, they are prompted to select one of the following knowledge areas:

- **Fixed networking**, which includes optical networking, SDN/P4, TSN, Data-plane acceleration, Quantum networks, etc.
- **Edge/cloud**, which includes virtualization, containerization, DevOps, Orchestration, Cloud security, etc.
- **Wireless**, which includes OpenRAN, SDR, Fronthaul, near RT-RIC/xAPPs, NTN, B5G/6G RAN, cloud-native RAN/Core, wireless networking drivers, IoT, mmWave, Smart Antenna Tech, Positioning, URLLC, mobility, etc.
- **Computing**, which includes HPC, Quantum, GPU/FPGA, etc.
- **Data & AI/ML**, which includes Data analysis, Federated learning for networking, AI/ML for RIC, etc.

More details of SLICES Academy can be found in Deliverable D4.2.

1.2. Tutorials for the online courses' platform of SLICES Academy

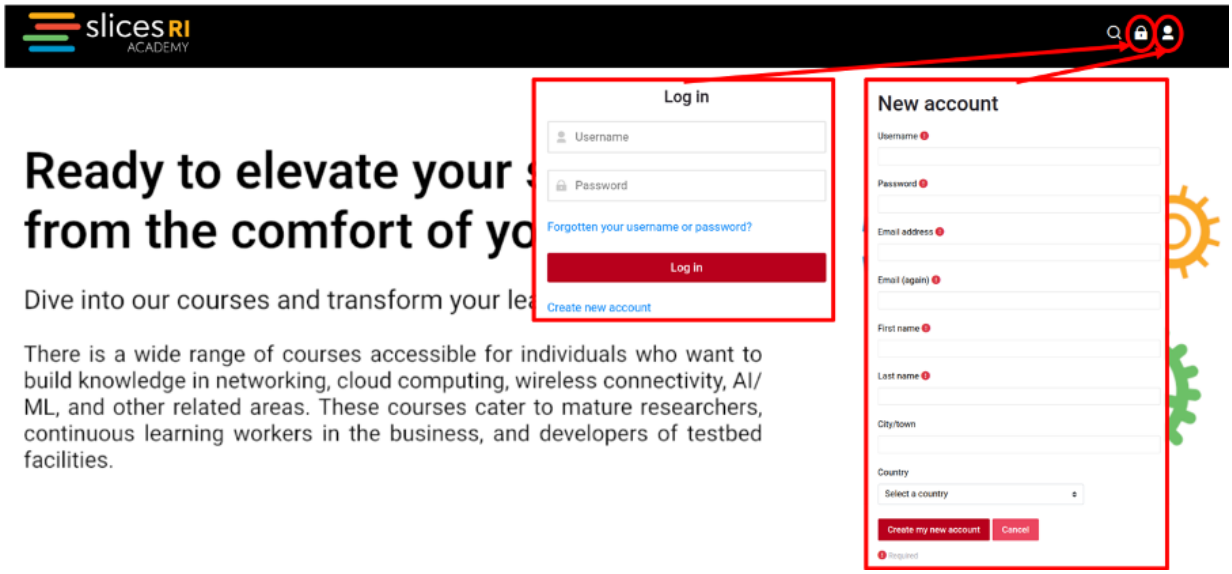


Figure 2. The SLICES Academy platform for online courses enables multiple users to be connected using their own credentials and access the information that is allowed by their authorization. Depending on their role, they are capable either to create a course or to enroll to a given course or to do both of them.

Figure **2** shows where a user can log in or create an account on the platform. When a user is created after the sign-up process, by default his/her role is student, who can enroll to the available courses. After contacting the administrator of the platform, the user can be upgraded to Course Creator, who is able to create new courses. Each Course Creator is **OBLIGED TO** provide a **PROFILE** photo that will be used for the frontpage of his/her courses.

1.3. Tutorial for Course Creators

The Course Creators are responsible for creating the courses. When Course Creators are logged in, they can see a left-side course menu that can be hidden or unhidden by clicking the orange double arrow, as it is depicted in Figure **3**.

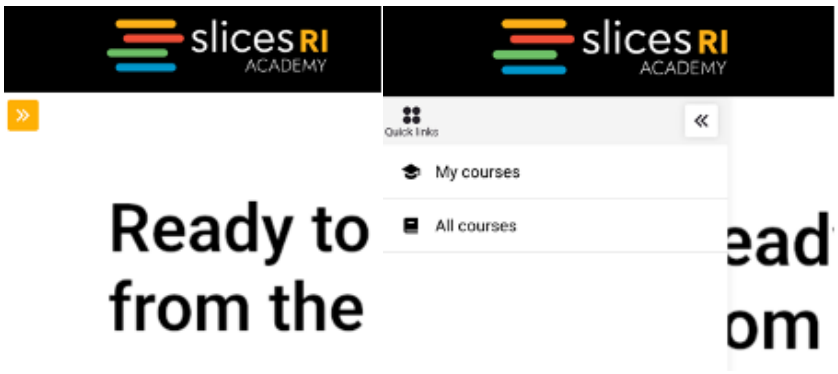


Figure 3. The left-side course menu of the user of the SLICES Academy platform for online coursing.

Using this menu, the users can display their courses or all available courses. When they choose to reveal 'My courses', they see a list with the courses that they have either enrolled as Students or created as Course Creators. In Figure 4, we can see the list of 'My courses' for a Course Creator, who has enrolled to the 1st and 4th course and has created the 2nd and 3rd courses in the middle. As it is depicted in the same figure, there is a button at the right side of the page for the creation of a new course, pointed with a red circle.

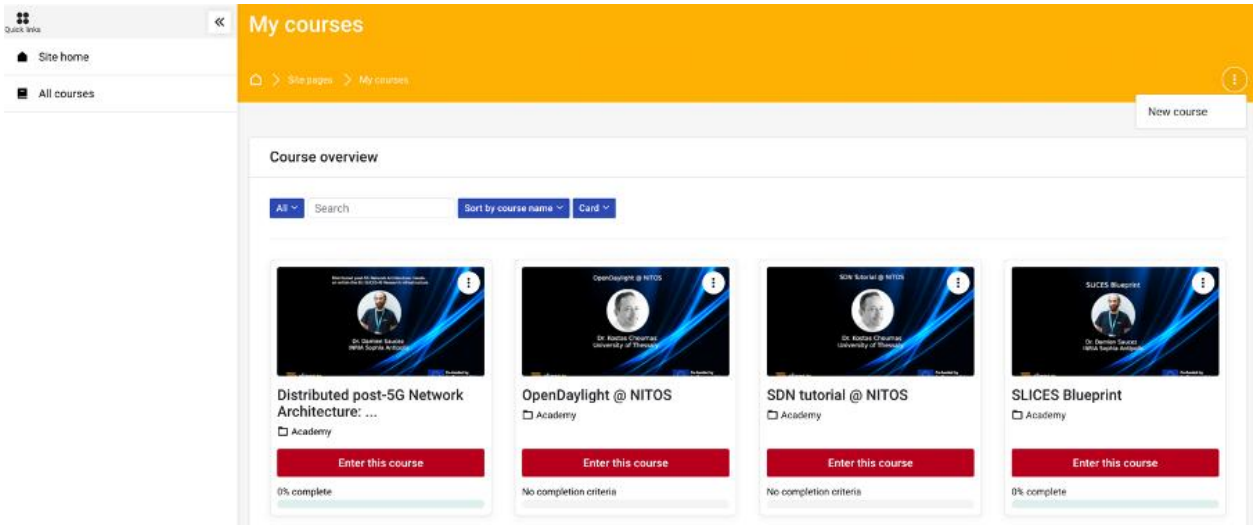


Figure 4. A typical view of 'My courses'.

When the Course Creators initiate a new course, they must fill in the form of Figure 5, which has an extensive set of fields. The required fields are the 'Course full name', 'Course short name' and 'Course category' in the General section at the top of the form, as well as the 'Tags' section at the bottom of the form.

- The course names should be filled appropriately.
- The **'Course Category' MUST** be one of the three: **'Experimental Researcher'**, **'Industrial Engineer'**or **'Testbed Developer'**, indicating the role that this course is oriented toward.
- At least one of the **Tags** of each course **MUST** be one of the five: **'Fixed Networking'**, **'Edge/Cloud'**, **'Wireless'**, **'Computing'** and **'Data & AI/ML'**, indicating the research areas that this course is related with.
- Lastly, the **expiration date** of the course should **disable**, as it is set by default.

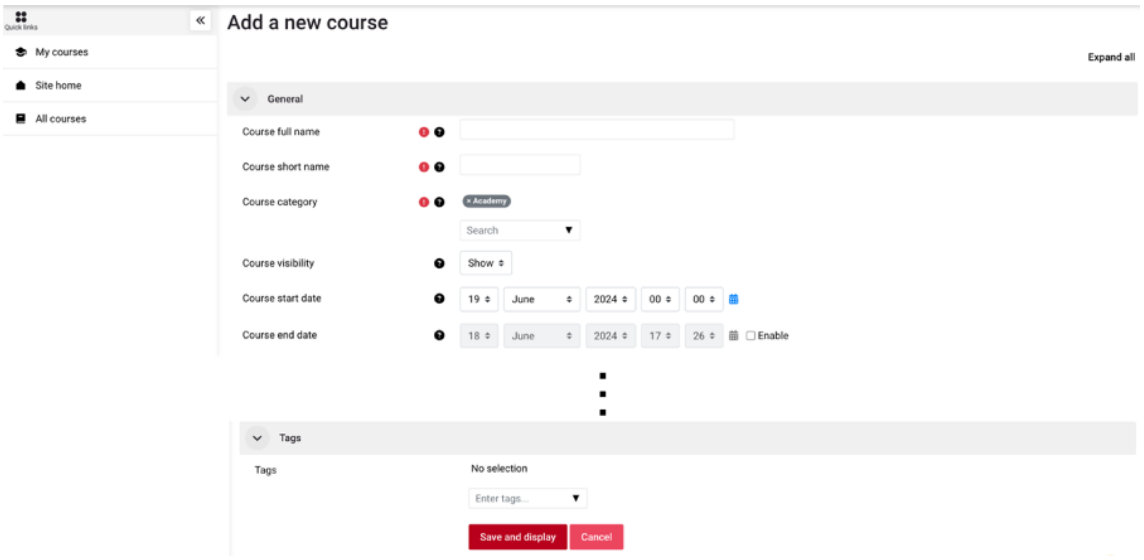


Figure 5. The form for creating a new course.

Course Creators are automatically assigned as Teachers for their courses, and they have the right to assign other users as additional Teachers to their courses.

1.4. Tutorial for Students

Students can only enroll to courses. Using the left-side shown in Figure **6**, they can see the list of 'All courses', as it is depicted in Figure 7. They can also use the filtering process described before, in order to give their role and the research area that they are interested in, to receive a reduced set of available courses.

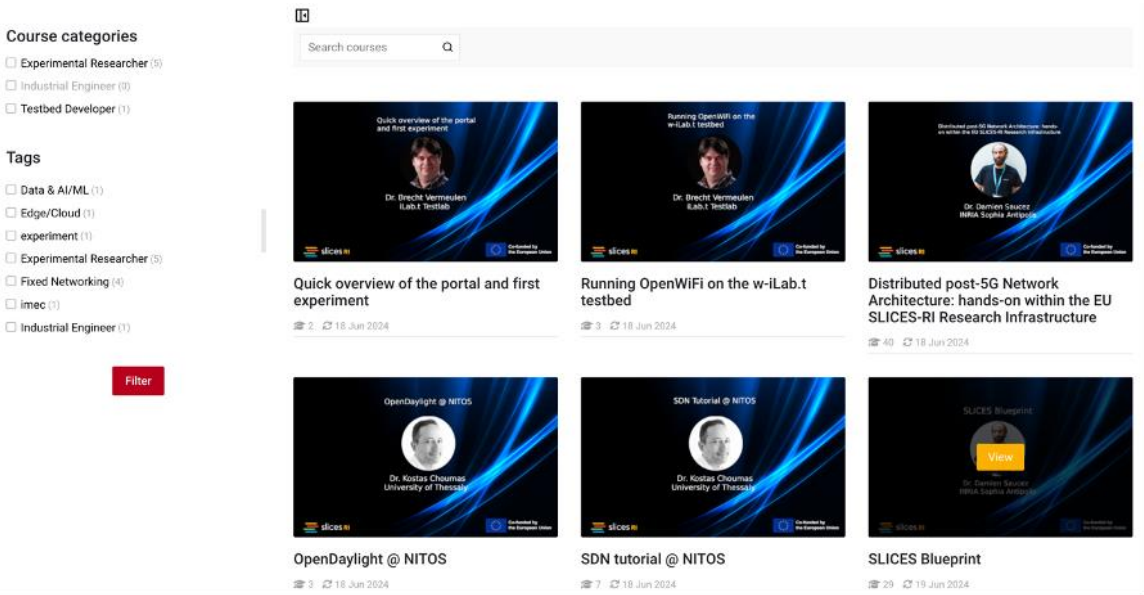


Figure 6. A typical view of 'All courses'

When the students click the button 'view' over a course (pointed with a red circle), then they go to the course page that is like the following in Figure 8, which enables their enrollment to this course. They must click the 'Enroll now' to complete the process.

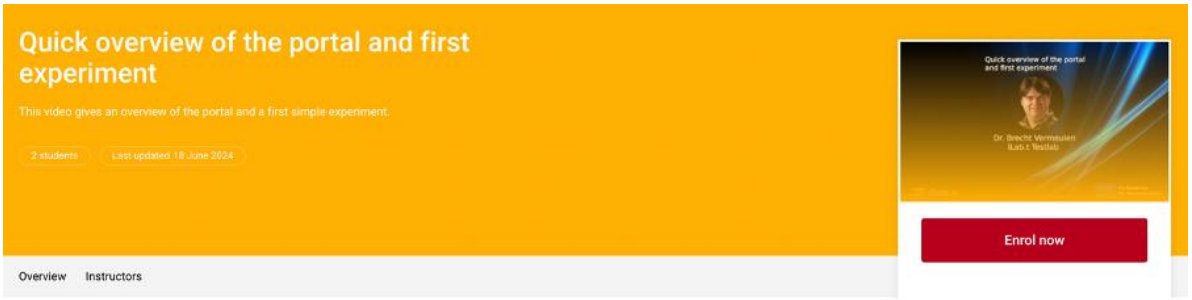


Figure 7. The course page used for the enrollment of a student

2. TheNetworkingChannel

SLICES community building and awareness will also be expanded through the uptake of the support of the operation of the NetworkingChannel[4]. The NetworkingChannel began during the COVID pandemic, when traditional forms of community gatherings were not possible, as a twice-a-month informal online activity "to maintain and build our networking research and education community." The NetworkingChannel is a series of events – organized as an online 'channel' – with events on topics of interest to the networking community, ranging from research to descriptions/discussions of commercial networked systems, to global societal considerations, to education and careers in networking. Lessons learnt from its four years of operation, shows that The NetworkingChannel is working as a fantastic venue for the collaboration between EU and USA. In the last years, characterized by the explosion of virtual events, The NetworkingChannel has succeed on attracting the networking community thanks to its top-quality talks and speakers. The top watched event has exceeded 2,800 post-event views on the YouTube channel. The NetworkingChannel continues its operation with new events the SLICES umbrella together with the NSF PAWR Office, and in cooperation with ACMSigcomm, facilitating the community building, sustaining the international community that counts more than 6000 people and disseminating SLICES' results.

[4] TheNetworkingChannel, https://networkingchannel.eu [Last accessed 26 August 2024]

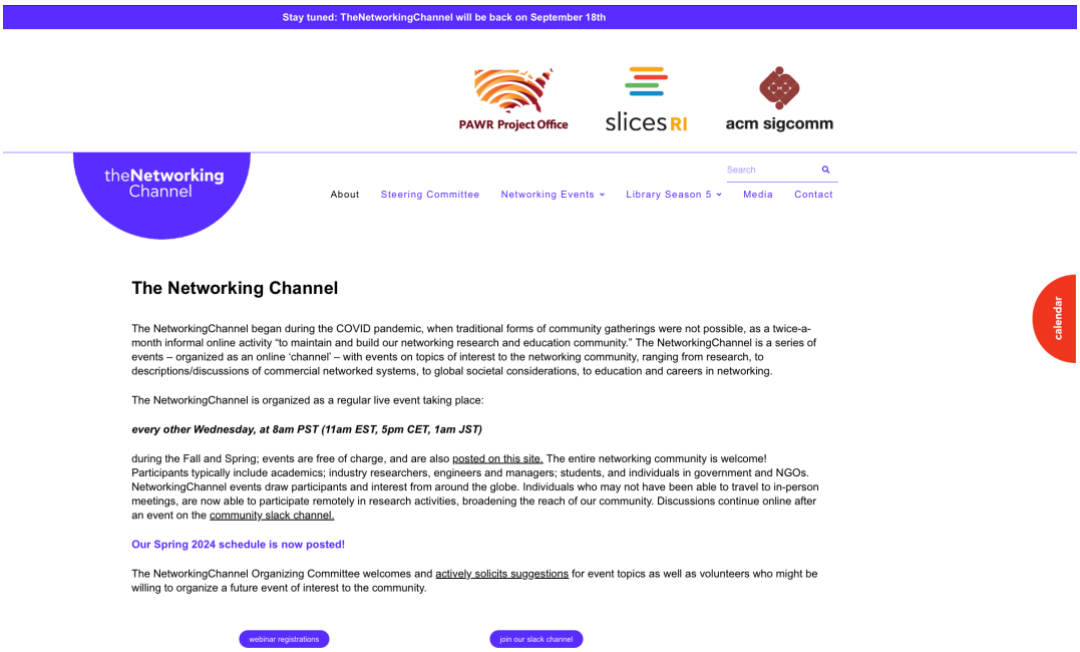


Figure 8. TheNetworkingChannel

TheNetworkingChannel is organized as a regular event, taking place ***every other Wednesday, at 8am PST (11am EST, 5pm CET, 1am JST)***, where a diversity of events is organized for the community, live and pre-recorded. Topics are broad and open ranging from research to experimentation and education. The channel consists of webinars, panels, tutorials, virtual site visits, keynotes, and any other innovative forms of community interaction. The following diagram depicts the attendees of the different events in relation with their origin. In summary, we had 3021 attendees from Europe, 2369 from North America, 422 from South America, 661 from Asia, 101 from Asia and 9 for Oceania. In total 6583 participated in the events.

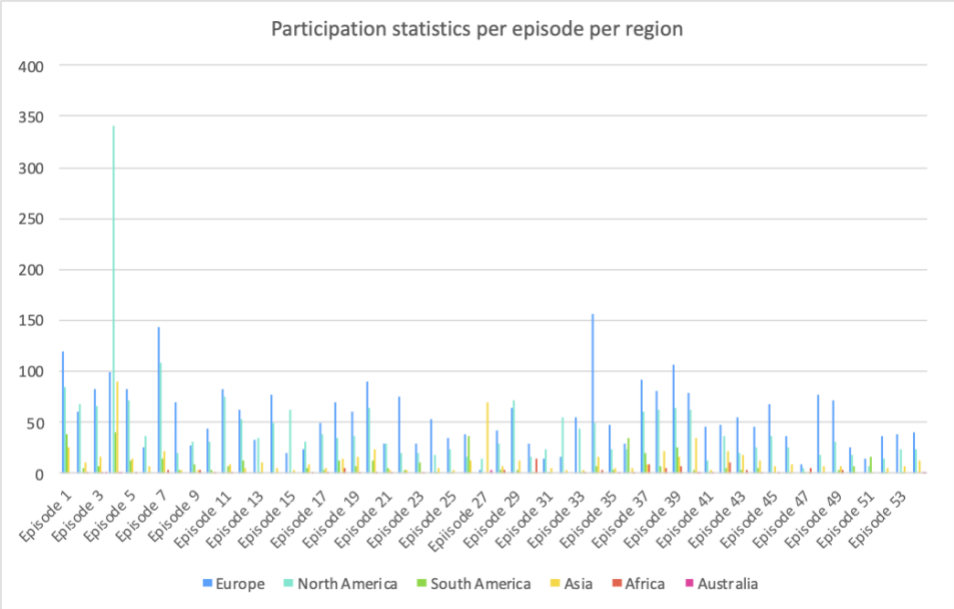


Figure 9. Participation statistics per episode per region

The list of events organised are depicted in the table below:

Title of episode	N of attendees	N of post views
The Network will be programmed by many, operated by a few	268	1200
A Journey with mmWave research	147	686
5G and Next G Innovation Opportunities and Challenges	175	593
Advice on how to succeed in grad school	573	1100
Emerging Trends in AI/ML and Implications for Networking Research	182	680
Challenges at Layer 8: Network neutrality, the digital divide and spectrum	69	n/a
Demonstrating Advanced 5G and Edge Services on the 5G-VINNI platform	292	302
Networking Education During and After the Pandemic	96	335
Experiments in the Edge to Cloud Continuum	76	193
A day in the life of Netflix streaming	83	245
Quantum Networks	174	2700
Human-centered Networking	134	538
QUIC and its impact on secured transport layer management in SATCOM systems	80	342
How can we improve diversity and inclusion in the systems and networking community?	132	230
How the Internet grew up outside the US, and lessons learned for the future	87	159
Transatlantic perspectives on 6G Vision, Roadmap and Development Model	71	118
Open Educational resources for teaching and learning networking	97	235
Network Datasets: what exists, and what are the problems?	137	319
End-to-End Network Programmability with P4	121	365
Magma: Current Focus and Road Ahead for 5G	192	1000
6G EU and US Programmes	70	265
Strategic and geopolitical implication of Networks	105	316
FutureG Research platform capabilities leveraging public-private partnership testbeds	64	95
Wireless Security Networking Panel	80	67
How to survive a PhD: fears and issues. A perspective from students	63	116
SDN Experience from the Asia-Pacific Region	103	179
The Transforming Challenges of Internet Governance	91	288
Living on the Edge for a Quarter Century: An Akamai Retrospective	87	352
Networking in Africa: Connectivity, Education and research topics	152	1900
Student & Early Career Networking Researcher Roundtable: an international perspective	62	115
Navigating Dual Use Harms in Networking Research	45	339
How to give an interesting talk for a SIGCOMM/NSDI or similar audience?	74	126
What is 6G and what are the research challenges: the vision of the European 6G Flagship project Hexa-X	106	282
O-RAN Alliance: Next Generation research Group	232	1500
Entrepreneurship in Computer Networks: Learn from the lessons of those who have already tried it	83	251
Network Programmability: The Road Ahead	95	196
AI for networking, and networking for AI	192	1000
Large Language Models and Networking: What are the Challenges and Opportunities?	178	1800
Lessons learned from 40+ years of the Internet	219	632
Greening Digital Infrastructures: Current Solutions and Future Research Challenges	183	537
Lessons learned from 40+ years of the Internet: An Industry Perspective	65	119
Digital Twins in Networking: Next Generation Testing and Emulation	124	359
Large ISPs: How do they work? What are the challenges they face and the Engineering/CS skills they need?	99	822
LEO Satellite Mega Constellations – the `New Space' potential	89	316
Cloudflare in the Context of CDN Services: Architecture, operations, and their impact on research	114	794
What network connectivity is needed to super-connect the connected and bridge the digital divide between developing and developed nations?	75	330
Vehicular networking	24	115
Are we living the long-awaited AI revolution for Networking with Generative AI?	103	224
Integrating LLMs in Computer Networking Education: can it be done? what are the challenges?	54	525

How to Survive a PhD in Another Country	40	154
Quantum Internet: Evolutionary and Revolutionary Perspectives	59	230
Evolving AI architectures in support of heterogeneous end-to-end next generation networks	71	143
New Frontiers in Wireless Sensing	69	178

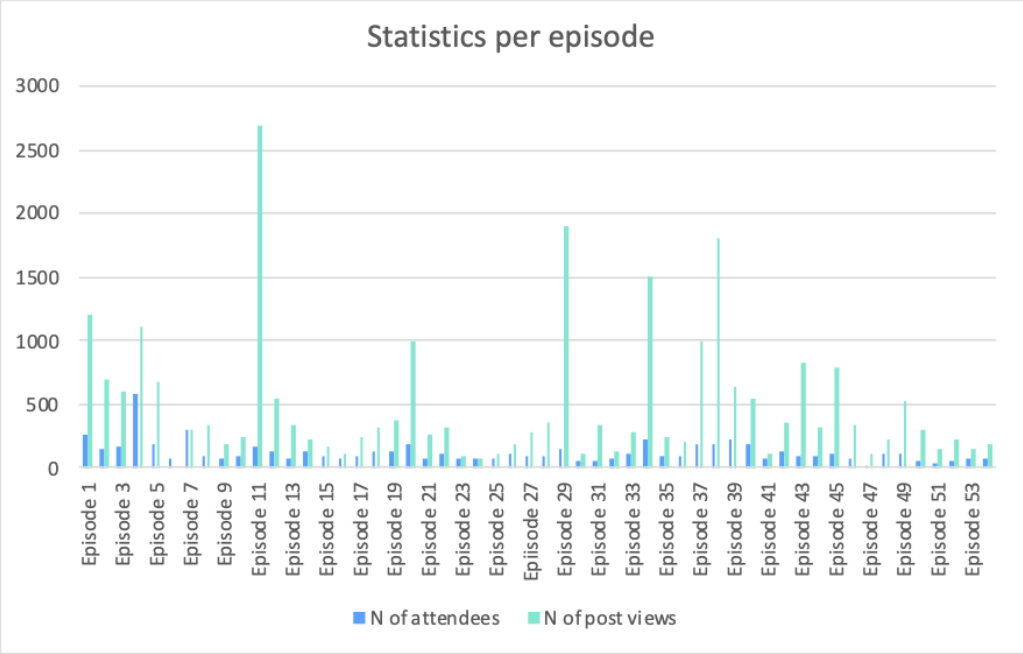


Figure 10. Statistics per episode (nb or attendees vs n of post views)

A dedicated YouTube channel used for the recordings of the events[5], is available where previous streams can be downloaded and viewed asynchronously.

There are currently more than 1180 subscribers in the YouTube Channel and the recordings of the events have been viewed hundred times. There 26295 replays of the recordings in total.

[5] TheNetworkingChannel YouTube Channel, https://www.youtube.com/channel/UCAtFAG5JdQrHac6ArIWJ-hw [Last accessed 26 August 2024]

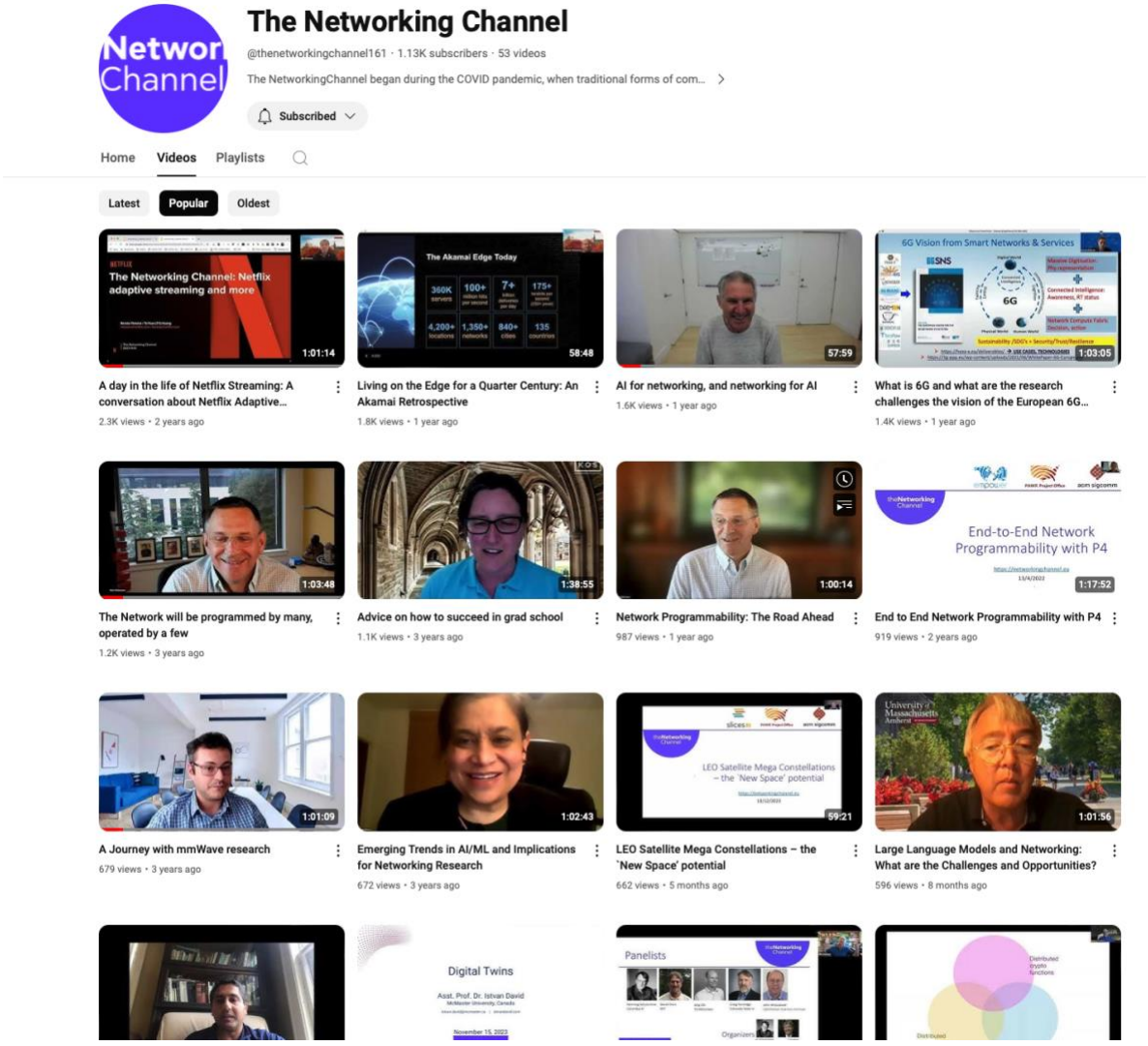


Figure 11. TheNetworkingChannel YouTube Channel

TheNetworkingChannel has organised its dedicated social media, including X (Twitter) account[6] with 262 followers and LinkedIn account[7] with 233 followers.

The uptake of theNetworkingChannel by SLICES will create a great impact to the community and will facilitate the sustainability and exploitation of SLICES activities and results.

[6] TheNetworkingChannel X account: @thenetworkingc1

[7] TheNetworkingChannel LinkedIn account, https://www.linkedin.com/company/the-networking-channel/ [Last accessed 26 August 2024]

3. SLICES Summer Schools

3.1. SLICES Summer School 2022, Volos

The 1st SLICES-SC Summer School was organized with great success in Volos, titled: Open-RAN/Core/Edge Solutions for Cloud-Native Telco Experimental Platforms. The agenda at the details of the Summer School can be found at SLICES portal[8].

This three-day school took a deep dive into some of the available open software and hardware solutions for building experimental telecommunication networks that can be used by researchers to develop innovations leading to 6G network architectures in initiatives such as SLICES-RI, PAWR, Fabric and Horizon Europe SNS JU. A key objective of the school was to highlight cloud-native tools leading to fully converged cloud and telecommunication infrastructures. The event covered initiatives including O-RAN, ONF Aether/SD-Fabric/SD-RAN, OpenAirInterface RAN and Core, Mosaic5G, Magma and related cloud-native frameworks based on Kubernetes. In addition, for newcomers to the 3GPP ecosystem, SLICES-SC provided a crash course on 3GPP networks and protocols.

More than 70 people participated physically and much more online. The recordings of the Summer School are available under the training events of the SLICES Academy.

Figure 12. Volos Summer School

[8] 1st SLICES-SC Summer School, https://slices-ri.eu/events/slices-sc-summer-school/ [Last accessed 26 August 2024]

3.2. SLICES Summer School 2023, Oulu

The 2nd SLICES-SC Summer School was organised from 13th to 15th of June 2023 by University of Oulu (UOULU) in the beautiful city of Oulu at the Radisson Blu Hotel Oulu, Finland.

The three-day SLICES Summer School with the headline of "**Efficient wireless communication and computing experimental research in 6G-era**", did introduce and familiarize its participants with the pan-European Scientific Large-Scale Infrastructure for Computing/Communication Experimental Studies Research Infrastructure (SLICES-RI), the unique experimental research capabilities it offers and foster the skills and knowledge for conducting experiment-based research. Aside from getting an overview of the various communication and computing SLICES-RI, the students got a unique opportunity to experiment with some of these infrastructures remotely from their own laptops. The participants got information about the best practices of experiment planning and data handling, and the novel, groundbreaking concepts paving the way beyond 5G towards the 6G communication and computing ecosystem.

A key objective of the school was to introduce audience to the SLICES-RI and all possibilities it offers to the research community and third parties. Architectures and concepts were shown to be used by researchers to develop new business concepts and innovations for beyond 5G and 6G networks, technologies, and solutions. The data management and GDPR compliance of the research together with novel business concepts and ecosystems are was the focus of the school as well.

15 lectures were given by key players in the experimental wireless research community i.e. SLICES-SC partners: UOULU, SU, SZTAKI, UGENT, IMDEA, INRIA, PSNC, IoTLab, IM, UC3M, IMEC, UA, TUM, COSMOTE, UTH and Nokia.

89 people were registered in this three-day summer school. The Summer School was extended with Researcher Mobility Day for those 8 students who were awarded with the mobility grant. Students visited to Nokia test laboratory and got opportunity to dive deeper in the 5G and beyond.

Figure 13. Oulu Summer School

3.3. SLICES Summer School 2024, Lipari

The 3rd SLICES-SC Summer School has been organized in cooperation with the Lipari School on Advanced Networking Systems[9] from July 7th to July 11st, 2024 in the Lipari Island, Italy. The agenda and the details of the Summer School can be found at the following link. The title of the school was "Open and programmable 6G networks in the cloud/edge continuum: research challenges and experimentation tools in SLICES Research Infrastructures", which reflects the aim of the school to provide the participants with both an overview of the possible enabling technologies and fundamental research challenges of upcoming 6G systems and networks, and an introduction to the tools and methodologies offered by SLICES-RI for conducting experiment-based research in such cutting-edge research areas. To this end, the school program was structured into three main tracks.

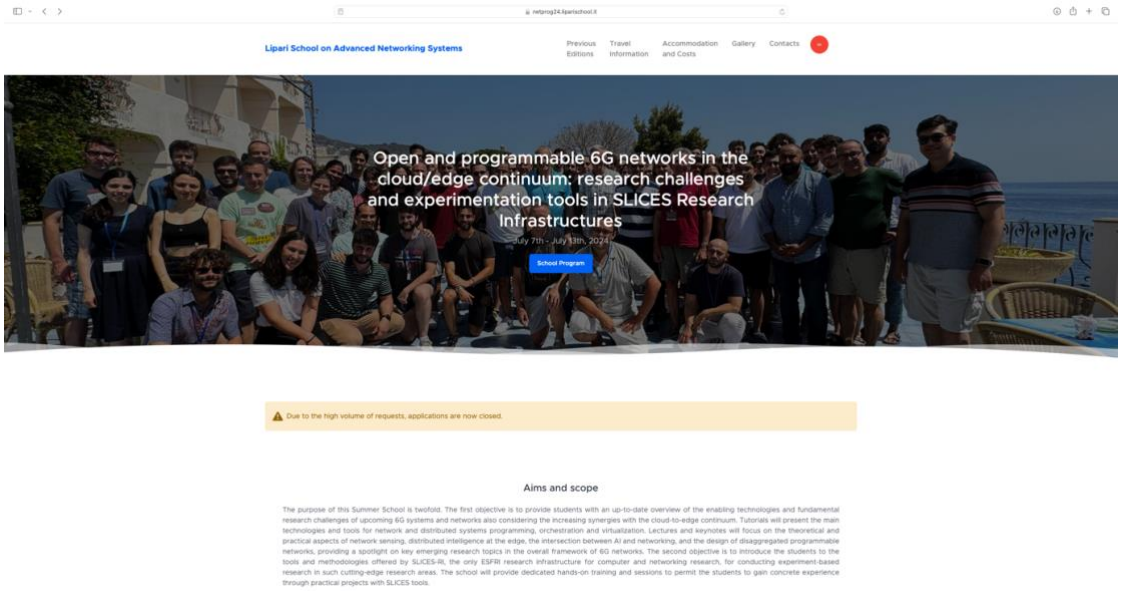


Figure 14. The web site of the Lipari Summer School

The first track was devoted to introducing the state-of-the-art technologies and tools for network and distributed systems programming and virtualisation, including NFV, micro-service architectures and deployment approaches, and orchestration frameworks. The second track aimed at providing the scientific background on the upcoming technologies, novel applications, and emerging research directions that are targeted by the SLICES RI, and it included technical lectures focusing on the theoretical and practical aspects of network sensing, distributed intelligence at the edge, the intersection between AI and networking, the design of disaggregated programmable networks, and the evolutions towards 6G standards. Finally, the third track focused on providing the participants with a hands-on experience on these emerging research topics, first by introducing the principles of the SLICES-RI blueprints, namely the comprehensive software and hardware architectures of the critical components of SLICES-RI, with a focus on post-5G systems and the cloud/edge continuum. In addition, the hands-on track has provided the students with a practical insight into OpenRAN Gym, a publicly-available research platform for data-driven O-RAN experimentation at scale. Finally, as also described in Section 3.4, the students were divided into groups and each group was assigned the development of a hands-on project based on the capabilities of either the SLICES-RI and PAWR OpenRAN Gym.

[9] Lipari School on Advanced Networking Systems, https://netprog24.liparischool.it/previous-editions [Last accessed 26 August 2024]

The 3rd SLICES-SC Summer School also offered the possibility to the students of being assessed for the purpose of requesting official credit transfers (ECTS) from their home institutions. The assessment was graded on an A - F basis according to the score that the students received on a final exam composed of 25 multi-choice questions on the topics of the lecturers. Upon conclusion of the summer school, transcripts were sent to participants, and it is responsibility of the students to contact the academic secretary of their home institutions to check how the hours completed and the grades obtained can be transferred into official credits. Participants not interested in credit transfer have instead received a certificate of attendance, stating the courses and number of hours completed.

SLICES-SC has financially supported the organisation of the school through the awarding of mobility grants to 12 PhD students from SLICES-RI partners and covering the travel and accommodation expenses of the speakers. All other school costs (transportation, lunches and coffee breaks, social events) were covered through the registration fee of 600 Euro. The 3rd SLICES-SC Summer School has been very successful with 52 PhD students and 17 Auditors (i.e., participants not enrolled to a PhD program) from various European countries (Italy, Spain, Germany, France, Norway, Greece, Poland).

Figure 15. The opening of the Summer School in Lipari

4. SLICES supported workshops highlights

4.1. SLICES supported events

As part of SLICES-SC Networking activities, SLICES members have organized numerous *project events* and actively participated in a wide range of *third-party events* organized by the scientific community, including those supported by the European Commission and other prominent venues. These engagements have significantly elevated the visibility of SLICES, furthering the objective of attracting more users and contributors to the research infrastructure. SLICES-SC partners were actively involved in organizing various events to disseminate the project's activities, including Networking & Engagement Workshops, Local Engagement Events and Webinars. A detailed list and presentation of all the above events is included in Deliverable D6.3. In this section, we include the detailed description of the some of the SLICES workshops/events.

4.2. EUCNC 2022

SLICES jointly with PAWR organised a workshop titled "Empowering Transatlantic Platforms for 5G Advanced and 6G Network" within EUCNC 2022 organised in Grenoble on 7th of June 2022. The agenda of the workshop Is depicted below:

14:00-14:15 Opening: Didier Bourse (Nokia), Serge Fdida (Sorbonne Université), Abhimanyu Gosain (Northeastern University), Stavroula Maglavera (UTH), Alain Mourad (Interdigital)

14:15-14:45 Keynote: Innovation around 5G, Sumit Roy (University of Washington & DoD)

14:45-15:45 Session 1: Presentation of the EU and US platforms

- Key 5G Infrastructure PPP projects platforms and demonstrated vertical use-cases, Alex Kaloxylos (6G-IA)
- OpenAirInterface, Raymond Knopp (Eurecom)
- The COSMOS platform, Ivan Seskar (Rutgers)
- The AERPAW platform, Ismail Guvenc (NCSU)

15:45-16:15 Coffee break

16:15- 17h Session 2: The 6G roadmap vision

- Highlights on the transatlantic EU-USA 6G, the EMPOWER roadmap, Alain Mourad (InterDigital)
- Presentation by HEXA-X, Volker Ziegler
- 6G vision by Orange, Jean Schwoerer

17:00-17:30 Panel: Challenges ahead for EU-US cooperation on test facilities

Moderator(s): Serge Fdida (Sorbonne Université), Abhimanyu Gosain (Northeastern University)

Panelists: Bernard Barani (EC), Mauro Boldi (Telecom Italia), Ivan Seskar (Rutgers), Murat Torlak (NSF-remote),

Round table of representatives of EC and US Platforms. Active discussion on the future of the Platforms and their expected technology evolution.

17:30 Closing

Figure 16. SLICES workshop @EUCNC2022

4.3. EUCNC 2023

SLICES jointly with PAWR organised a workshop titled "Empowering Transatlantic Platforms for 5G Advanced and 6G Network" within EUCNC 2023. The workshop took place on 6th of June 2023 in Gothenburg. This main objective was to further put in contact key persons on Europe and USA to further develop collaborations and discuss possible joint activities and evolution of the wireless platforms at both sides of the Atlantic towards 5G Advanced and 6G technologies. The workshop was mainly driven by EU ESFRI SLICES, EU 6G IA and NSF PAWR representatives. The workshop opened by Serge Fdida and the presentation of SLICES, continued with the presentation of ARA platform from Hongwei Zhang, Iowa State University) and AERPAW (Ismail Guvenc, NCSU). Then Kostas Trichias form 6G-IA presented SNS Phase 1 Stream C projects platforms and targeted use-cases. Tommaso Melodia & Abhimanu Gosain (Northeastern Univ) continued with the presentation of COLOSSEUM RF Digital Twin platform and the session closed with Raymond Knopp (Eurecom) presented the OAI. Stavroula Maglavera presented the lessons learnt from theNewtorkingChannel. The workshop presented the opportunities through programmes like NSF Portfolio related to 6G and relevant test platforms, Torlak, Murat (NSF), the EC SNS JU and 6G-IA including related Platforms and EU-US Cooperation, by Didier Bourse (Nokia) followed by active discussion on the future of the Platforms their expected technology evolution and potential for joint activities.

Figure 17. SLICES Workshop @EUCNC2023

In addition, SLICES had a booth that demonstrated the latest achievements of the SLICES in providing a first version of the SLICES infrastructure available to external researchers. The exhibition assisted towards raising awareness and extending the SLICES community, by targeted dissemination to all relevant researchers and industrial stakeholders who can take advantage of SLICES.

Figure 18. SLICES booth @ EUCNC 2023

4.4. EUCNC 2024

SLICES was one of the main projects presented in the EUCNC workshop for "Strengthening EU-US Cooperation in Experimental Infrastructures Towards 6G". SLICES-RI is one of the 4 EU testbed platforms presented in this workshop, together with 6G-XR, CONVERGE and 6G-SANDBOX. Simultaneously, multiple US platforms were presented, including COSMOS and PAWR, FABRIC and ACCoRD. The workshop offered a great opportunity for all participants to contribute to or at least to follow the discussion on how the US-EU collaboration could be boosted and what is the future in these efforts. One of the main takeaways from this discussion is that the research community's training on common tools and protocols would facilitate the evolution of both ecosystems, the EU and US testbed collections, in similar directions. Kostas Choumas, the SLICES-RI presenter, emphasized the role of SLICES Academy in this area, emphasizing that it provides a platform for numerous researchers to acquire standardized testbed usage skills, potentially leading to their adoption by all other testbeds.

One of the many booths in the EUCNC hall featured SLICES-RI. The SLICES-RI booth displayed a roll-up, posters, and a monitor showcasing video demonstrations of SLICES. Multiple researchers came to the SLICES-RI booth to learn about this facility, either to use it or to contribute to it with their testbed. We equipped the booth with flyers and distributed them to multiple tables in the hall, encouraging more researchers to learn about SLICES and approach the booth for this purpose. More than 50 people came to the SLICES booth and learned more about this. Most of their questions were related to its usage, and the rest were questions about how a new node can be part of SLICES-RI. We took the contact details from 21 people, and we keep exchanging emails with them, either to advertise to them the courses offered by SLICES Academy or inform them about the latest updates in SLICES-RI. The booth in EUCNC helped a lot in boosting the visibility of SLICES-RI.

Figure 19. SLICES booth at the EUCNC 2024

4.5. IFIP Networking 2022 - SLICES Workshop

SLICES together with PAWR office organised a workshop within IFIP Networking 2022 conference that took place in Catania on June 13th, 2022[10].

Following the call for papers on four main topics (Advanced wireless networking experimentation; Testing Smart/intelligent infrastructure operation and management; Design and validation of new Edge/Fog infrastructures; Methodology for designing and operating a scientific instrument), the purpose of this workshop was to bring together experts in the field of scientific instruments, mainly in advanced wireless, to exchange on testbeds design and components through a series of concrete examples. Organised in collaboration with the PAWR Office, this SLICES event aimed to continue the work started in the INFOCOM 2019 "Workshop on Experimentation Meets Platforms: A Survey of macro trends in mobile communication research and its impact on future testbed development".

4.6. IFIP Networking 2024 – SLICES Workshop

SLICES together with PAWR office organised a workshop within IFIP Networking 2024 on June 3rd, 2024 in Thessaloniki[11]. The workshop titled: Thought experiments, data and reproducibility for networking and FutureG research (SLICES) 2024. Following the call for papers on four main topics (Advanced wireless networking experimentation; Testing Smart/intelligent infrastructure operation and management; Design and validation of new Edge/Fog infrastructures; Methodology for designing

[10] IFIP Networking 2022 SLICES Workshop Program, https://networking.ifip.org/2022/index.php/slices-workshop/program-slices-worskhop.html [Last accessed 26 August 2024]

[11] IFIP Networking 2024 SLICES Workshop Program https://networking.ifip.org/2024/index.php/workshops/slices [Last accessed 26 August 2024]

and operating a scientific instrument), the purpose of this workshop was to bring together experts in the field of scientific instruments, mainly in advanced wireless, to exchange on testbeds design and components through a series of concrete examples.

A keynote speech titled: **Understanding the Potential of Open Campus Networks for driving an Open 6G - Lessons learned from the German Flagship Project CampusOS** was given by *Thomas Magedanz* (TU Berlin / Fraunhofer FOKUS, Germany).

Figure 20. IFIP Networking SLICES workshop

5. SLICES Hackathons and hands-on activities

SLICES-RI relies on blueprints and their associated support (including documentation) to enable researchers to replicate and extend the work done by the community. To reach this objective, the blueprints provide a set of replicable tools, software, hardware, and methodologies to make sound experimental research with cutting-edge post-5G environments. Focus is being placed on reproducible outcomes of the deployments of blueprints. As such, researchers worldwide can focus on their core research (e.g., testing a new frequency allocation scheme) and leverage the rest of the infrastructure offered by the community. Several events took place in order to facilitate the further extension and experimentation capabilities offered by the SLICES-RI blueprints, as described below.

5.1 SLICES Hackathon (IFIP Networking 2024)

One of the goals of the IFIP Networking 2024 Hackathon that took place in Thessaloniki on June 3rd, 2024 was to bootstrap new software and features for the research community with the particular objective of integration with the SLICES portal. The selection of projects also took into consideration the potential of them to be implemented during the day. A list of suggested projects for the Hackathon was provided during the initial launch and call for projects with indicative topics the following:

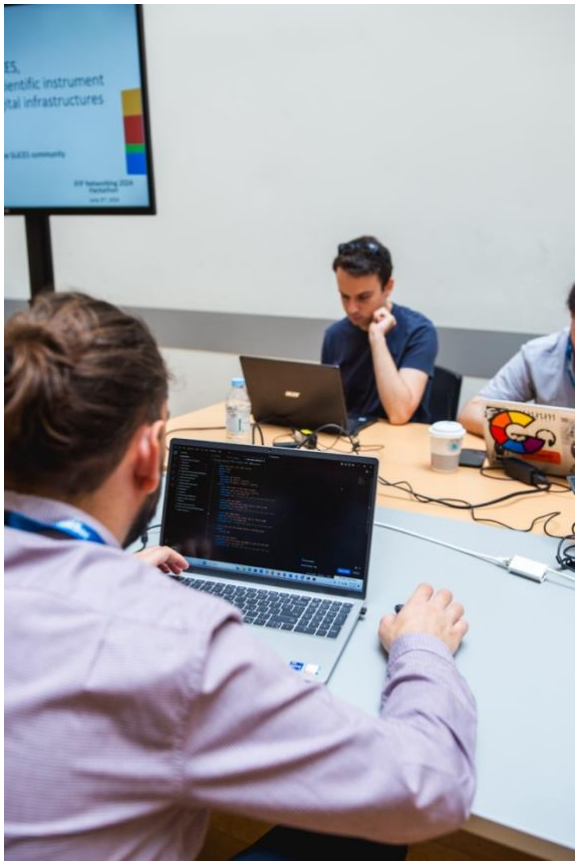
- Improving automation and CI/CD of SLICES-RI (e.g., Ansible, Terraform...)
- Advanced wireless networking experimentation
- Smart/intelligent infrastructure operation and management (e.g., Rancher, Kubernetes, Keycloack, OpenID)
- Design and validation of new Edge/Fog/Open RAN infrastructures
- Methodology for designing and operating a scientific instrument
- API backend and Frontend

- Integration of bare metal and physical custom resources into cloud environments (e.g., k8s CRD)

Five projects were submitted and selected to take place in the Hackathon. During the Hackathon, an initial slot of 20 minutes to introduce SLICES to the attendees was held. After this introduction, we directly kick-started coding new features over the 5 projects designed to be implementable in one day. The projects were the following:

Project 1: Integration of CEPH storage into the 5G blueprint by exposing CEPH volumes in the k8s clusters

Since effectively using storage resources within SLICES is of paramount importance one of the projects was dedicated to this aspect. In this context, the project took advantage of the CEPH[12] framework that can create clusters of storage resources and made use of Container Storage Interfaces (CSI) [13] in order to expose the storage components to clusters created by the post-5G blueprint of SLICES-RI (https://doc.slices-sc.eu/blueprint).



[12] Sage A. Weil, Scott A. Brandt, Ethan L. Miller, Darrell D. E. Long, and Carlos Maltzahn. 2006. Ceph: a scalable, high-performance distributed file system. In Proceedings of the 7th symposium on Operating systems design and implementation (OSDI '06). USENIX Association, USA, 307–320.

[13] CEPH-CSI, https://github.com/ceph/ceph-csi [Last accessed 26 August 2024]

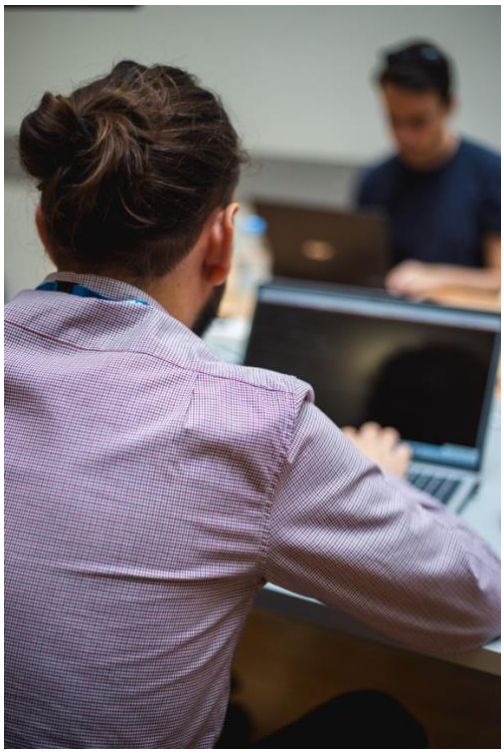


Figure 21. The SLICES Hackathon in action

During the hackathon, the following contributions were made:

1. Development of Ansible scripts to instantiate a new CEPH cluster, with storage provided by new nodes
2. Accompanying Ansible scripts for attaching new nodes to the storage cluster,
3. Extensions to the post5G blueprint of SLICES with the CEPH-CSI framework to use the CEPH storage as ephemeral/permanent storage devices within the clusters.

Project 2: Use of the SLICES portal as an authentication provider for the SLICES VPN service

The second project focused on extending the connectivity framework among the different SLICES nodes. Currently, interconnectivity among the different nodes (residing in different countries) is achieved by using VPN links. Such links require the authentication based on certificates/credentials issued by the VPN server. As the SLICES-SC portal allows for the authentication of experimenters to access the infrastructure in a similar manner, the project focused on creating the link between the OpenVPN server and the authentication back-end of the portal towards allowing the link creation to be instantiated with the SLICES-SC portal credentials. The extensions were committed to the post-5G blueprint code of SLICES.

Project 3: Addition of the RAN-split for bare metal resources in the blueprint reference implementation

The third project focused on creating new functionality on the telecommunications network setups provided by the post-5G blueprint. The student implementing the project focused on providing the disaggregated network addressing both data plane and control plane disaggregation at the base station level (CU-CP/CU-UP/DU/RU disaggregated architecture). The code was provided as Ansible scripts that can be used for deploying the blueprint on bare metal machines.

Project 4: Correction of a bug that appeared in POS resource booking calendar

All the services provided over SLICES need to be correctly authenticated over the SLICES portal. For this purpose, different protocols can be used, such as for example the OpenID Connect (OIDC). POS[14] was restructured and new OIDC drivers were implemented in order to allow such authentication to take place. Nevertheless, this revealed some software bugs with respect to the calendar-based resource booking system that POS was using. One of the projects during the Hackathon was devoted to resolving these issues and allowing POS to correctly work with all the supported features, when implemented using the OIDC connectors.

Project 5: Addition of RBAC to the post-5G blueprint backend using casbin

As the post-5G blueprint is based on Kubernetes (K8s) for its deployment, different users need to take access to different parts of the deployments, in an isolated manner. In this context, Role Based Access Control (RBAC) provided by K8s is employed and configured in order to ensure the isolation of slices of the infrastructure. In order to achieve the seamless integration with the portal, casbin[15] was used, as the library used to connect the K8s RBAC models and the portal users, according to the privileges that they have/projects they have access to. The respective reference implementation of the project has been integrated to the Sophia (INRIA) SLICES-SC node.

All five projects managed to deliver a first version of the proposed code that is expected to be integrated in the pre-op of SLICES. At the end of the day, attendees received congratulations from the coordinator of SLICES-SC.

Figure 22. The closing of the Hackathon and the congratulations to the participants

5.2 SLICES BoF @ TNC 2024[16]

Research has become more technological than ever, not for the sake of technology but because answering complex questions requires complex interactions of software and hardware. So much that a single researcher or even a traditional team cannot have the skills to master their domain of science and at the same time setup and operate computational and validation tools. Interestingly, even though the field of application of the research instruments might be drastically different (if not

[14] Sebastian Gallenmüller, Dominik Scholz, Henning Stubbe, and Georg Carle. 2021. The pos framework: a methodology and toolchain for reproducible network experiments. In Proceedings of the 17th International Conference on emerging Networking EXperiments and Technologies (CoNEXT '21). Association for Computing Machinery, New York, NY, USA, 259–266. https://doi.org/10.1145/3485983.3494841 [Last accessed 26 August 2024]

[15] Casbin authorization library: https://github.com/casbin [Last accessed 26 August 2024]

[16] SLICES BoF @ TNC 2024, https://tnc24.geant.org [Last accessed 26 August 2024]

orthogonal); all of them rely on complex hardware/computing systems that are interconnected and share some common needs and services. SLICES is an instrument dedicated to bridge this gap and provide the necessary infrastructure (hardware and software).

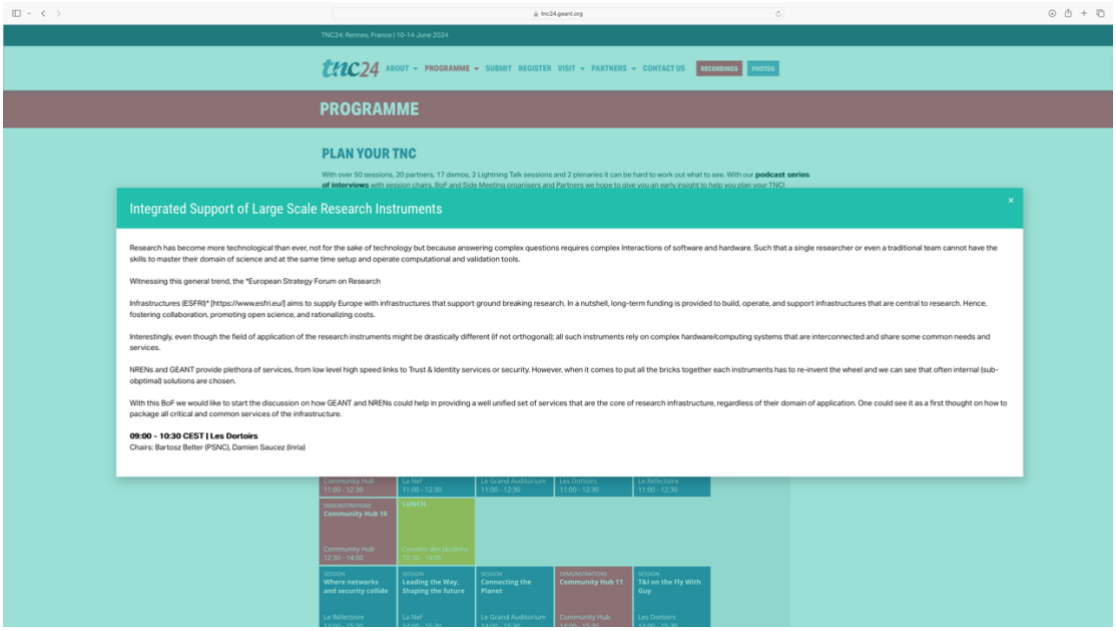


Figure 23. The SLICES BoF at the web site of the TNC 2024

NRENs and GEANT provide plethora of services, from low-level high-speed links to Trust & Identity services or security. However, when it comes to put all the bricks together each instrument has to re-invent the wheel and we can see that often internal (sub-oboptimal) solutions are chosen.

This BoF was dedicated to starting the discussion on how GEANT and NRENs could help in providing a well unified set of services that are the core of research infrastructure, regardless of their domain of application. One could see it as a first thought on how to package all critical and common services of the infrastructure. Several discussions based on the tools that can be provided by GEANT and NRENs to SLICES took place, such as for example using EduVPN[17] service for accessing SLICES resources etc. Another important point that has been discussed is how can be provide right levels of documentation to the potential users by means of academies and tutorials.

[17] GEANT EduVPN: https://www.eduvpn.org/ [Last accessed 26 August 2024]

Figure 24. The SLICES BoF at TNC 2024

5.3 Post-5G BP pre-op Code Sprint 2024

As part of the continuous developments and integration in the SLICES post-5G blueprint components, a code sprint took place at Inria Sophia-Antipolis in order to integrate and further develop new functionalities with the post-5G blueprint to be run in pre-op. The code sprint was held in the week of 24-28 July 2024, with participants from Inria, SU, TUM, UCLAN (Cyprus), and UTH. The components and new functionalities developed during the code sprint were the following:

- **Objective 1:** restructure the implementation repository(ies) in order to include more explanatory documentation and clear up from obsolete implementations/files
- **Objective 2:** integrate flexRIC[18] and Submariner in the implementation. FlexRIC support has been developed in order to provide near-RT control of the deployed gNBs. The implementation was integrated with the main contributions of the post-5G blueprint. Similarly, submariner[19] has been used in order to enable secure and dynamic service exposure between Kubernetes clusters that implement the post-5G blueprint.
- **Objective 3:** integrate the Metadata Registry System (MRS) in the implementation. As such the MRS system that collects and organizes metadata from experiments within SLICES has been integrated with the post-5G blueprint resources.

[18] FlexRIC O-RAN compliant controller for OpenAirInterface: https://gitlab.eurecom.fr/mosaic5g/flexric [Last accessed 26 August 2024]

[19] Submariner: direct networking between Pods and Services in different Kubernetes clusters, https://submariner.io/ [Last accessed 26 August 2024]

- **Objective 4:** deploy an MRS in IMEC Vwall resources. As the resources will be used as a first central hub for accessing the SLICES-RI infrastructure, the MRS back-end was installed in the Vwall resources.
- **Objective 5**: deploy a submariner broker in Vwall resources. In order for submariner to work correctly, a broker instance is required for advertising the available exposed services across the integrated clusters. The respective broker was installed and integrated with the rest of the post-5G resources.
- **Objective 6:** restructure documentation to be LLM friendly. The project has developed an LLM model in order to make experimentation with the infrastructure user friendly. When using the LLM model, the experimenters engage into chatting with the chatbot[20], and get recommendations on the resources that they need to use, as well as code used for deploying their experiment. Nevertheless, the LLM model needs to be efficiently trained in order to produce the required outputs. During the meeting, the changes that need to be made to the documentation, as well as a new documentation style were discussed and agreed, in order to enhance the training process for the LLM model.
- **Objective 7:** enable monitoring of resources and dashboard interfaces for the post-5G blueprint. A complete monitoring solution, with a centralized storage (located and to be integrated with the central hub) were developed. These contributions rely on the Prometheus[21] monitoring stack instantiated at each cluster and utilizing the remote write feature to a centrally located Prometheus instance. Similarly, the promtail[22] framework was integrated with the blueprint, allowing the scraping of logs from K8s pods from the different clusters, in the most non-intervening manner possible for the experimenter. The data gets labeled and pushed to a central Grafana Loki instance[23]. On top, a central Grafana visualization tool can be used to visualize metrics and logs scraped from the different post-5G clusters.
- **Objective 8:** deploy the pos framework in the post-5G SLICES infrastructure. A pos server has been deployed in TUM. It will control all resources in SLICES. During the week, we attached bare metal servers from the Sophia Antipolis site to this pos server. This has required to setup secured VPN links and recabeling the IPMI of the infrastructure to provide proper isolation. In addition, to speed up experimentation deployments proxy caches have been installed to prevent using international links when it is not absolutely required.

During the meeting, details on the implementation of the central hub, the interconnections among sites, and overall topology and locations of where each service will be hosted were discussed.

5.4 Hands-on during SLICES Summer School 2024

During 7-12 July 2024, the Lipari School on Advanced Networking Systems was organized in cooperation with the pan-European Scientific Large-Scale Infrastructure for Computing/ Communication Experimental Studies Research Infrastructure (SLICES-RI)[24]. The primary goal of the summer school was to provide the participants with an overview of the possible enabling technologies and fundamental research challenges of upcoming 6G systems and networks, as well as an introduction to the tools and methodologies offered by SLICES-RI for conducting experiment-based

[20] D. Kefalas, S. Christakis, S. Fdida, N. Makris, I. Syrigos, V. Passas, and T. Korakis, "slAIces: an LLM Chatbot for Simplifying Experiments with the SLICES-RI," in *2024 IFIP Networking Conference (IFIP Networking)*, Thessaloniki, Greece, June 2, 2024

[21] J. Bastos and P. Araujo, *Hands-On Infrastructure Monitoring with Prometheus*. Packt Publishing, 2019.

[22] Promtail Framework: https://grafana.com/docs/loki/latest/send-data/promtail/ [Last accessed 26 August 2024]

[23] Grafana Loki Log aggregation system: https://grafana.com/oss/loki/ [Last accessed 26 August 2024]

[24] SLICES Summer School 2024, https://www.slices-ri.eu/events/slices-summer-school-2024/ [Last accessed 26 August 2024]

research in such cutting-edge research areas. The school was organized into three tracks (lectures/keynotes/hands-on). The hands-on sessions were broken down into two different parts, and the participants were shared among the two groups, depending on the infrastructure and type of project that they selected between the SLICES-RI and PAWR OpenRANGym. With respect to the SLICES-RI related projects, the session resembled a Hackathon, with approx. 20 participants being initially introduced to the key concepts of SLICES around the post-5G blueprint and allowing them to select a project of their own that will help them validate their approaches. A repository was setup[25] to help them start their experiments in one of the following topics:

- setting up a split Radio Access Network in a multi-nodes kubernetes cluster
- modifying 5G Radio parameters and evaluating their performance
- setting up xAPPs to manage the radio network using a Radio Intelligent Controller (RIC)

By the end of the Summer School, participants were invited to share their results with the summer school attendees, regarding their experimental findings, and provide feedback on the use of the platforms.

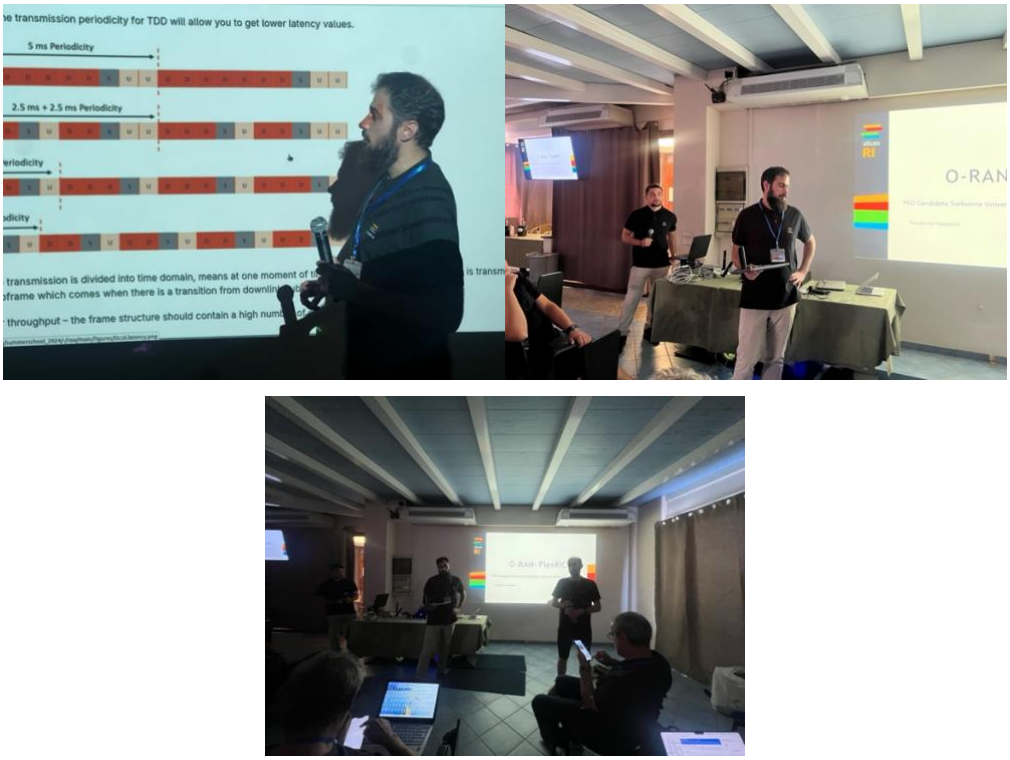


Figure 25. Hands-on at SLICES Summer School in Lipari

[25] SLICES Summer School 2024 – Gitlab, https://gitlab.inria.fr/slices-ri/blueprints/post-5g/summerschool_2024/ [Last accessed 26 August 2024]

Figure 26. Hands-on at SLICES Summer School in Lipari

5.5 SLICES Hackathon (Sophia Antipolis)

EURECOM organized the OAI Near-RT RIC Spring of Code during the period February-June 2024[26].

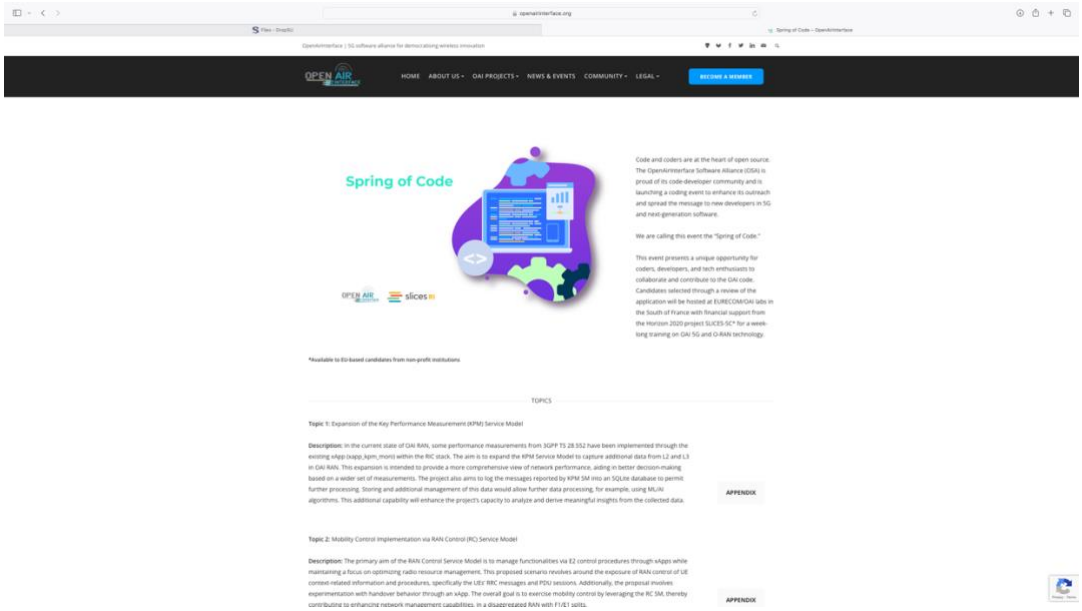


Figure 27. The OAI Spring of Code supported by SLICES

The original time plan is shown in Figure **28**.

[26] "Spring of Code" website, https://openairinterface.org/spring-of-code/ [Last accessed 26 August 2024]

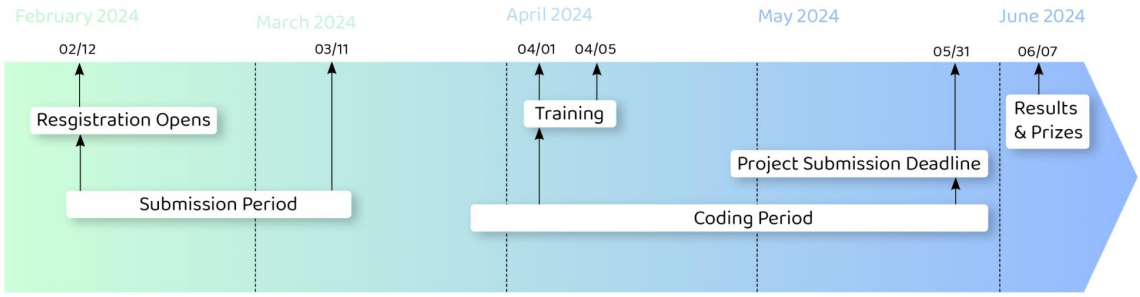


Figure 28. OAI Spring of Code 2024

The applicants were asked to propose subjects in the following categories topics.

Topic 1: Expansion of the Key Performance Measurement (KPM) Service Model

Description: In the current state of OAI RAN, some performance measurements from 3GPP TS 28.552 have been implemented through the existing xApp (xapp_kpm_moni) within the RIC stack. The aim is to expand the KPM Service Model to capture additional data from L2 and L3 in OAI RAN. This expansion is intended to provide a more comprehensive view of network performance, aiding in better decision-making based on a wider set of measurements. The project also aims to log the messages reported by KPM SM into an SQLite database to permit further processing. Storing and additional management of this data would allow further data processing, for example, using ML/AI algorithms. This additional capability will enhance the project's capacity to analyze and derive meaningful insights from the collected data.

Topic 2: Mobility Control Implementation via RAN Control (RC) Service Model

Description: The primary aim of the RAN Control Service Model is to manage functionalities via E2 control procedures through xApps while maintaining a focus on optimizing radio resource management. This proposed scenario revolves around the exposure of RAN control of UE context-related information and procedures, specifically the UEs' RRC messages and PDU sessions. Additionally, the proposal involves experimentation with handover behavior through an xApp. The overall goal is to exercise mobility control by leveraging the RC SM, thereby contributing to enhancing network management capabilities, in a disaggregated RAN with F1/E1 splits.

Topic 3: Implementation of the Cell Configuration and Control (CCC) Service Model

Description: The CCC Service Model (SM) is designed to unveil node and cell level configuration information and initiate control and configuration of parameters at both levels. The proposal requires a comprehensive implementation of CCC ASN.1 encoding/decoding for node and cell-level configuration within the RIC framework. Moreover, the plan includes replicating the existing OAI O1 demo, with a specific focus on requesting DU node-level attributes and effecting modifications for bandwidth changes, in addition to executing base station soft-restart procedures.

Applicants submitted proposals in early March 2024 which were judged. The target scenarios concerned the development of both near real-time RAN intelligent Controller software using OAI's FlexRIC and the corresponding service models which will become part of the OAI radio-access network software packages. The selected proposals attended a training session by EURECOM/OAI staff in early April which took place at EURECOM. It was attended by representatives of the following institutions:

- I2CAT, Spain, 4 participants
- CTTC, Spain, 1 participant
- CNR, Italy, 1 participant
- Politecnico di Milano, Italy, 1 participant
- Sorbonne, France /University of Thessaly, Greece, 1 participant

- Fraunhofer IIS, Germany, 1 participant
- Fraunhofer HHI, Germany, 3 participants
- Gradiant, Spain, 2 participants
- Eindhoven University, 2 participants
- IT Aveiro, 1 participant

A few snapshots of the training session at beginning are shown in Figure 29. All EU participants received reimbursement for their trip and stay in Sophia Antipolis thanks to SLICES-SC funding.

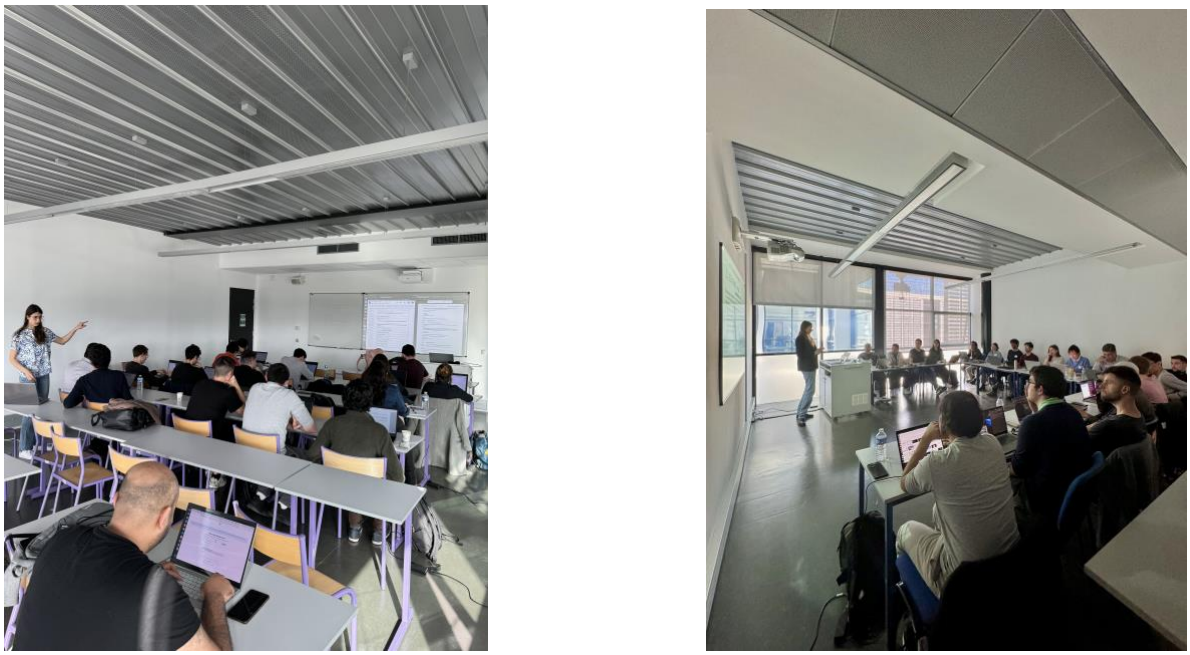
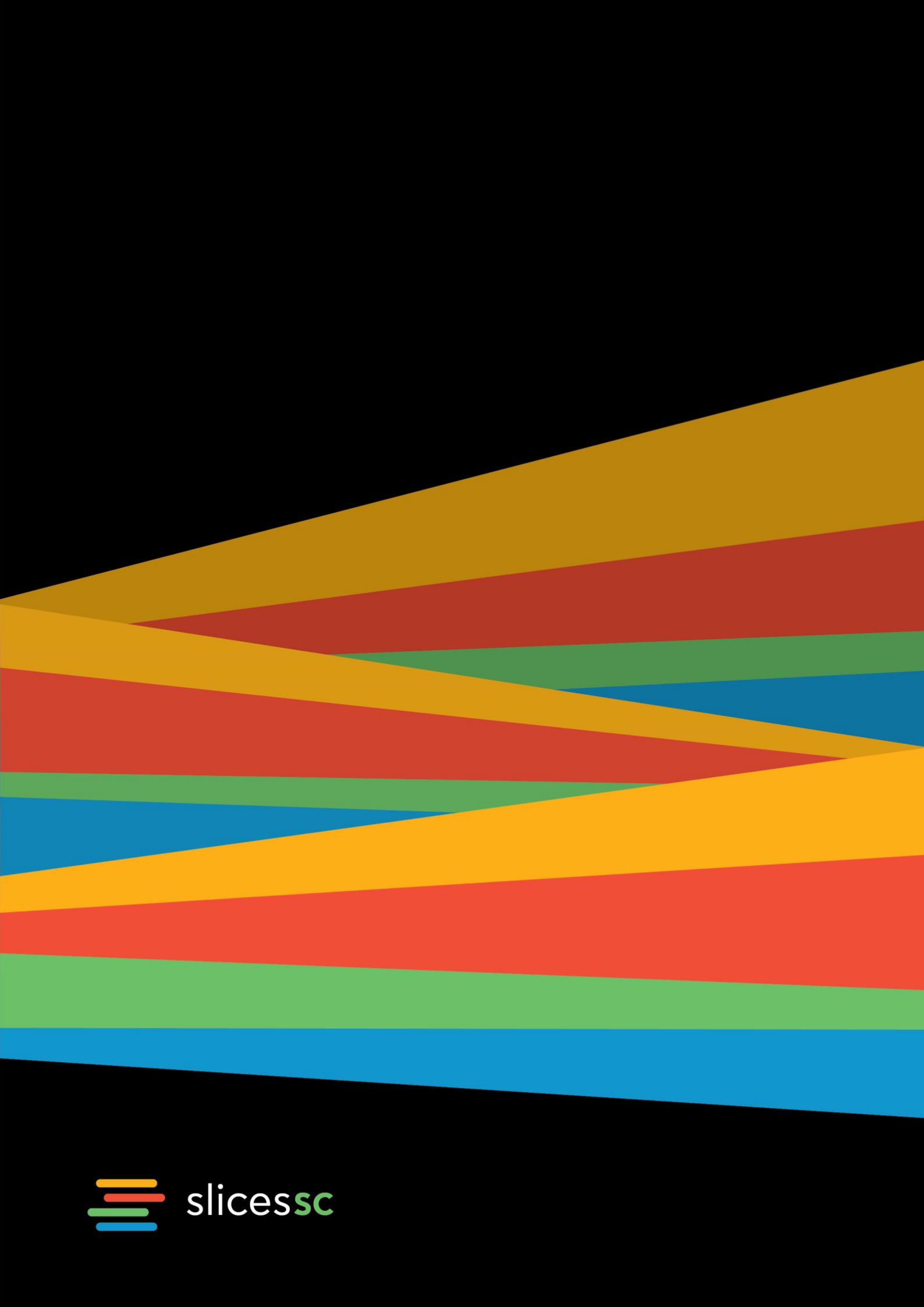


Figure 29. Some Snapshots from Spring of Code Training

After the training session the candidates worked remotely on their own infrastructures and using the EURECOM infrastructure (gitlab and ssh). Interactions with the training team occurred on the OpenAirInterface Slack channel. Originally, the work was planned until the end of May 2024, but this was extended by one month to allow the candidates to produce more complete contributions to the codebase. Monetary prizes were awarded to the top three contributors. 5000 euros for first prize, 3000 euros for second and 2000 euros for third. This was provided using funds from the OAI Software Alliance which come from donations from its industry patrons. The code generated by the Hackathon initiative will progressively be integrated into the main develop branch of OAI in the coming months.

6. Conclusion

The implementation of the SLICES educational and training activities supported the engagement of the stakeholders and the creation of the community. The SLICES training and educational activities are based on an effective support framework for all stakeholders to facilitate their interaction with the SLICES services and tools provided by different means as described in this deliverable and including SLICES Academy, SLICES Summer Schools, SLICES Workshops, SLICES Hackathons. In order to support the uptake of the different SLICES services there is a need for strategic planning, continuous reflection, deployment of innovative tools and resources, and a strong component of capacity building based on different tools. SLICES stakeholders involved in the process of reinventing the numerous opportunities will need to be committed and engaged in the mission they are about to embark on. They will have to receive training and support to evolve in the various fronts of action. Recognition of their efforts should be in place as a motivational factor and finally, the whole professional and user community should be involved to ensure the changes are consolidated and largely adopted. For the above reasons, the SLICES members committed to continue the operation of the tools described above through other initiatives such SLICES-PP, or other new activities and collaboration.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