Open Call 5

Experimental validation of 5G Open RAN architecture evolution based on OpenAirInterface

Deliverable 3: Experiment Results and Final Report

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Deliverable 3: Part I

Analysis, results, and wider impact

1 Abstract

The main goal of this NGI Atlantic experiment is to integrate the Open RAN interfaces implemented by Allbesmart with the RAN Intelligent Controller (RIC) applications developed by VT (US) and validate its performance on top of the Commonwealth Cyber Initiative testbed (US). The outcome of this experiment has contributed to the publicly available open-source OpenAirInterface software library with new O-RAN features and software tools towards an open and renovated 5G architecture. Thanks to the support of NGI-Atlantic, Allbesmart has developed the open-source 5G test network OAIBOX(www.oaibox.com). The OAIBOX product was launched in the OpenAirInterface Noth America workshop at Qualcomm in San Diego (California).

2 Project Vision

Practical experimentation with cellular networks has been historically reserved exclusively to network equipment vendors and telecommunication operators, primarily due to high equipment costs and licensing constraints. In recent years, the state of play has been changing with the advent of open- source 3GPP protocol stacks based on increasingly more affordable Software-Defined Radio (SDR) systems. In this context, the OpenAirInterface project emerges as the leading open-source initiative that provides a reference implementation of 5G base station (gNB), User Equipment (UE), and 5G core network, standard-compliant with 3GPP Release 15 and that runs on general-purpose x86 computing platforms along with off- the-shelf SDR hardware platforms. OAI distinguishes itself from other similar projects through its unique open- source license, the OAI public license v1.1 which was created by the OAI Software Alliance (OSA) in 2017. OAI is completely open-source and freely available on the EURECOM gitlab server. The OAI is in its origin a European project, established by EURECOM (France) and welcomes contributions to anyone who signs the license agreement. The OpenAirInterface code can be adapted to different use cases and deployment and new functionality can be implemented, making it an ideal platform for 5G and 6G collaborative research and innovation.

Especially the OAI open-source stack enables the scientific community and company researchers to explore and test the 5G architecture evolution, such as the emerging Open Radio Access Network (O- RAN) paradigm proposed by the Open RAN Alliance. Open RAN defines a new, flexible architecture for the 5G RAN, where the base station or gNB is split into three logical nodes: the Central Unit, (CU), the Distributed Unit, (DU) and the Radio Unit, (RU), each capable of hosting different functions of the 5G NR protocol stack. Disaggregation of the RAN in CU-DU-RU nodes brings more flexibility to network deployment and, potentially, enables vendor specialization, breaking the traditional, vertically integrated supply chain.

3GPP has defined eight main options called functional splits between the nodes CU-DU-RU. Each split describes how the logical nodes interrelate to one another, and what specific activities each undertakes. When rolling out a 5G network, mobile operators must choose the best functional split based on the services they provide and the economics of the available transport networks.

As networks evolve toward more disaggregated and virtualized environments, there are significant opportunities to optimize network operations. One of the central components within Open RAN architecture is the RAN Intelligent Controller (RIC), which provides an open hosting platform and is responsible for controlling and optimizing the RAN functions.

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Allbesmart, an SME from Portugal, is an associated member and key contributor of the OpenAirInterface Alliance, actively contributing to developing the Open RAN interfaces in the open-source OAI code.

Virginia Tech, a top university in the US with extensive experience in 5G, has developed scientific research on RAN Intelligent Controller (RIC) applications based on ML/AI optimization. VT is a Commonwealth Cyber Initiative (CCI) member, operating a state-of-art wireless xG Testbed.

In this context, the main goal of this experiment is to integrate the Open RAN interfaces implemented by Allbesmart (EU) with the RAN Intelligent Controller (RIC) applications developed by VT (US) and validate its performance on top of the Commonwealth Cyber Initiative xG Testbed (US).

Moreover, Allbesmart has the vision to develop 5G products based on open-source OAI targeting the 5G testing markets and 5G Private networks.

3 Details on participants (both EU and US)

EU team – Allbesmart LDA

- **Paulo Marques** received his Ph.D from the University of Aveiro (Portugal) – 2007 in Wireless Communications. He led the European R&D projects COGEU (Cognitive radio systems for efficient use of TV white spaces in the European context) and CRS-I (Cognitive Radio Standardization initiative). He is a coauthor of the IEEE P1900.6 spectrum sensing standard and an active member of the European Telecommunications Standards Institute (ETSI) in the RRS WG. He is the author/co-author of more than 70 scientific publications. He was demo chair of IEEE DySPAN 2015 conference and General chair of CROWNCOM 2017. He is co-founder of Allbesmart LDA where he has been involved in several H2020 projects on 5G networks (H2020 5GinFIRE, H2020 ORCA, H2020 MONROE and H2020 Fed4FIRE). His team has actively contributed to the 5G RAN OpenAirInterface project, especially on PHY/MAC/RRC, both at UE and gNB. <u>Role in the project:</u> project coordinator.
- **Roberto Magueta** received his Ph.D from the University of Aveiro (Portugal) – 2020 in Wireless Communications. His thesis — "Hybrid precoding and equalizer techniques for 5G mmWave and massive MIMO based wireless systems" was distinguished with the Best Iberian PhD Thesis award by the Iberian Association for Information Systems and Technologies (AISTI). Since June 2019 Roberto is a software radio engineer in Allbesmart working on 5G NR projects and contributing to OpenAirInterface software developments. <u>Role in the project:</u> researcher, development of O-RAN interfaces in OpenAirInterface.

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- **Luís Pereira** received his MSc in Software Engineering and BSc in Telecommunications Engineering from the Instituto Politécnico de Castelo Branco (Portugal). He has more than 7 years of experience in developing software solutions for various kinds of systems, including software defined radios and deeply embedded real-time systems. In Allbesmart since 2015, he has developed a deep understating of the 3GPP protocol stack, and he is an active contributor to OpenAirInterface, especially on the MAC layer of 5G NR SA. Role in the project: researcher, test and integration of the OpenAirInterface code developed in the project.

US team – Virigina Tech:

- **Lingjia Liu** (PhD in Electrical and Computer Engineering – Principal Investigator): He is a Professor in the Bradley Department of Electrical and Computer Engineering at Virginia Tech and is also the Associate Director of Wireless@Virginia Tech a university research center focuses on wireless communications. He is an Elected Member on the Executive Committee of the National Spectrum Consortium and is an expert in 5G networks and machine learning with 200+ publications in leading journals and conference proceedings. Prior to joining academia in 2011, he was a leading delegate from Samsung in 3GPP RAN1 leading Samsung's efforts on multiuser MIMO, CoMP, and HetNets in 3GPP LTE/ LTE- Advanced standards. He has 20+ granted US patents and 10+ essential intellectual property rights (IPRs) for 3GPP LTE- Advanced networks. Lingjia Liu is a representative from VT in O- RAN Alliance. Role in the project: coordinator of the US team.
- **Lianjun Li** received the B.S. degree in telecommunications engineering from Zhejiang University, Hangzhou, China, and the M.S. degree in electrical engineering from the University of Texas at Dallas, Richardson, TX, USA. He is currently pursuing the Ph.D. degree with the Bradley Department of Electrical and Computer Engineering, Virginia Tech, Blacksburg, VA, USA. After receiving his B.S. degree, he joined Ericsson, China, as a Wireless Network Optimization Engineer for seven years. His research interest is applying reinforcement learning and deep learning techniques to wireless communications. Role in the project: researcher, development of near- real- time RIC Apps, powered by ML/ AI, and focusing on multi- user scheduling to improve network efficiency and resiliency.
- **Shadab Mahboob** received the B.S. degree in Electrical and Electronics Engineering from Bangladesh University of Engineering and Technology, Dhaka, Bangladesh in September 2017, and the M.S. degree in Electrical Engineering from the Rensselaer Polytechnic Institute, NY, USA in December 2021. He has been currently pursuing his Ph.D. degree in Computer Engineering at the Bradley Department of Electrical and Computer Engineering in Virginia Tech, Blacksburg, VA, USA since Spring 2022. His current research interest lies in applying machine learning in wireless communications. Role in the project: researcher, experimental validation of RIC Apps powered by ML/AI in the CCI xG testbed.

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- **Aloizio Silva** receive the PhD in Computer Engineering from ITA – Aeronautical Institute of Technology in 2015, he was Research Fellow and 5G Portfolio Manager at University of Bristol UK. He is currently the 5G Wireless Security Testbed Director at Commonwealth Cyber Initiative (CCI), and Research Faculty at Virginia Tech. Role in the project: CCI testbed manager.

4 Results

- Allbesmart has organised an Open Air Interface (OAI) hands-on training workshop for the VT team on 21 July 2022. The Allbesmart team has provided remote support and training to VT PhD students on OAI (RAN and CN).
- Several interoperability tests of the OAI gNB with different 5G CNs and UE components from different vendors were performed in cooperation with the VT team. Specifically, interoperability with the OAI CN has been fully validated. Concerning the UE components, interoperability was fully validated with the Quectel RM500Q-GL module4, Huawei mate 30 pro smartphone and OAI UE and validated with SIMCOM SIM8200EA module.
- A RAN Intelligent Controller (RIC) is a software-defined component of the Open RAN architecture responsible for controlling and optimising RAN functions. The RIC is a critical piece of the Open RAN disaggregation strategy, bringing multivendor interoperability, intelligence, agility, and programmability to radio access networks. This project has contributed to the development in OAI of the O-RAN E2 interface between the RIC and the RAN (CU/DU/RU). The E2 implementation is public available in the OAI GitHub repository.
- The E2 interface enables the collection of metrics from the RAN to the near-real-time RIC, either periodically or after pre-defined trigger events. Allbesmart has developed a cloud-based dashboard designed for real-time monitoring and management of the 5G OAI setup. In the context of the Open RAN architecture, the dashboard works as a xApp.
- The project results have led to the open source 5G test network product line OAIBOX (www.oaibox.com) being commercialised by Allbesmart. The OAIBOX was launched in the OpenAirInterface Noth America workshop at Qualcomm in San Diego (California).
- The OAIBOX has been advertised as a 5G product with a “Made in EU” label.
- Virginia Tech has been an early adopter of the OAIBOX dashboard, giving valuable feedback on usability issues and contributing to the selection of KPIs and the definition of the product roadmap for advanced 5G features.
- Virginia Tech appears listed as a partner/customer of the OAIBOX product line, which contributes to the OAIBOX reputation and facilitates the reach of the US market.
- Virginia Tech and Allbesmart have participated in the Mobile World Congress, Las Vegas (US), Sep. 2022 with open source 5G demonstrators.

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- This project has contributed to increasing the visibility of VT in the overall open-source OAI community with the possibility to contribute and influence OAI development priorities towards 6G.
- Allbesmart has participated in the OpenAirInterface North America Workshop (8-9 Nov. 2022 at Qualcomm in San Diego (US)) with a demonstrator showcasing its OAIBOX product line. This participation triggered several contacts with US companies such as Qualcomm, NVIDIA, AMD, NI and BATSWireless.
- In the follow-up of the trip to the US, the company BATSWireless (www.extendingbroadband.com) becomes the first paying customer of the OAIBOX product.
- The US company NI (National Instruments) has shown interest in collaborating with Allbesmart promotion the OAIBOX (which uses SDR cards made by NI) for the education market.

4.1 Discussion and Analysis on Results

This experiment uses the Commonwealth Cyber Initiative (CCI) testbed facility available in VT. The CCI Testbed allows research in network systems, with a focus on large- scale experimentation using open- source and open standards to realize open- architecture technologies. The Wireless Testbed group in VT specializes in the application and development of advanced hardware and software technologies to future advanced wireless networks for 5G and beyond. CCI's 5G testbed draws upon the deep expertise found throughout Virginia (US). The testbed is deployed in the CCI hub located in Arlington, Virginia, and four regional nodes across Virginia. Together, CCI provides a complete 5G infrastructure and development platform. The goal of the CCI Testbed is to enable research and development from physical to application layers. Its architecture envisions the softwarization and orchestration of network functions.

The CCI reconfigurable radio testbed at VT provides virtualized radio hardware, software virtualisation, Cloud-RAN, Network Functions Virtualisation (NFV), and Software Defined Networking (SDN) technologies. Radio resources include 24 USRP N310 ceiling mounted nodes equipped with SBX daugtherboards supporting frequency ranges of 400 MHz-6000 MHz offering up to 100 MHz of bandwidth (Figure 1).

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Figure 1 Large-scale Software Defined Radio testbed at CCI/VT for advanced wireless experimentation in 5G.

OpenAirInterface 5G FlexRIC (RAN Intelligent Controller)

The 5G FlexRIC controller is an extension of the previously available FlexRAN controller. FlexRAN was based on client-server architecture, where FlexRAN clients, embedded on top of OAI 5G protocol stack and capable of direct control of various 5G RRC parameters, interact with a FlexRAN server developed as a Web Technology entity. Accordingly, FlexRAN controllers enable 5G controls through standardized Web technology APIs and message formats, such as REST and JSON, instead of 3GPP-specific ASN.1 standards.

The general principles of RICs are similar to FlexRAN controllers, but an O-RAN E2 interface has been adopted for enhanced interoperability between various RAN and RIC implementations. The O-RAN E2 interface is used by RICs to control the underlying RAN elements. A E2 interface provides four basic operations:

- Report – asks the RAN to report a specific information.
- Insert – the RIC asks the underlying RAN to activate a particular user-plane function.
- Control – the RIC asks the underlying RAN to activate a particular control-plane function.
- Policy – the RIC sets a particular policy function on an activated function.

For example, a RIC may ask over the E2 interface to obtain RAN parameters, activate a particular slice or even provide policies for a scheduler.

The OAI RAN (gNB stack) has been extended by a E2 agent communicating with the FlexRIC controller over the E2 interface. Figure 2 shows the OAI FlexRIC architecture.

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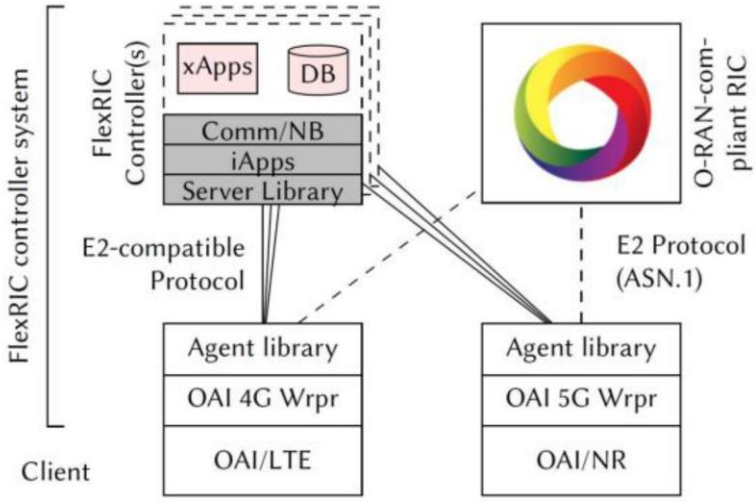

Figure 2 OAI FlexRIC architecture [source:OAI].

On top of OAI, we have extended the FlexRAN controller server to support RIC specifications, in particular real-time functions. FlexRIC has a built-in Service Model (SM) for monitoring and slicing, that can be easily customized and extended to fulfil the diverse 5G use cases. FlexRIC's Application Protocol (AP) and Service Models (SM) are encoding and decoding agnostic. It also supports the creation of new SMs "à la carte" to satisfy specific, yet not standardized, use cases. Lastly, FlexRIC is expected to act as a booster for the type and quality of Machine Learning algorithms deployed in 5G as it easily enables their validation in real 5G deployments as shown here with the OAI 5G stack.

Dashboard for monitoring 5G RAN KPIs using E2 interface

The E2 interface standardized by O-RAN enables the collection of metrics from the RAN to the near-RT RIC, either periodically or after pre-defined trigger events. In the context of this project, Allbesmart has developed a cloud-based dashboard designed for real-time monitoring and management of the 5G OAI setup. The solution allows the visualization of the following parameters through a web browser:

- gNB real-time plots: aggregated downlink and uplink bitrates.
- UE real-time plots: downlink and uplink bitrates, RSSI, RSRP, CQI, MCS, BLER, rank indicator, PMI.
- gNB configurations.
- Visualization of attached UEs.
- Save gNB detailed statistics and export to other formats.

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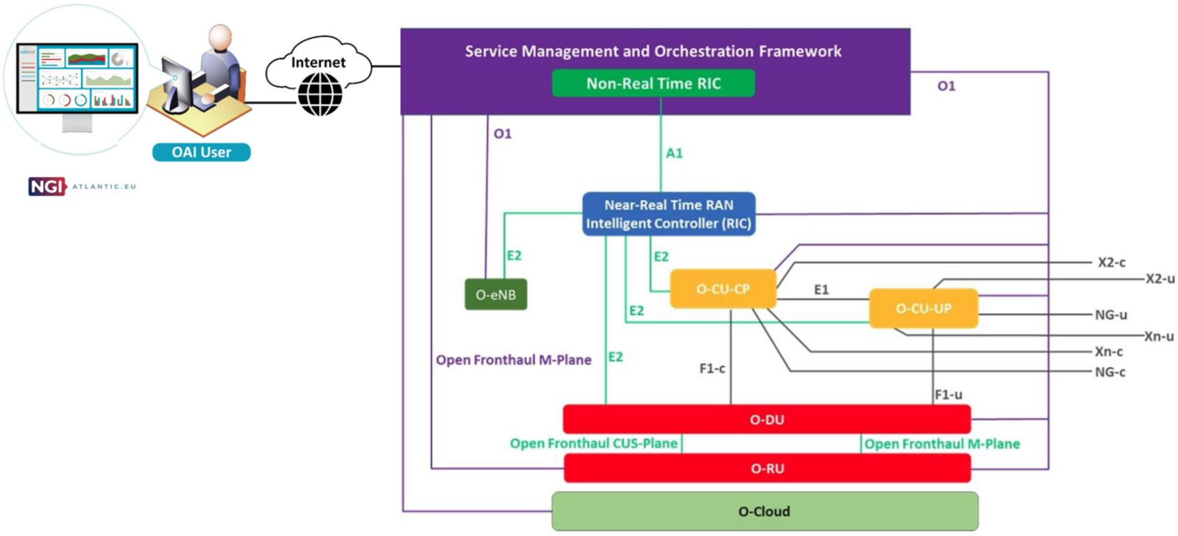


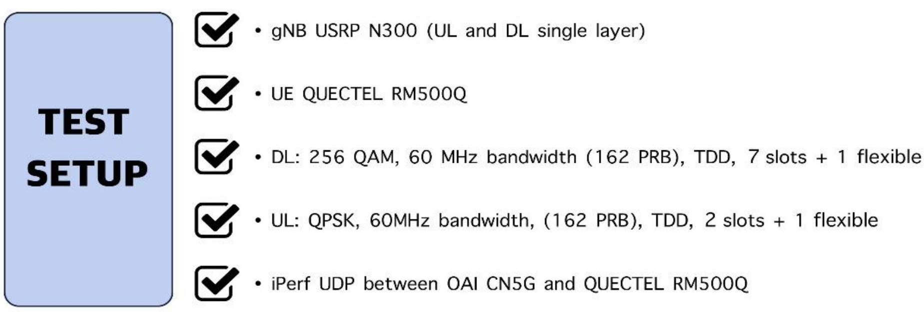
Figure 3 O-RAN architecture with the cloud-based management tool integrated in the context of this experiment.

Allbesmart has deployed an end-to-end implementation of OAI 5GNR in the VT testbed and carried out the following tests:

- Test the interoperability between OAI gNB and COTS UE (Quectel RM500Q).
- Test the performance and maximum downlink throughput that OAI gNB can handle.

The test comprises a OAI 5G Core Network, a OAI gNB connected to a USRP N300 with the following configurations:

- TDD configuration: (D:7, F:1, U:2), 30kHz SCS (Subcarrier Spacing)
- Downlink configurations: 256 QAM max, 60 MHz bandwidth (162 PRB), single layer
- Uplink configurations: QPSK max, 60MHz bandwidth (162 PRB), single layer



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Minimum hardware requirements:

- Laptop/Desktop/Server for OAI CN5G and OAI gNB
  - Operating System: Ubuntu 20.04.4 LTS
  - CPU: 8 cores x86_64 @ 3.0 GHz
  - RAM: 32 GB
- Laptop for UE
  - Operating System: Microsoft Windows 10 x64
  - CPU: 4 cores x86_64
  - RAM: 8 GB
  - Windows driver for Quectel MUST be equal or higher than version 2.2.4
- USRP N300
  - Quectel RM500Q
  - Module, M.2 to USB adapter, antennas and SIM card
  - Firmware version of Quectel must be equal or higher than RM500QGLABR11A06M4G


Figure 4 QUECTEL RM500Q modem used as COTS 5G NR UE device for the interoperability tests.

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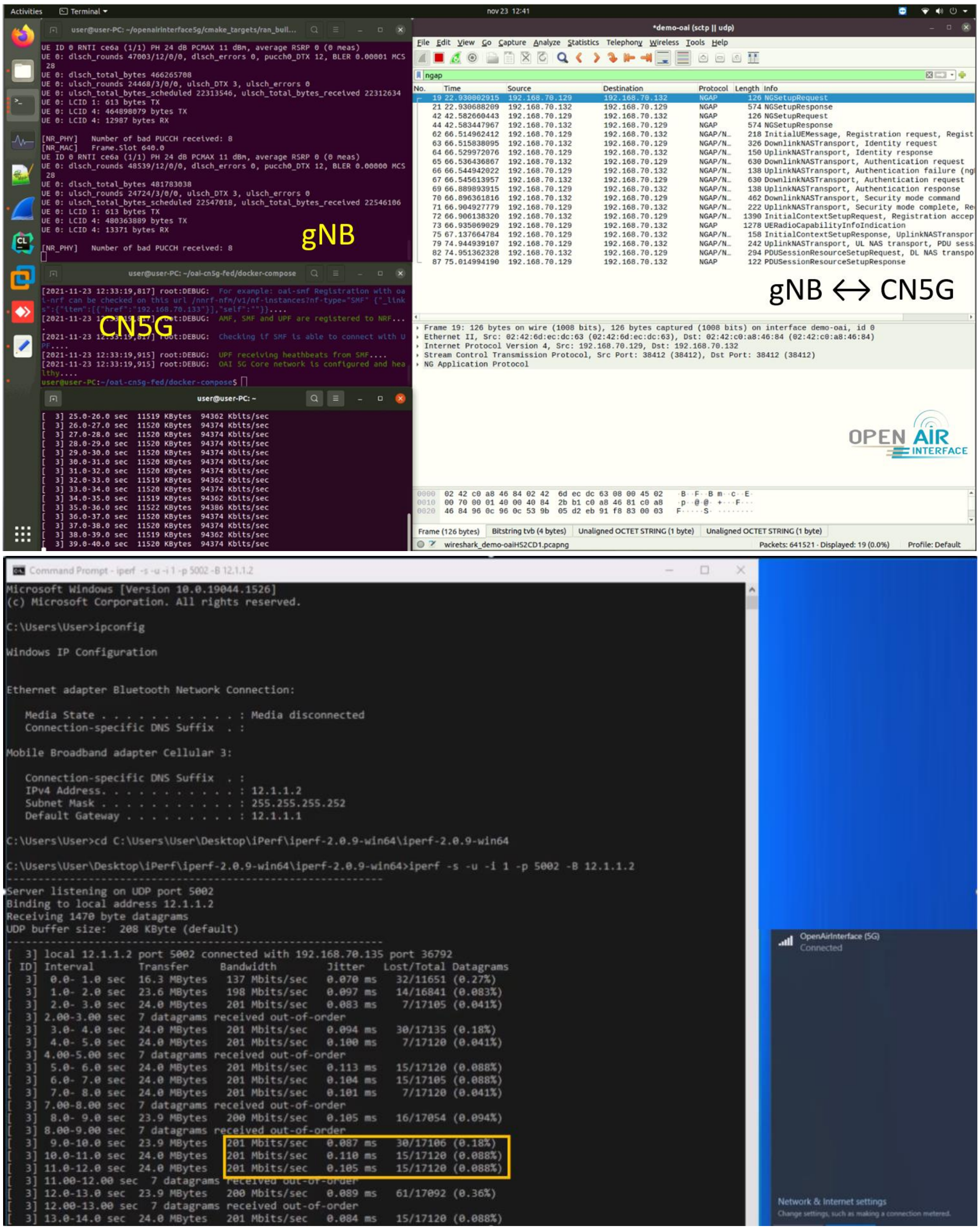

Figure 5 Screenshot of the iPerf test reaching: DL 201 Mbps, Jitter 0.087 ms and total packet lost of 0.18%.

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Figure 6 Screenshot of the 5G NR OAI UE GUI showing the 256 QAM constellation used for DL testing.

Table 1 Summary of the 5G NR SA test configurations and results.

Configuration	Bandwidth [MHz]	DL throughput [Mbit/s]
SISO	40	123
SISO	60	188
MIMO 2x2	40	201
MIMO 2x2	60	340
MINO 2x2	100 MHz	605

Monitorization of RAN KPIs using the O-RAN E2 interface

Allbesmart has developed a cloud-based management software tool for OAI 5G test networks (OAIBOX dashboard). The tool allows access to the gNB and UE information in real-time using the O-RAN E2 interface implemented in the OAI code base. This management tool works as

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an abstraction layer to facilitate the use of OAI. The collected data can be saved and exported to different formats and used by R&D teams working on ML techniques for 5G RAN optimization. The VT team in the US is working on ML algorithms based on KPIs collected in the OAI test setup. The following figures show the OAIBOX dashboard with examples of KPIs collected using the CCI (US) testbed.

The OAIBOX dashboard main panel is depicted in Figure 7.

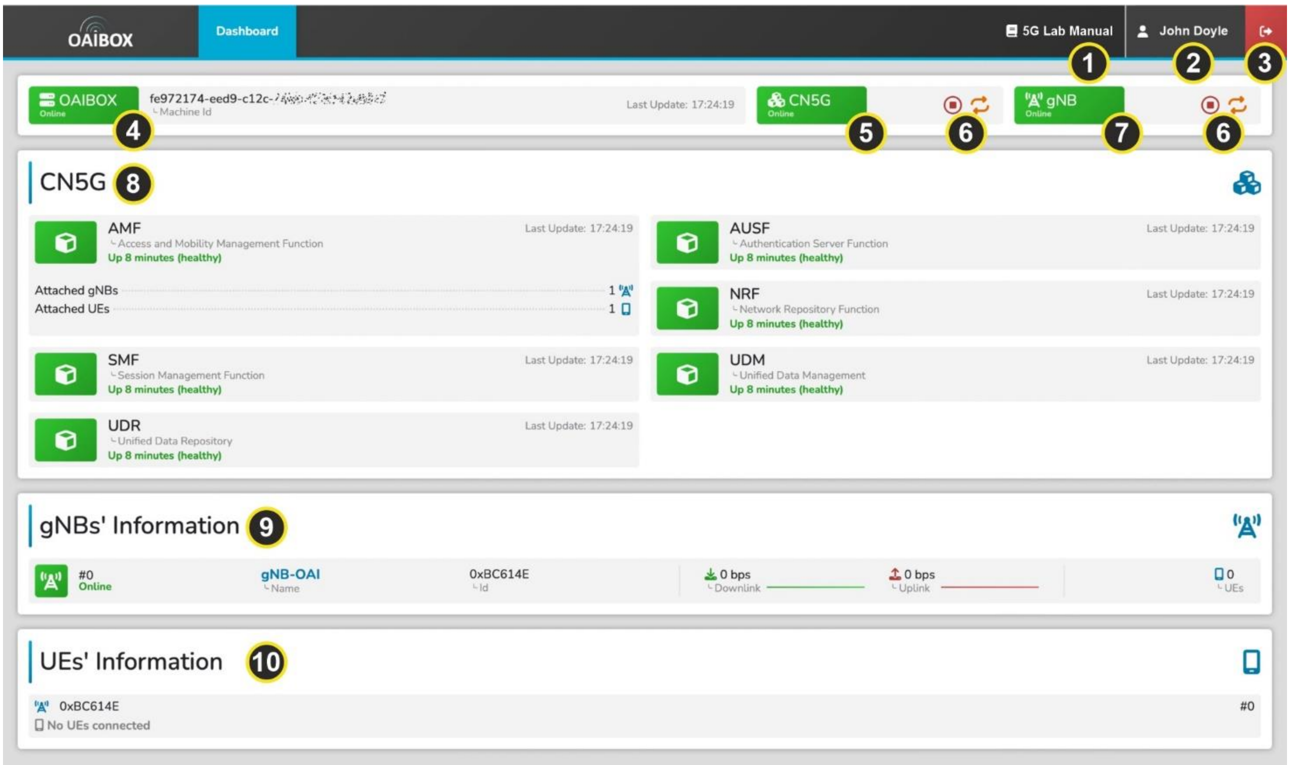

Figure 7 The OAIBOX dashboard is a cloud-based management tool for OAI 5G test networks. Information from the CN5G, associated gNBs and attached UEs is shown through a web portal (after a login process).

Each identified area is explained below:

❶ A quick link to the online 5G Lab Manual.

❷ The identification of the user account currently logged in the OAIBOX Dashboard. You can customize your profile, such as change the e-mail address, the first and last name of the user associated with this account, and activate the two-factor authentication.

❸ The OAIBOX Dashboard logout button.

❹ The online status of this particular OAIBOX (Red: Offline; Green: Online) and its current IP address. Each OAIBOX has a unique *Machine ID*. Your OAIBOX needs to have Internet access to achieve the Online status.

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❺ The online status of the 5G core network (Red: Offline; Orange: Starting; Green: Online). Your OAIBOX needs to have Internet access to achieve the CN5G Online status.

❻ The Stop and Restart buttons for the associated modules (CN5G or gNB).

❼ The online status of the gNB (Red: Offline; Orange: Starting; Green: Online). Your OAIBOX needs to have Internet access to achieve the gNB Online status.

❽ The 5G core network functions.

❾ Summary information about the gNB, including its name, unique *identification* (Id), the real-time *download* (DL) and *upload* (UL) throughputs, and the number of associated UEs.

❿ Summary information about the UEs currently attached to the gNB.

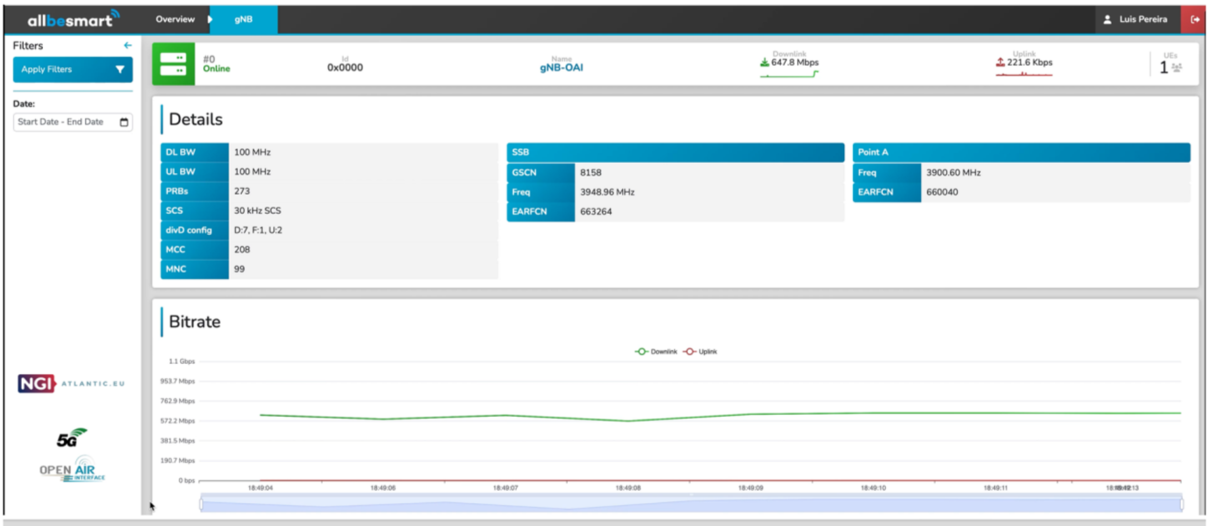

Figure 8 Visualization in real time of the gNB configurations and the aggregated bitrate (DL and UL).

Figure 9 Visualization in real-time of PHY layers parameters for a specific UE.

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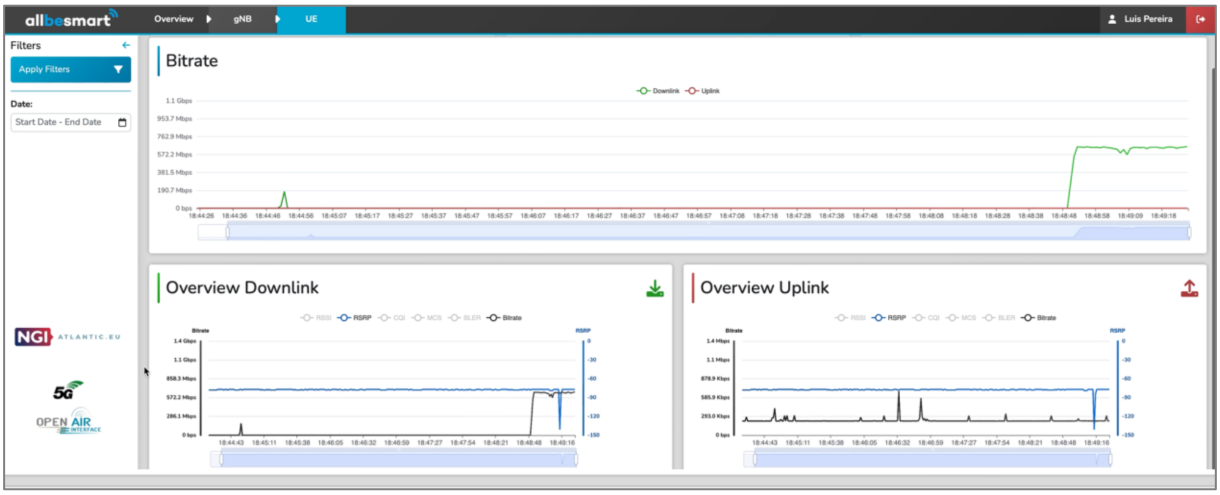

Figure 10 Visualization in real-time of the DL and UL bitrate for the UE (reaching a stable DL throughput of 605 Mbps).

5 Present and Foreseen TRL

The project's outcome has reached the market of 5G testing solutions and, therefore TRL9. The OAIBOX website (www.oaibox.com) was launched on 8th Nov. It provides technical details of the OAIBOX product line and allows potential customers to ask questions and put orders. In the follow-up to the visit to the US for the OAI Workshop, the company BATSWireless (www.extendingbroadband.com) becomes the first client of the OAIBOX40 product.

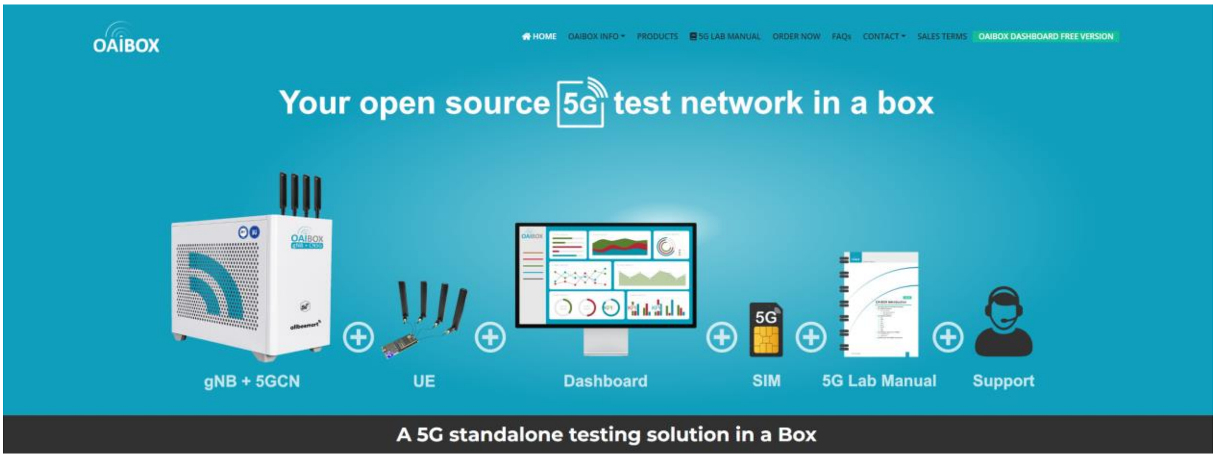

Figure 11 Main page of the OAIBOX website (www.oaibox.com).

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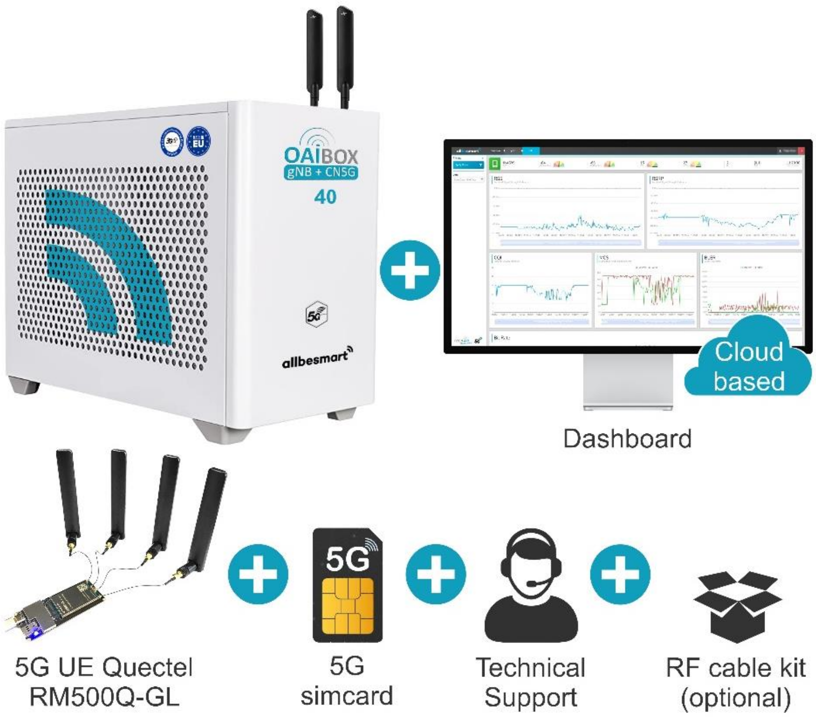

Figure 12 The OAIBOX40 product is on the market (TRL9) with a reference price of 10.000 €. The product shows the "Made EU" label.

6 Exploitation, Dissemination and Communication Status

In the following, we have listed the main dissemination activities:

1. Participation with a prototype demonstrator in the OpenAirInterface Summer Workshop in Paris, 12-13 July 2022.
2. Organize a hands-on training workshop to promote OpenAirInterface for 5G experimentation in the CCI, 21 July 2022.
3. Participation with an O-RAN end-to-end demonstrator in the MWC 2022 in Las Vegas (US), Sep. 2022. Joint participation with the CCI team.
4. Meeting with ADM to promote the cloud-based 5G network management tool and the O-RAN dashboard developed in the project.
5. Presentation of the project results to the OAI open-source community at the OpenAirInterface North America Workshop at Qualcomm, San Diego (US), 8-9 Nov. 2022.
6. Demo the OAIBOX product in the OpenAirInterface North America Workshop at Qualcomm, San Diego (US), 8-9 Nov. 2022.
7. Production of a promotional video promoting the OAIBOX product, available on Youtube.
8. Production of an OAIBOX flyer where VT is listed as a client/partner thanks to the participation in NGI Atlantic.

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Exploitation plans after the end of the project:

- Demo at the MWC 2023 in Barcelona in the AMD booth.
- Submit a joint scientific paper with the VT team (e.g., EUCNC 2023). The focus of the paper will be on O-RAN experimentation using OAI.
- Participation in the CCI Symposium 2023, April 17-18, 2023
- Participation in the OpenAirInterface summer workshop 2023

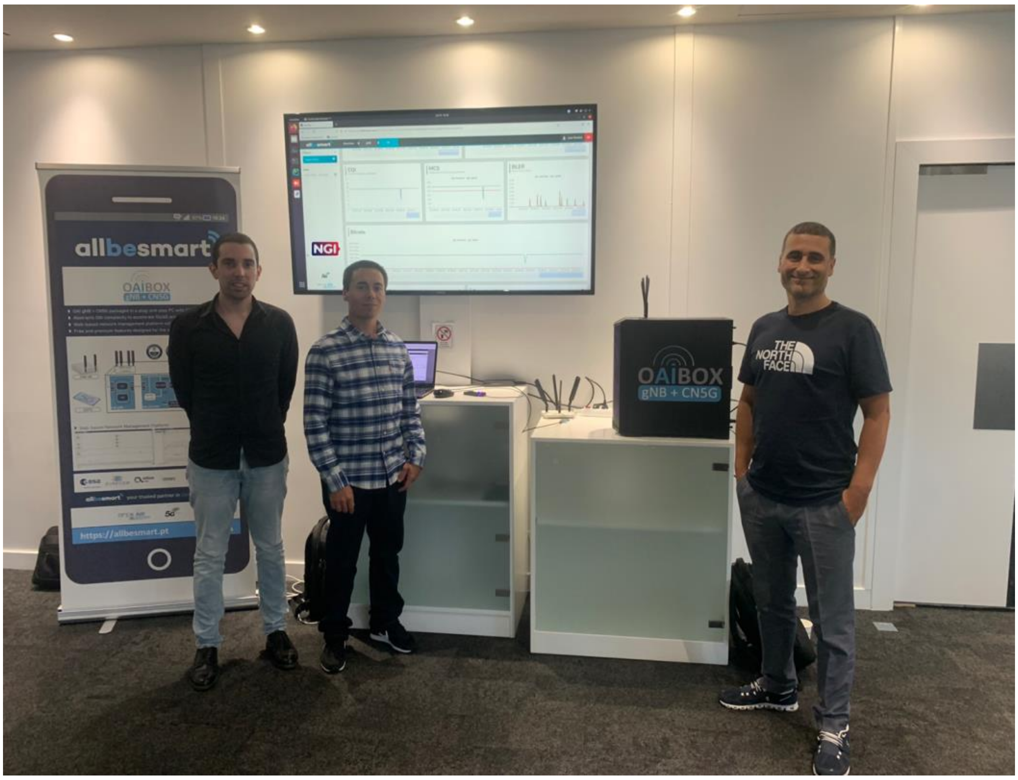

Figure 13 Allbesmart team (Roberto Magueta, Luís Pereira, and Paulo Marques) presented a prototype of the 5G network management platform with O-RAN interfaces. OpenAirInterface Summer Workshop, Paris, 12-13 July 2022.

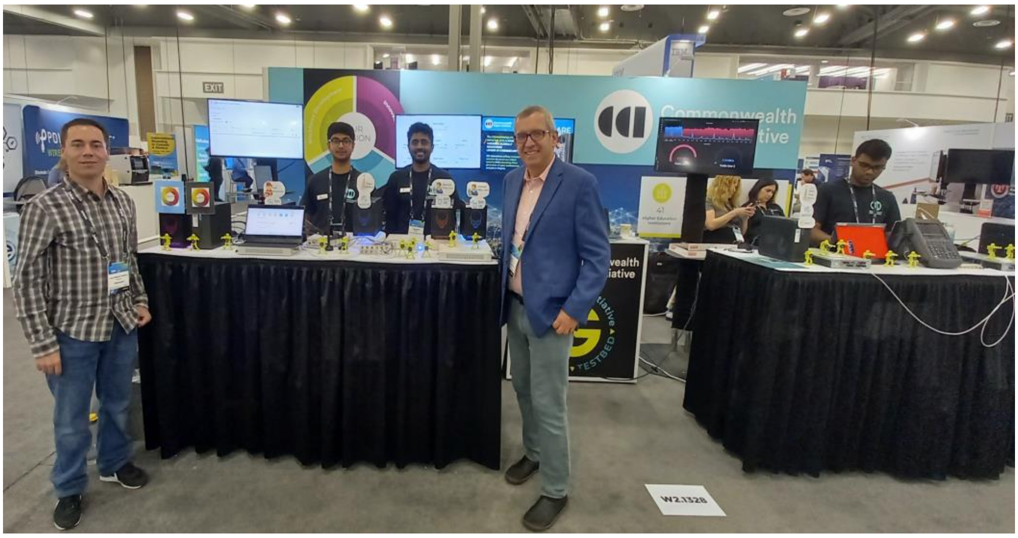

Figure 14 Luis Pereira (Allbesmart's 5G team leader) and Luiz da Silva (Head of the CCI) in the O-RAN demo, MWC Las Vegas (US), Sep. 2022.

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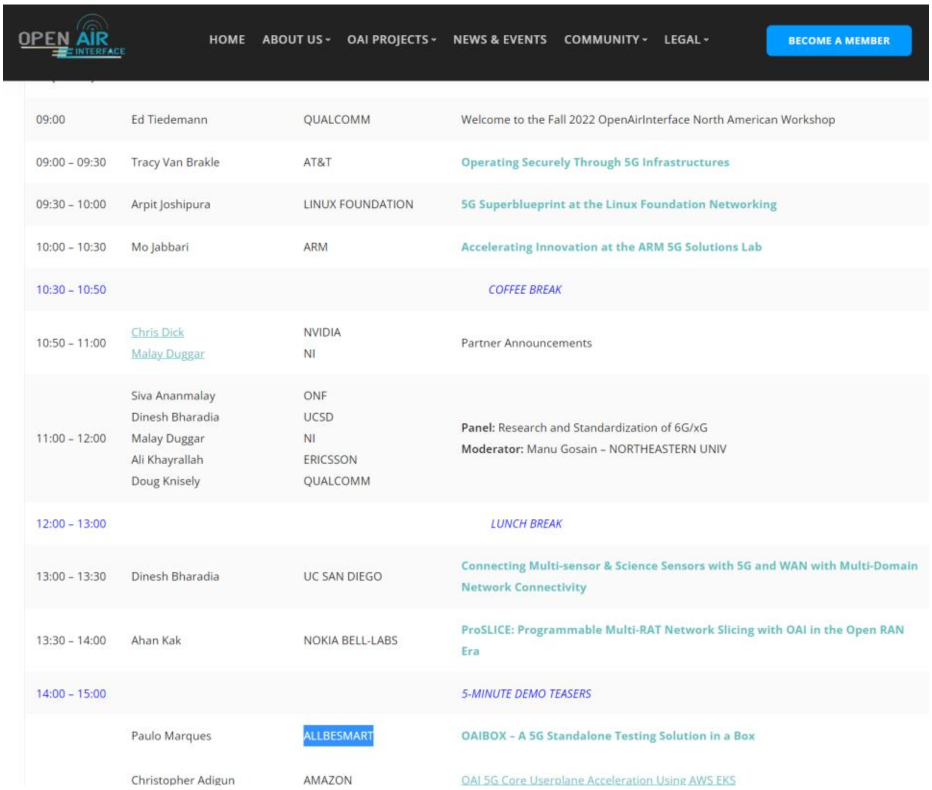
Figure 15 Meeting between Luis Pereira (Allbesmart) and the AMD team (US) to discuss potential projects related to using OpenAirInterface with PHY HW accelerator cards from AMD. The introduction was triggered by VT. MWC Las Vegas (US), Sep. 2022.



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09:00	Ed Tiedemann	QUALCOMM	Welcome to the Fall 2022 OpenAirInterface North American Workshop
09:00 – 09:30	Tracy Van Brakle	AT&T	Operating Securely Through 5G Infrastructures
09:30 – 10:00	Arpit Joshipura	LINUX FOUNDATION	5G Superblueprint at the Linux Foundation Networking
10:00 – 10:30	Mo Jabbari	ARM	Accelerating Innovation at the ARM 5G Solutions Lab
10:30 – 10:50			*COFFEE BREAK*
10:50 – 11:00	Chris Dick Malay Duggar	NVIDIA NI	Partner Announcements
11:00 – 12:00	Siva Ananmalay Dinesh Bharadia Malay Duggar Ali Khayrallah Doug Knisely	ONF UCSD NI ERICSSON QUALCOMM	**Panel:** Research and Standardization of 6G/xG **Moderator:** Manu Gosain – NORTHEASTERN UNIV
12:00 – 13:00			*LUNCH BREAK*
13:00 – 13:30	Dinesh Bharadia	UC SAN DIEGO	Connecting Multi-sensor & Science Sensors with 5G and WAN with Multi-Domain Network Connectivity
13:30 – 14:00	Ahan Kak	NOKIA BELL-LABS	ProSLICE: Programmable Multi-RAT Network Slicing with OAI in the Open RAN Era
14:00 – 15:00			*5-MINUTE DEMO TEASERS*
	Paulo Marques	ALLBESMART	OAIBOX – A 5G Standalone Testing Solution in a Box
	Christopher Adigun	AMAZON	OAI 5G Core Userplane Acceleration Using AWS EKS

Figure 16 Program of the OpenAirInterface North America Workshop at Qualcomm, San Diego (US), 8-9 Nov. Allbesmart joined big names from the US industry.

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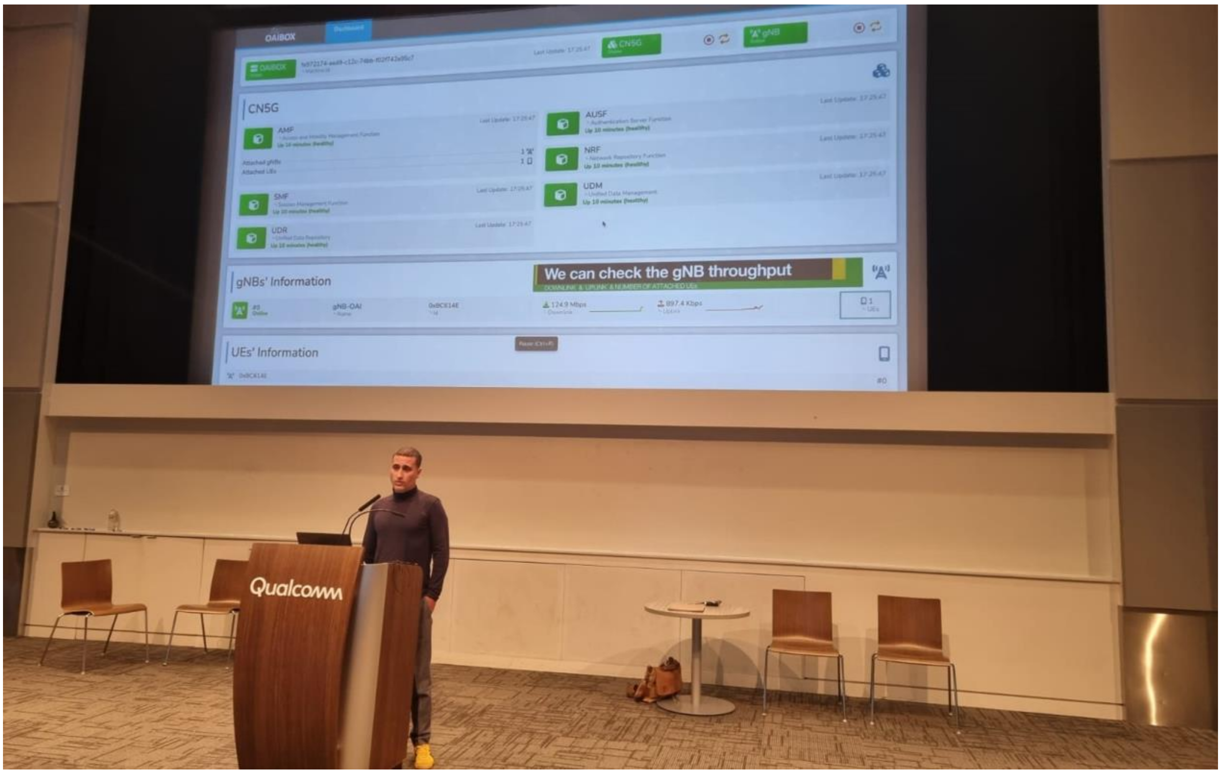

Figure 17 Paulo Marques presenting the OAIBOX 5G test solution during the OpenAirInterface North America Workshop at Qualcomm, San Diego (US), 8-9 Nov. 2022.

Figure 18 Allbesmart team (Luís Pereira, Paulo Marques, and Jorge Ribeiro) demonstrating the OAIBOX product and the NGI Atlantic project in the OpenAirInterface North America Workshop at Qualcomm, San Diego (US), 8-9 Nov. 2022.

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Figure 19 Promotional video of the OAIBOX product line. https://www.youtube.com/watch?v=kO0d9lW9wvg&t=1s

Figure 20 OAIBOX flyer where VT is listed as client/partner thanks to the participation in NGI Atlantic.

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7 Impacts

Impact 1: Enhanced EU – US cooperation in Next Generation Internet, including policy cooperation.

The current 5G supply chain is concentrated around a small number of vertically integrated, global infrastructure vendors. At the same time, the developing global geopolitical situation highlights the risks associated with the current concentration of 5G network vendors. Trade restrictions are forcing sub-optimal decisions to be made, and the ongoing threat of retaliation, from China, for example, risks cutting off supplies of vital components, potentially impacting wireless services. Recognising these threats, many governments in the EU and the US are looking to stimulate a radical restructuring of the 5G supply chain, where Open RAN disaggregation plays a significant role. In this context, this experiment has developed open-source O-RAN interfaces contributing towards the common goal of European and US sovereignty in 5G technologies and beyond. The new product developed by Allbesmart, the OAIBOX – a 5G test network in a box, has been marketed with the "Made EU" label.

Impact 2: Reinforced collaboration and increased synergies between the Next Generation Internet and the US Internet programmes.

This experiment has reinforced the collaboration and synergies with the CCI (Commonwealth Cyber Initiative), a well-funded programme by the Virginia State (US). The partner VT got funded by the CCI. There was no NSF funding in this experiment.

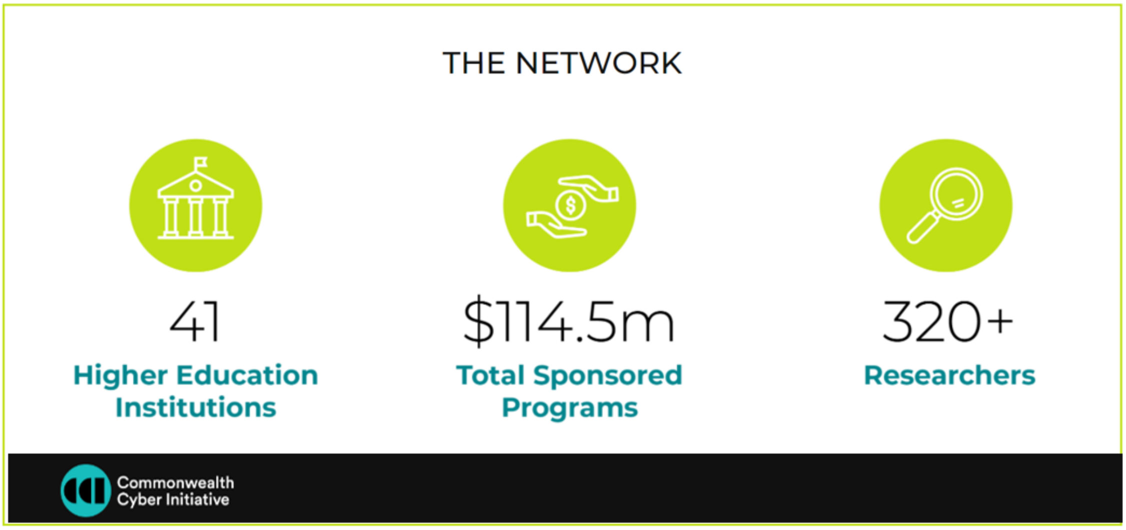

Figure 21 The CCI in numbers (https://cyberinitiative.org/) .

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Impact 3: Developing interoperable solutions and joint demonstrators, contributions to standards.

Open RAN provides Telcos with the opportunity to reduce network costs as it maximizes the levels of flexibility of RAN deployments and operations. However, a disaggregated RAN means that Telcos can expect more vendors and products in the ecosystem. The traditional system integrator needs to evolve to tackle not only the Open RAN challenges but also to secure the delivery of end-to-end network solutions, especially in a 5G context. Interoperability is a key element of O-RAN. Allbesmart wants to exploit this emerging market by acting as a solution integrator and interoperability tester. Access to an O-RAN setup over the CCI xG Testbed is an excellent playground for experimentation and testing.

The O-RAN features developed and tested in this experiment are royalty-free, under the OAI Public License V1.1, as an enabler to test and validate O-RAN standardised interfaces and a starting point for developing commercial solutions.

Impact 4: An EU - US ecosystem of top researchers, hi-tech start-ups / SMEs and Internet-related communities collaborating on the evolution of the Internet

The NGI Atlantic project has given the opportunity to Allbesmart to collaborate with Virginia Tech, a world-leading university in wireless communications. The expertise of the VT team in RIC ML/ AI applied to 5G network optimisation helped Allbesmart define the OAIBOX product roadmap.

The interaction with the vibrant ecosystem in VT and CCI has triggered EU-US collaborations and new business opportunities for Allbesmart, contributing to a long-term economic impact. The participation in the NGI Atlantic project has triggered several contacts with US companies such as Qualcomm, NVIDIA, AMD, NI and BATSWireless.

Moreover, thanks to the participation in NGI Atlantic, Allbesmart has access to the state-of-art testbed provided by the CCI in the US. The 5G network and testing equipment available in the CCI testbed is not usually available for an SME like Allbesmart.

8 Conclusion and Future Work

This experiment has integrated the Open RAN interfaces implemented by Allbesmart with the RAN Intelligent Controller (RIC) applications developed by VT (US) and validated its performance on top of the Commonwealth Cyber Initiative testbed (US). The outcome of this experiment has contributed to the publicly available open-source OpenAirInterface software library with new O-RAN features and software tools towards an open and renovated 5G

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architecture. Thanks to the support of NGI-Atlantic, Allbesmart has developed the open-source 5G test network OAIBOX(www.oaibox.com). The OAIBOX product was launched in the OpenAirInterface Noth America workshop at Qualcomm in San Diego (California). The first client is the US company BATSWireless.

Allbesmart and the CCI will continue cooperating, using OAI as a platform for collaborative research in 5G and beyond. The OAIBOX product will continue to be validated by the CCI team as early adopters, and suggestions will be integrated into the new releases.

Collaboration with a top university as VT was instrumental for the scientific credibility of the OAIBOX product and in reaching the US market.

9 References

- Allbesmart: www.allbesmart.pt
- Commonwealth Cyber Initiative (CCI): https://cyberinitiative.org/
- OpenAirInterface Software Alliance: https://openairinterface.org/
- OAI Summer Workshop: https://openairinterface.org/summer-2022-openairinterface-workshop-paris/
- OAI North America Workshop: https://openairinterface.org/fall-2022-openairinterface-north-american-workshop/
- Open RAN Alliance: https://www.o-ran.org/
- OAIBOX product website: www.oaibox.com

10 Glossary

5G	Fifth Generation (mobile/cellular networks)
CCI	Commonwealth Cyber Initiative (CCI)
NGI	Next Generation Internet
OAI	OpenAirInterface
O-RAN	Open Radio Access Network
R&D	Research and Development
RIC	RAN Intelligent Controller
SCF	Small Cell Forum
SDR	Software Defined Radio
TRUST-IT	TRUST-IT (Project Partner)
VNF	Virtual Network Function
VT	Virginia Tech University
WIT	Waterford Institute of Technology (Coordinating Partner)

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