H2020 5Growth Project
Grant No. 856709

D5.3: Demonstrations at EuCNC'20 or equivalent

Abstract

One of the dissemination goals of 5Growth is to conduct technology demonstrations in a high impact venue, such as EuCNC or similar venue. This document briefly explains the demonstration activities carried out during offline conferences and online events. Other information related to the demonstrations carried out by the project is also provided.

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Disclaimer

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1. Introduction

As part of the Communication, Dissemination, and Exploitation Plan (CoDEP) [1] of the project, one of its dissemination goals of 5GROWTH is to present technical demonstrations of project results in relevant events. They are used to showcase in a tangible way what is presented in the form of deliverables, papers, talks, etc. in other venues. This document briefly explains the demonstration activities carried out during four online events and/or conferences, namely:

- The 25th Annual International Conference on, Mobile Computing and Networking, ACM MobiCom 2019 [2] (Offline).
- The Optical Networking and Communication Conference & Exhibition, OFC'20 [3] (Offline).
- Joint 5Growth,5G-DIVE, 5G-EVE, 5G-VINNI, 5G-Tours Workshop "5G end to end experimentation by verticals in EU projects" [4] (Online).
- 5G PPP Technology Board Workshop 2020 [5] (Online).

During these events, two different demonstrations were shown:

- vrAIn Proof-of-Concept — A Deep Learning Approach for Virtualized RAN Resource Control.
- Remote Control of a Robot Rover Combining 5G, AI, and GPU Image Processing at the Edge.

Information on other demonstrations carried out by the project as well as a summary of communication, dissemination, and exploitation activities can be found in D5.2 [1].

2. Demonstrations

2.1. vrAIn Proof-of-Concept — A Deep Learning Approach for Virtualized RAN Resource Control

The envisaged paradigm of 5G mobile technologies is aimed to serve a broad spectrum of applications having diverse requirements on various key performance indicators (KPIs), ranging from high reliability and low latency to large-scale connectivity and massive data rates. To accommodate such an ambitious vision of 5G, new generation wireless access networks are required not only to integrate various flexible multi-access technologies such as mmWave and massive MIMO but also to provide a versatile radio resource management (RRM) system that can ensure efficient spectrum utilization and seamless interoperability.

A powerful concept addressing such needs is the virtualization of the radio access network (RAN), wherein the legacy communication system is decoupled by centralizing the software radio access through virtual machines or containers running on servers at the edge of the cellular network. While this makes the network more agile and minimizes the requirement of expensive dedicated hardware, the edge may host several applications competing for resources, thereby limiting the efficiency of radio functions. Further, the unification of hybrid technologies under the 5G umbrella adds to the complexity of the problem, thereby making the use of conventional communication theoretic approaches often inadequate to achieve optimum traffic and resource management, owing to intricate mathematical modeling and complex dependencies between network and channel variables. It has therefore become indispensable the design of innovative solutions that can swiftly and effectively deal with the system complexity thanks to a fully automated, data-driven approach.

Recently, learning-based techniques including supervised, unsupervised, reinforcement learning (RL), and deep learning have shown to hold enormous potential in addressing the challenges of applying standard mathematical optimization frameworks to resource allocation problems in virtual RANs and in allowing an automatic system control. Due to the very complex dependency between the radio conditions and the computing resources needed to provide the baseband processing functionality, attaining an efficient resource control is particularly challenging.

In this demonstration, it was showcased vrAIn, a vRAN dynamic resource controller that employs deep reinforcement learning to perform resource assignment decisions. vrAIn, which is implemented using an open-source LTE stack over a Linux platform, can achieve substantial savings in the used CPU resources while maintaining the target QoS for the attached terminals and maximize throughput when there is a deficit of computational capacity.

The goal of this demonstrator was to show the effectiveness of vrAIn in achieving a lower resource usage footprint while maintaining adequate QoS level and maximize throughput upon a deficit of computational capacity. Also, vrAIn attained these results in a model-free way. While this demonstrator uses only one specific hardware configuration, vrAIn does not need to be specifically configured for a target NFV infrastructure. Specifically, the vrAIn demonstrator builds on: (i) three

laptops that play the roles of VRAPs host and UEs attached to those VRAPs, (ii) four Software-Defined Radio (SDR) boards that provide the radio front-ends, and, (iii) one display to let the audience interact with vrAIn.

The performance of a virtual BS is a very complex function of the contexts and the resource assignment, motivating the use of Deep Learning. The problem was solved by using a novel combination of Sparse Autoencoders, a Reinforcement Learning algorithm, and a Neural Network Classifier. The demonstrated solution minimizes the costs with unlimited resources and maximizes the performance with limited resources. With respect to state-of-the-art solutions, vrAIn achieves.

The demonstrated approach showed good results with models trained with real data and implemented a proof-of-concept of the solution:

- CPU savings: ~30% with unlimited resources.
- Throughput increase: ~25% per virtual Base Station.

The received results are showing that the chosen direction of the research is correct and the evolution of the RL-based technologies integration into the resource control management systems is beneficial for the telecommunications industry.

A detailed description of the approach is provided on the demonstration slides, available at:

https://5growth.eu/wp-content/uploads/2020/06/11.50-12.30-vrain_4_demo.pdf

2.2. Remote Control of a Robot Rover Combining 5G, AI, and GPU Image Processing at the Edge

The combination of 5G Ultra Reliable Low Latency Communications (URLLC), supported by a low latency optical fronthaul and backhaul, and of intelligence at the edge, supported by accelerated micro data-centers, is paving the way to the remote control of moving machineries (e.g., robots, robot rovers, cars). Such remote control would allow lowering the cost of moving machineries by offloading most of their intelligence to the network. Standard Development Organisations (SDOs) are conducting several initiatives in this direction. One of the important working items of Release 16, expected to be released in ASN.1 in the second quarter of 2020, is the Enhancement of URLLC support in the 5G Core network. In parallel, to decrease the end-to-end latency further, Multi-Access Edge computing (MEC) or, more in general, edge technologies are being developed. Edge technologies can also benefit from the development of edge micro data-centers in which the traditional elaboration based on Central Processing Units (CPU) is complemented with elaboration offloaded to Graphical Processing Unit (GPU) or programmable hardware, such as Field programmable gate array (FPGA). Artificial Intelligence (AI) and Machine Learning (ML) algorithm can benefit from these accelerated data-centers for implementing part of the machinery remote control.

The proposed demonstration was organized as follows. A four-wheel drive robot rover was connected to an edge micro data-center where the rover remote control was deployed. A 5G network provided the connectivity between the rover and the data center. The rover remote control was based

on an algorithm recognizing traffic signs. The algorithm resided in an edge node attached to the 5G Core Network (CN). The algorithm recognizing the signs is based on Artificial Intelligence. The algorithm was run on GPUs forming the edge micro data center. The rover sent the live scene acquired through a camera to the AI algorithm that recognized the traffic signs. The recognized sign (e.g., left turn or right turn) was sent to the rover remote control that sent the corresponding command (e.g., left turn or right turn) to the rover through the 5G network (i.e., optical backhaul, fronthaul and wireless channel).

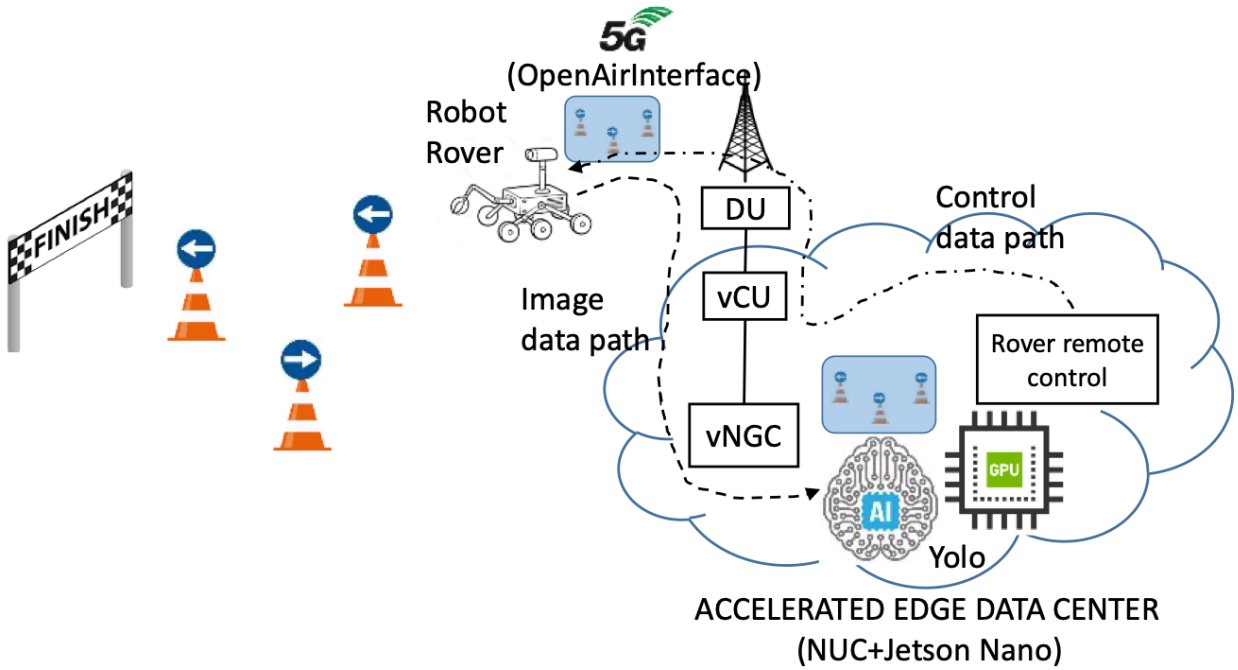

FIGURE 1: OFC'20 POSTER

From the demo components perspective, the rover was communicating through the WIFI-5G bridge. 5G infrastructure was also including Distributed Unit (DU), the virtualized Central Unit (vCU), and the virtualized Next Generation Core (NGC). The image recognition application is based on the You Only Look Once (YOLO) software, which is a Unified, Real-Time Object Detection software based on a single neural network applied to the full image.

The rover is presented in Figure 2.

FIGURE 2: THE DEMP ROVER USED IN THE DEMONSTRATION AT OFC'20

The 5G access setup is captured in Figure 3.

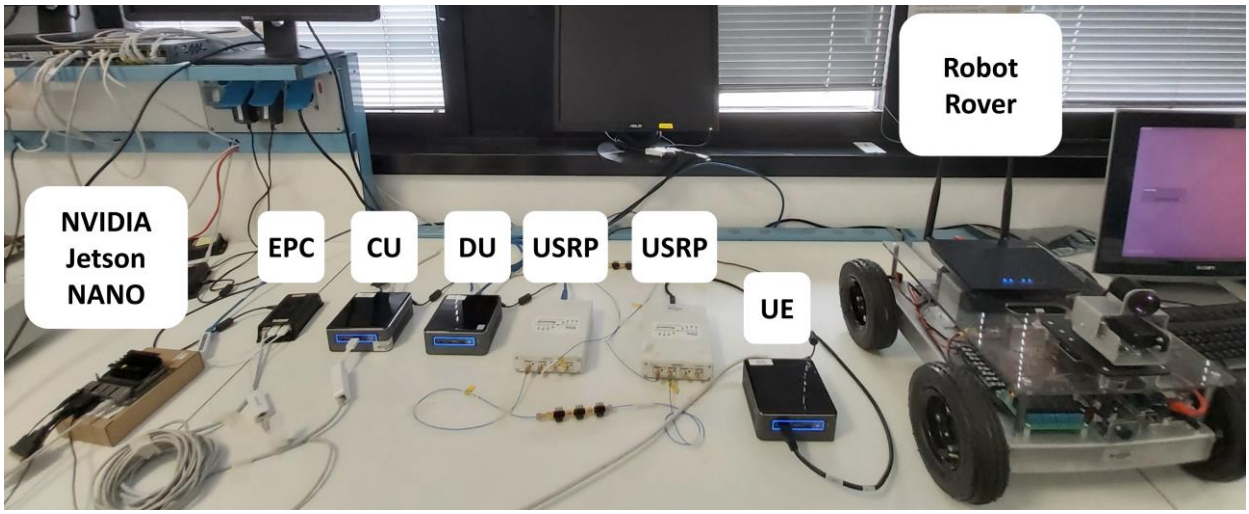

FIGURE 3: SETUP USED FOR THE DEMONSTRATION

Visitors to the demo experienced the capability of the 5G network, AI, and GPU based edge image recognition to identify the different traffic signs attached to the posts and to send command to the four wheel-drive robot rover to turn in the right direction. Visitors could challenge the rover performance by piloting the rover through a joystick.

The innovation introduced by this demo is multifold. The demo combines very recent solutions in the service and communication fields.

First of all the considered service (i.e., the remote control of a moving machinery) is being considered as a first step toward assisted/autonomous driving. Moreover, it is currently a matter of investigation in the robotic research (i.e., the so called cloud robotics) to reduce robot cost by moving most of the intelligence at the edge.

The second innovation consists in the utilization of the 5G technology, including optical fronthaul and backhaul, to reduce the end-to-end latency. Indeed, when an application is extremely latency sensitive (i.e., when the time occurring between sensing a phenomenon and applying the control must be short) it is important that the mobile network, including bot the air interface and the fixed infrastructure, guarantees URLLC.

Last but not least, another important novelty is represented by the utilization of an edge micro-data center next to the 5G Next Generation Core (NGC). The deployment of intelligence at the edge allows the latency of the communication between the controlled machinery and the remote control to be minimized. To further reduce the latency, an accelerated edge data-center equipped with GPU is exploited.

Thus, the demo will show how the latency introduced by all the components of the whole service chain (including network (including virtualization), elaboration, and actuation latencies) for the remote control of robot rover will impact the service performance.

The demo shows advances in network and service deployment in a laboratory environment toward field trials.

In particular, it shows the capability of 5G, including air interface, fronthaul and backhaul, of providing a low latency communication between robot rover and remote control.

The demo deals also with edge computing for low latency remote control. In particular, it shows how, by deploying the intelligence at the edge in micro data-center equipped with GPUs, low latency, at the application level, is achievable.

Finally, it shows the potentials of utilizing AI/ML in combination with GPU acceleration for data analytics. In particular, the AI-based image recognition algorithm combined with GPU acceleration, allows to sensibly reducing the latency of the task with respect to a CPU based approach. Thus, the potentials of accelerated edge data center in reducing the end-to-end application-level latency are also shown.

3. Conferences and online events

The demonstrations explained above have been presented in various events (offline and online) to which the project participated or organized by 5Growth.

3.1. ACM MobiCom 2019

MobiCom 2019 is the 25th Annual International Conference on Mobile Computing and Networking. The conference took place on Oct 21-25 in Los Cabos, Mexico. It is the twenty-fifth in a series of annual conferences sponsored by ACM SIGMOBILE dedicated to addressing the challenges in the areas of mobile computing and wireless and mobile networking. The MobiCom conference series serves as a highly selective, premier international forum addressing networks, systems, algorithms, and applications that support mobile computers and wireless networks. In addition to the regular conference program, MobiCom 2019 included a set of workshops, research demonstrations, and a poster session that included the ACM Student Research Competition.

3.1.1. Media content

The poster for the MobiCom conference is shown in the figure below, also available in a large format in Appendix A - MOBICOM19 Poster.

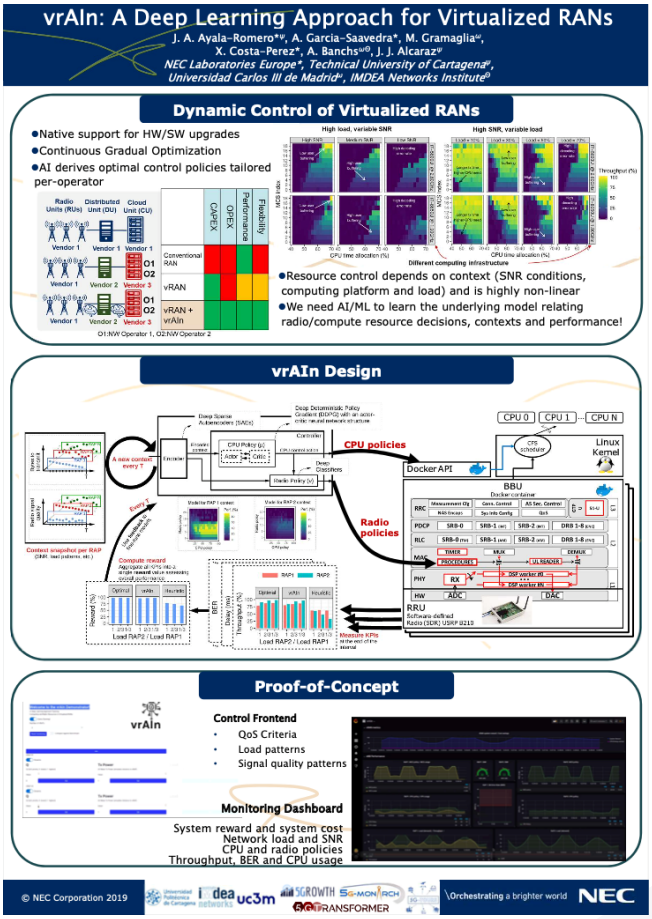

FIGURE 4: MOBICOM19 POSTER

The poster is also available at the 5Growth web site at: https://5growth.eu/wp-content/uploads/2019/06/191015_NEC_vrAIn_Mobicom19_poster.pdf. The presentation process is captured on the next photo.

FIGURE 5: MOBICOM19 PRESENTATION PROCESS

3.1.2. Demonstration details

The concept of the demonstration is described in section 2.1.

3.1.3. Recognition

We were very happy to receive a best demo runner-up award, captured in the following photo.

FIGURE 6: RECEIVING THE BEST DEMO RUNNER-UP AWARD

3.2. 5G end to end experimentation by verticals in EU projects

5Growth led the organization of an online workshop on 5G end-to-end experimentation by verticals in EU projects, in which also 5G-DIVE, 5G-EVE, 5G-VINNI and 5G-Tours projects participated.

3.2.1. Media content

Information on the workshop is available at: http://5growth.eu/5g-end-to-end-experimentation-by-verticals-in-eu-projects/

The demonstration recording is available at: https://youtu.be/YMn5WMIaEV8?t=5520

The presentation banner is shown in Figure 7.

FIGURE 7: PRESENTATION BANNER ON "5G END TO END EXPERIMENTATION BY VERTICALS IN EU PROJECTS" WORKSHOP

3.2.2. Demonstration details

The concept of the demonstration is described in section 2.1.

The demonstration process has been captured in the screenshot shown in Figure 8.

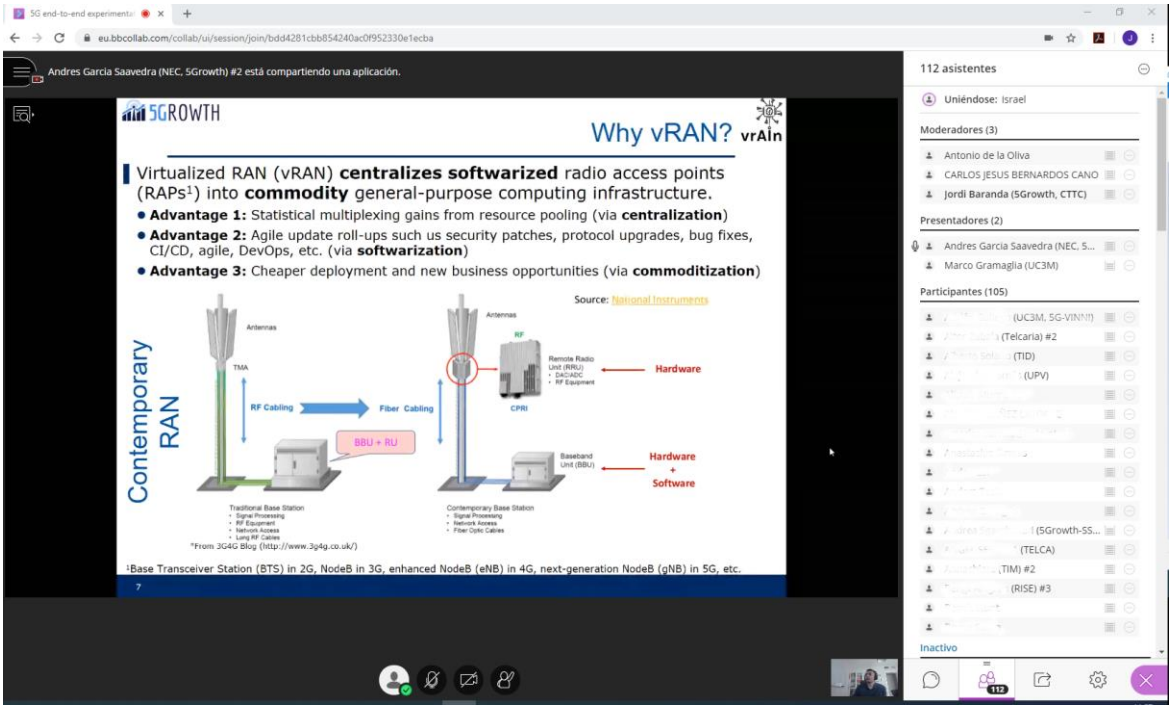

FIGURE 8: DEMONSTRATION PROCESS IN THE "5G END TO END EXPERIMENTATION BY VERTICALS IN EU PROJECTS" WORKSHOP

3.2.3. Recognition

There were about 112 online participants to the workshop. The recording on the YouTube channel has been viewed 299 times as of the time of submission of this updated deliverable.

The survey circulated to attendees that followed the demonstration showed positive results in terms of attendee satisfaction with the program of the workshop, as shown in Figure 9.

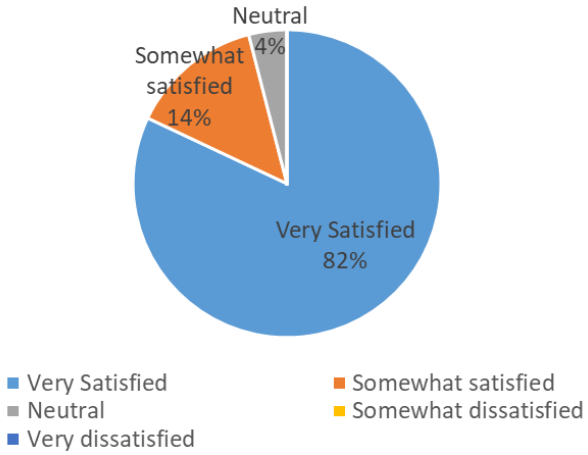

FIGURE 9: RESULTS OF THE ATTENDEE SATISFACTION POLL OF THE "5G END TO END EXPERIMENTATION BY VERTICALS IN EU PROJECTS" WORKSHOP

3.3. 5G PPP Technology Board Workshop 2020

During the 26th and 27th of May of 2020, a two-day 5G PPP Technology Board Workshop took place. This workshop was organized as an online virtual event due to the COVID-19 pandemic. During these two days more than 70 people participated in seven different sessions.

The first day started with sessions on the collaboration among infrastructure and vertical validation trials in 5G PPP projects, on the three 5G PPP automotive projects, and on the Test, Measurement and KPIs Validation WG latest activities. The first day completed its activities discussing the latest status of three white papers, under preparation by the Technology Board, that analyze Edge Computing solutions, the impact of 5G to vertical industries and the use of 5G in indoor environments.

During the second day, several solutions related to the use of Artificial Intelligence and Machine Learning were presented followed by a discussion about their potential impact on 5G networks. The following session was dedicated to the methodology of capturing and analyzing the latest key achievements of 5G PPP Phase II and Phase III projects. Finally, the workshop concluded with a session related to business validation aspects.

As part of the Use of AI & ML in Networks – Part 1 session, 5Growth presented the demonstration on A Deep Learning Approach for vRAN Resource Orchestration.

3.3.1. Media content

Information on the workshop is available at: https://5g-ppp.eu/5g-ppp-technology-board-workshop-2020/

The recording of the demonstration is available at: https://5g-ppp.eu/wp-content/uploads/2020/06/AI-ML-session-1.mp4

The slides presented ara available at: https://5g-ppp.eu/wp-content/uploads/2020/06/4.-AI_Network_Workshop_Andres.pdf

The heading slide of our demonstration is shown in the following screenshot (Figure 10) captured while the demonstration was presented in the workshop.

FIGURE 10: THE HEADING SLIDE OF OUR DEMONSTRATION IN THE 5G PPP WORKSHOP

3.3.2. Demonstration details

The concept of the demonstration is described in Section 2.1.

3.4. OFC'20

OFC is the largest global conference and exhibition for optical communications and networking professionals. The program is comprehensive – from research to marketplace, from components to systems and networks and from technical sessions to the exhibition. OFC draws attendees from all corners of the globe to meet and greet, teach and learn, make connections and move the industry forward.

The five-day technical conference features peer reviewed presentations in 100+ sessions and more than 120 invited speakers, the thought leaders in the industry presenting the highlights of emerging technologies. Additional technical programming throughout the week includes special symposia, special sessions, in-depth tutorials, workshops, panels and the thought-provoking rump session.

The show floor is buzzing with new product announcements and what's trending in the market. Over 100+ exhibitors keep you current on all the latest products and innovative solutions.

The conference took place in San Diego, CA, USA in March 2020.

3.4.1. Media content

Information on the conference is available at: https://www.ofcconference.org

The article is available at: https://www.osapublishing.org/abstract.cfm?uri=OFC-2020-M3Z.10

3.4.2. Demonstration details

The concept of the demonstration is described in Section 2.1.

4. References

[1]. 5GROWTH. "Communication, Dissemination, and Exploitation achievements of Y1 and plan for Y2" Deliverable 5.2, Jun 2020 available at http://5growth.eu/wp-content/uploads/2020/05/D5.2-Communication-Dissemination-and-Exploitation-achievements-of-Y1-and-plan-for-Y2.pdf

[2]. ACM MobiCom 2019, The 25th Annual International Conference on, Mobile Computing and Networking, Oct 21-25, Los Cabos, Mexico, https://sigmobile.org/mobicom/2019/

[3]. The Optical Networking and Communication Conference & Exhibition, https://www.ofcconference.org/en-us/home/

[4]. 5G end to end experimentation by verticals in EU projects, http://5growth.eu/5g-end-to-end-experimentation-by-verticals-in-eu-projects/

[5]. 5G PPP technology board workshop 2020, https://5g-ppp.eu/5g-ppp-technology-board-workshop-2020/

Appendix A - MOBICOM19 Poster