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Orchestration and Reconfiguration Control Architecture

D7.3: Summary of results of second Open Call for experiments

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Authors	Kai Zhang (MARTEL), Wei Liu (IMEC), Kai Zhang (MARTEL), Walter Nitzold (NI), Yi Zhang (TCD), Roberto Bomfin (TUD), Ivan Seskar (Rutgers)
Reviewers	Ingrid Moerman (IMEC)

Abstract	D7.3 will collect the summaries and conclusions of the second Open Call for Experiments. It introduces the Call, the winners, provides an overview of the problem addressed, the main

	challenges, the proposed solution, the results obtained and the main findings with respect to the use of the ORCA testbed and SDR platforms for each of the projects. This deliverable will be used for promotion of the ORCA facility in WP8.
Keywords	Open Call, testbed, SDR

Disclaimer

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PU	Public, fully open, e.g. web	✓
CI	Classified, information as referred to in Commission Decision 2001/844/EC	
CO	Confidential to ORCA project and Commission Services	

EXECUTIVE SUMMARY

This report summarises the organisation and operation of the ORCA 2nd Open Call for Experiment (OC2 EXP).

There are eight winners for OC2 EXP, four fall under the category "Scientific Excellence", and the other four "Industry", as listed below. The main results and conclusions are:

- Scientific Excellence (4)
  - **MAGNUM**: Multi-Access edGe computiNg for fUture wireless systeMs. *Submitted by: Ss. Cyril and Methodius University in Skopje (UKIM) (Macedonia)*

    Main results:
    MAGNUM experiment investigates the container-based virtualization of radio access networks and identify its main benefits and drawbacks, in terms of traffic types, and the physical layer configuration of the RAN, as well as the amount of UE.

    Conclusions:
    The MAGNUM experiment showcases the benefits of RAN virtualization and its fast deployments and rapid/diverse system reconfigurations. These benefits come at a price of higher computational cost, which is not significantly affected by the number of served UEs, but significantly affected by the physical layer configuration of the RAN.

  - **SIREN**: ServIce level agReement ENforcement in ORCA. *Submitted by: Scuola Superiore Sant'Anna (Italy)*

    Main results:
    The ServIce level agReement ENforcement in ORCA (SIREN) experiment evaluated the viability of a solution based on Software Defined Network-Software Defined Radio (SDN-SDR) controllers in mapping Service Level Agreement (SLA) into slice Key Performance Indicators (KPIs) and enforcing KPI thresholds through specific network configurations. To guarantee slice performance isolation in terms of guaranteed minimum bandwidth to a slice the Openflow meter approach was used. If applied to a flow, a meter starts dropping packets if a flow exceeds the meter allowed capacity. Thus, the proposed method applies meters to the slices sharing the link with the slice to which minimum capacity shall be guaranteed. Thus the traffic and, in turn the interference, of the other slices with the slice for which minimum capacity shall be guaranteed is limited.

    Conclusions:
    The utilization of meters allows to guarantee to a slice, based on Openflow, minimum capacity by limiting the traffic of the slices sharing the same link. The meters, which are dropping packets, are effective when the link capacity is fully utilized by the flows sharing the link. However, the considered open virtual switch (OVS) meter implementation shall be improved because, currently, meters are discarding more packets with respect to the maximum allowed capacity for a slice.

  - **ORCA-RAT**: Experimental Study of Multi-RAT Networks. *Submitted by: Technische Darmstadt Universität (Germany)*

    Main results:
    The main goal of the ORCA-RAT experiment was to investigate a full-stack implementation of a Multi-RAT environment including LTE and WiFi. The setup was

used to understand the complications of coupling different access technologies that rely on different channels and associated channel access mechanisms.

Conclusions:
The experiment showed the impact of RAT selection on the overall network capacity with a full-stack and real-time implementation. Furthermore, the experiment gained insights into RAT selection under the constraint of rate imbalances between RATs at higher layers such as TCP congestion control mechanisms.

- **MinDFul:**mmWave Link Doubling Full-Stack Experiments Submitted by: University College Cork (Ireland)

  Main results and conclusions to be included in the next Deliverable 7.5 due to delay of implementation of the project.

- Industry (4)
  - **Concurrent multiple sensing for better channel utilization of Wi-Fi HaLow networks.** *Submitted by: Methods2Business BV (Netherland)*

    Main results:
    In this experiment Methods2Business used Digital Down Converter (DDC) filter banks for concurrent channel selection for Wi-Fi halow technology. They developed two metrics for channel classification, one based upon the CCA_busy_ratio which represents the percentage of period of time that the channel is occupied and another one based upon the Traffic Saturation Metric (TSM) representing the average channel idle time. Based on these two metrics, channels could be classified.

    Conclusion / lessons learned:
    The conclusion is that the two metrics developed in this experiment shows promising results for further usage in commercial market.

  - **multiRATsched:** The extension of multi-criteria LTE MAC scheduler for multiple RAT environment. *Submitted by: IS-Wireless (Poland).*

    Main results:
    The experiment utilized the Multi-RAT platform with LTE and WiFi. A SD-RAN controller was developed that provided RAT selection mechanisms based on different KPIs such as SINR as well as Application Layer Video QoE. The setup was enhanced with a dedicated LTE MAC scheduler.

    Conclusions:
    With the ORCA Multi-RAT platform and testbed, testing and validation of RAN controller product and radio resource management algorithm, both from IS-wireless, in the multi-RAT environment were possible by just focusing on the prototype design and development without caring about the underlying infrastructure implementation for the multi-RAT scenario.

  - **ELASTIC:** Experimental validation of resource management algorithms for elastic network slicing based on end-to-end QoS. *Submitted by: ALLBESMART LDA (Portugal).*

    Main results:

The ELASTIC algorithm proved to be very effective to increase the TCP throughput of the high priority slice if more CPU resources are required to comply with stringent QoS requirements. Testing revealed gains of 48% in downlink, 55,6% in uplink and 49,8% in simultaneous downlink and uplink. ELASTIC was also successful dealing with UDP traffic bursts, even with high throughput demand in both directions at the same time.

Conclusions:

The main conclusion of this experiment is that when two competing cloud RAN LTE slices are implemented over the same computational infrastructure, intelligent management of computational resources is an effective instrument to ensure that high priority slices can cope with demanding QoS requirements under shortage of computational resources. The ELASTIC algorithm implemented in this experiment proved to be effective to increase the performance of a high priority slice without disrupting the operation of the low priority slice.

- **BEE:** Building Emergency Ecosystems. *Submitted by: Level7 S.r.l.u. (Italy)*

  Main results:

  A webserver with proper GUI interface is developed to control ORCA SDR slicing mechanism. The slicing mechanism is used to prioritize traffic during emergency situation. Traffic latency is measured by ping application, it shows that the terminal with high priority's latency is not compromised during an emergency condition.

  Conclusions:

  BEE experiment is able ensure the full support of an emergency terminal, whose traffic is never degraded using the ORCA SDR slicing mechanisms.

TABLE OF CONTENTS

LIST OF FIGURES

LIST OF TABLES

1 INTRODUCTION

The Deliverable 7.3 aims to provide an overview of the results, key outcomes and findings from the Second Open Call for Experiments (OC2 EXP).

It includes an overview of the OC2 for Experiments (OC2 EXP), including call information and the winners (Chapter 2); and then dig deeper into each individual winner project, to analyse its results and implications on ORCA project, the testbed and the SDR platforms (Chapter 3)

Chapter 2 will include the following sub chapters:

- Call Information
- Winners

Chapter 3 will report in detail on the implementation of each winning project:

- Goal of the Experiment
- Main Challenges
- Description of Experiment Setup
- Main Results
- Conclusions and Feedback (with respect to the use of the ORCA testbed and SDR platforms)

2 SECOND OPEN CALL FOR EXPERIMENTS

2.1 Call Information

The OC2 EXP solicits for Experiments for rapid validation of innovative software defined radio (SDR) solutions using the facilities, SDR hardware platforms and software toolsets supported by the ORCA Consortium.

The following Table 1 demonstrates basic Call information

Project full name	ORCA - Orchestration and Reconfiguration Control Architecture
Project grant agreement No.	732174
Call identifier	ORCA-OC2-EXP
Call title	Second ORCA Open Call for Experiments
Submission deadline	Sunday the 9th December 2018, at 17:00 CET
Feasibility & relevance check deadline	Sunday the 2nd December 2018, at 17:00 CET

Table 1: ORCA OC2 EXP Basic Call Information

The SDR functionalities that are used in the OC2 EXP include:

- SDR data plane functionality
- SDR control plane functionality
- SDR management plane functionality
  - Over the testbed control backbone
  - Over the air

Within the context of ORCA, six testbeds were made available for experimentation by ORCA partners or by Third Parties selected via the OCs:

- IMEC w-iLab.t testbed for heterogeneous environments
- IMEC Portable testbed
- RUTGERS ORBIT heterogeneous multi-node testbed
- TCD IRIS network virtualization testbed
- TUD OWL scale testbed
- KUL dense multi-node networks testbed

In terms of financial information, the total budget for OC2 EXP: 350,000€. Maximum budget per Experiment: 50,000€. It is defined that each project will have guaranteed support of 28,000€, with an extra budget of typically €4000 per Experiment will be allocated to the ORCA consortium partner acting as Patron for guaranteed support. Since there were only six projects funded in OC1 EXP, remaining budget was able to fund one additional project under “Scientific Excellence” in OC2 EXP.

Therefore, for the two categories of projects to be funded, in total there are eight winners:

- Scientific Excellence (4 projects)
- Industry (4 projects)

2.2 Winners

An established, independent and impartial evaluation process, of confidential nature has been applied to filter and select the winning proposals. A brief summary of the process is as follows:

- Feasibility check
  - Candidates provide a first submission
  - Patrons evaluate the feasibility and relevance of the proposals and provide feedback
- Final submission and evaluation
  - Based on the feedback, the proposals passed the feasibility check will submit the final applications
  - External evaluators receive and review the final applications based on a set of criteria and give scores
  - Consensus meetings between evaluators were held when necessary to agree on the winners

The following projects have won the ORCA OC2 EXP, eight in total:

Scientific Excellence

- **MAGNUM:**Multi-Access edGe computiNg for fUture wireless systeMs
  Submitted by: Ss. Cyril and Methodius University in Skopje (UKIM) (Macedonia)
- **SIREN:** ServIce level agReement ENforcement in ORCA
  Submitted by: Scuola Superiore Sant'Anna (Italy)
- **ORCA-RAT:**Experimental Study of Multi-RAT Networks
  Submitted by: Technische Darmstadt Universität (Germany)
- **MinDFul:**mmWave Link Doubling Full-Stack Experiments
  Submitted by: University College Cork (Ireland)

Industry

- **Concurrent multiple sensing for better channel utilization of Wi-Fi HaLow networks**
  Submitted by: Methods2Business BV (Netherland)
- **multiRATsched:** The extension of multi-criteria LTE MAC scheduler for multiple RAT environment
  Submitted by: IS-Wireless (Poland)
- **ELASTIC:** Experimental validation of resource management algorithms for elastic network slicing based on end-to-end QoS
  Submitted by: ALLBESMART LDA (Portugal)
- **BEE:** Building Emergency Ecosystems
  Submitted by: Level7 S.r.l.u. (Italy)

The following Chapter 3 will provide detailed accounts on results of each of the winning project, with the exception of one winner under "Scientific Excellence" entitled mmWave Link Doubling Full-Stack Experiments (MinDFul).

The MinDFul experiment has not been reported in this deliverable due to some unexpected inconveniences throughout the time plan of the experiment. Initially, the experiment was planned to be finished by the end of September 2019. However, there were some relatively long discussions between the legal departments of the open call partner and ORCA, about the terms of the contract with the open call partner. As a result, the contract with the open call partner was extended such that the experiment was expected to be finalized by the end of December 2019.

In addition to that, this experiment has a particularity which involves emulating a mobility scenario with one of TUD's robots. Although the partner has remote access to TUD's testbed for designing the software part of this experiment, it is highly recommended that the he comes to TUD's laboratory to have a closer contact with the physical part of his experiment in our site, such that he has more freedom to perform the tasks. In this regard, open call partner needed to request for a VISA in order to enter Germany, where TUD is located, which was obtained only by the 13th November. Therefore, his first visit to TUD's testbed was from the 25th to 29th of November 2019. Since the open call partner plans to have a second visit at TUD to perform the experiment, it was not possible to report the results in this deliverable because they are still ongoing. Therefore, he will report his results in the next deliverable of open call for experiments.

3 SUMMARY OF RESULTS OF EACH PROJECT

3.1 Scientific Excellence

3.1.1 MAGNUM

3.1.1.1 Goal of the Experiment

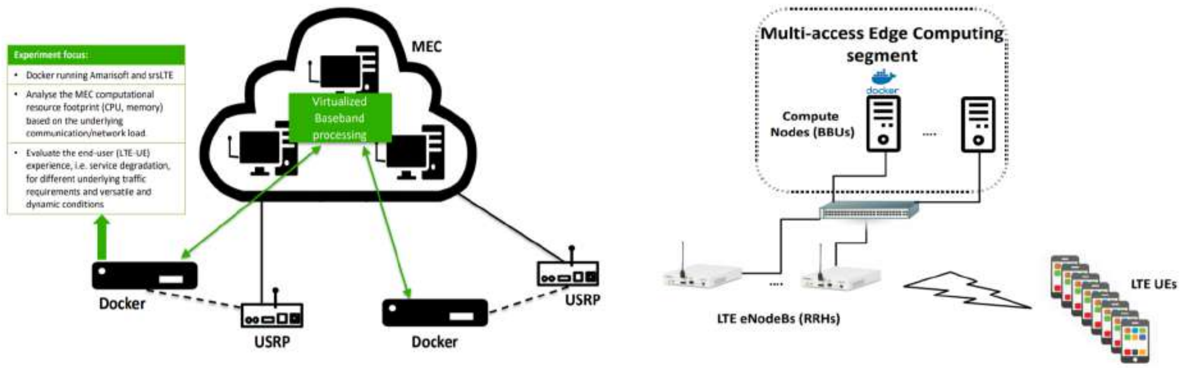
The main goal of the MAGNUM experiment is to investigate the container-based virtualization of radio access networks and identify its main benefits and drawbacks. The experiment also analyses the effects of scalability and traffic types and provides valuable insights for future practical deployments of full-stack containerized MEC-based RAN solutions.

3.1.1.2 Main Challenges

Exploit the software-defined operation of LTE and implement a Docker-based LTE virtualization Analyse the computational resource footprint based on the underlying communication/network load and configuration. Evaluate the effect of scalability in terms of active UEs and their traffic types. Discover the most appropriate computational resource scaling solution.

3.1.1.3 Description of Experiment Setup

The MAGNUM architecture comprises of two logical entities, Remote Radio Heads (RRHs) and Multi-access Edge Computing (MEC) segment, as indicated in Figure 1. The RRHs contain the RF hardware in the system and that do not perform any baseband signal processing. MAGNUM uses the Universal Software Radio Peripheral (USRP) X310 and B210 devices as RRHs. The MEC segment incorporates a container-based virtualization of an LTE base station that utilizes the docker framework. The specific experiment platform uses the Amarisoft commercial LTE BBU software, implementing a full stack LTE Rel. 14 base station. The LTE mobile station i.e. UEs, are also ran over USRP devices and use the srsLTE software.



a) b)

Figure 1 MAGNUM experiment: a) outline of the experiment; b) platform generic architecture

The MEC segment runs over a set of dedicated compute nodes. The nodes represent the available MEC pool of resources such as, CPU and RAM that are allocated to the virtual LTE instances. The nodes run on a server-grade machines with Intel Xeon processors over an Ubuntu 16.04 LTS using a low latency kernel. The fronthaul link between the RRHs and the BBUs is enabled by 10GbE links, routed over an 10GbE switch. Figure 2 depicts the implementation layout of the MAGNUM experiment in the ORBIT tested.

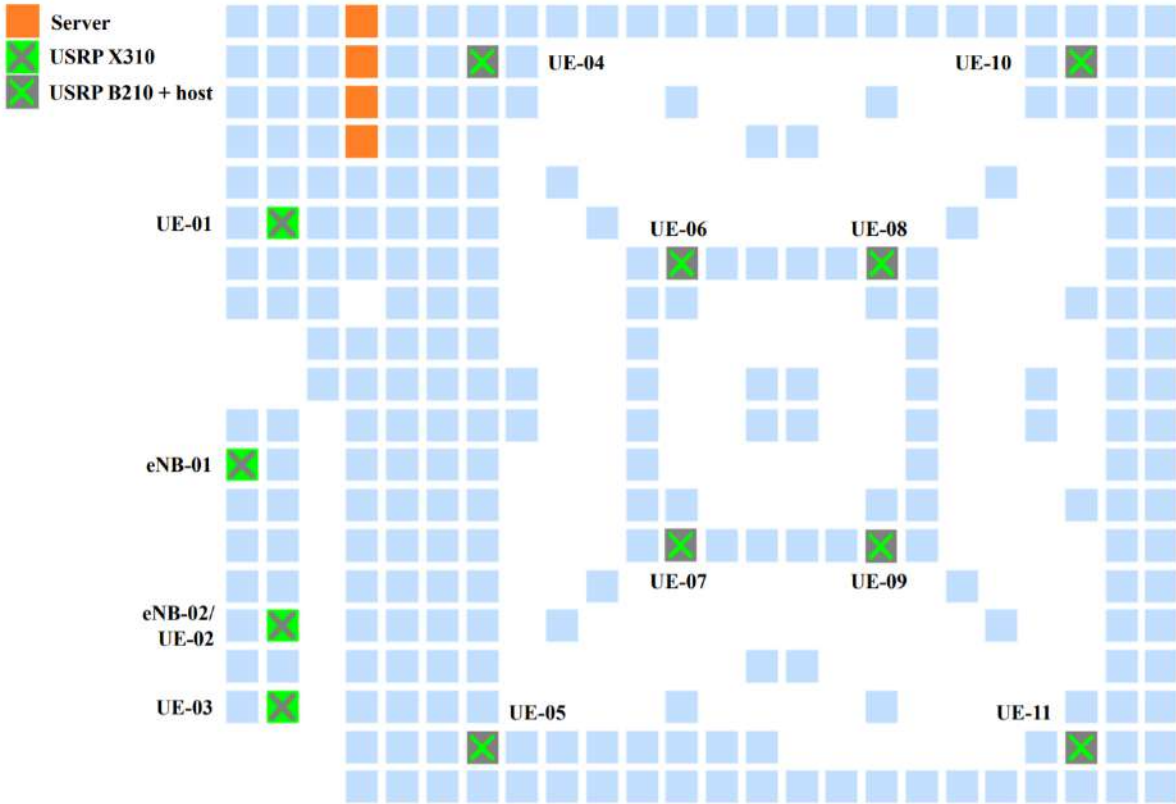


Figure 2 MAGNUM experiment layout over ORBBIT's grid

3.1.1.4 Main Results

Fostering efficient operation of the enabling self-organization and intelligence-based technologies for Cloud-RAN deployment, requires large knowledge base and understanding of the virtualized RAN performance behavior. MAGNUM specifically focuses on evaluating the full stack containerized LTE performance behavior for different system configuration and traffic loads. The results will be used as the primary step in understanding large scale commercial deployments. The experiment also focuses on the resource scaling and its impacts on the underlying user performance.

The MAGNUM experiment showcases the benefits of RAN virtualization and its fast deployments and rapid/diverse system reconfigurations. These benefits come at a price of higher computational cost, which is not significantly affected by the number of served UEs, but significantly affected by the physical layer configuration of the RAN. Infrastructure issues such as fronthaul design, need to be carefully considered, in order to provide stable and reliable virtualized RANs.

Figure 3 presents the time series of the CPU utilization and the LTE cell reconfiguration time between LTE bandwidths of 5 MHz and 10MHz for the SISO and the MIMO case. These results show that the reconfiguration delay is in order of few seconds, which proves the flexibility and the swiftness of the virtualized LTE solution. Moreover, the results clearly show that the MIMO configuration requires higher processing power, compared to the SISO case.

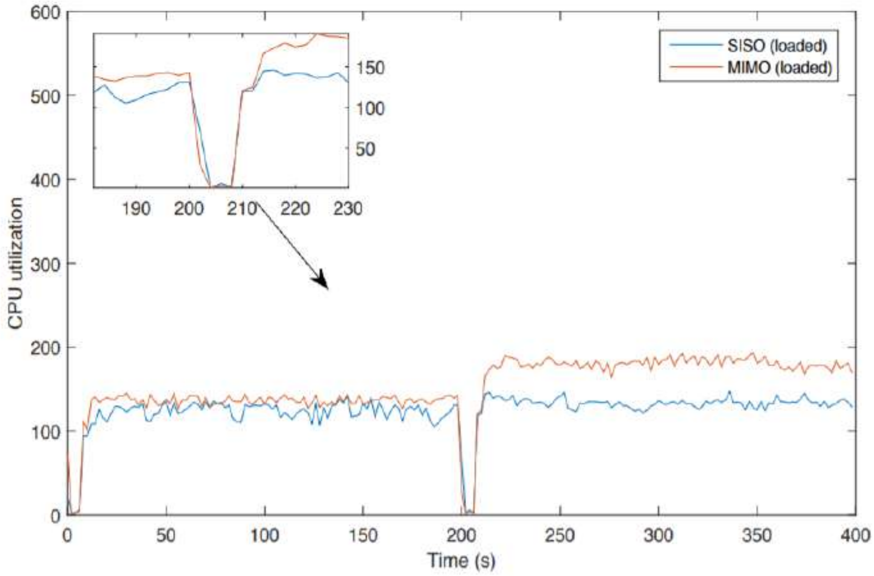


Figure 3 Time series of the transitions between 5MHz (0-200s) and 10 MHz (200-400s) in terms of CPU utilization, for the SISO and MIMO case and fully loaded LTE base station.

Figure 4 depicts the throughput cost in dependence of the number of active UEs, for a containerized full stack LTE base station in SISO mode. The throughput cost is defined as the ratio between the number of CPU cores used for each served Mpbs of aggregate traffic. The results clearly show that serving higher number of users, as well as using lower channel bandwidths is more resource costly, but the scalability effect (number of UEs) is not significant.

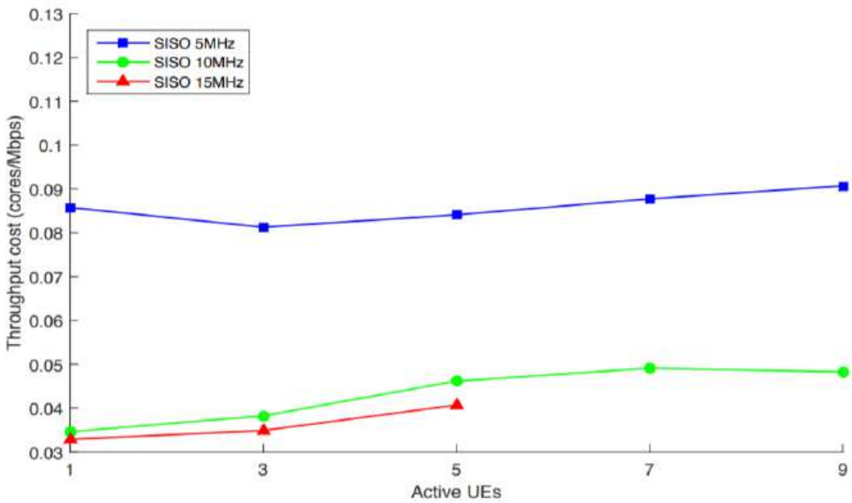


Figure 4 : Throughput cost vs number of UEs for a containerized full stack LTE base station in SISO mode.

3.1.1.5 Conclusions and Feedback (with respect to the use of the ORCA testbed and SDR platforms)

The main benefits of RAN virtualization are the fast deployments and rapid/diverse system reconfigurations. The number of served UEs has no significant impact on CPU consumption in LTE and 5G deployments, but physical layer configuration does. A high capacity, low latency fronthaul implementation is a necessity in C-RAN solutions.

ORCA provides a playground for fostering and experimenting with new ideas in the area of wireless networks. It is easy to use and deploy experiments on the platform. Thanks to the software tools and the hardware provided by ORCA it was easy to run the envisioned experiment.

3.1.2 SIREN

3.1.2.1 Goal of the Experiment

The ServIce level agReement ENforcement in ORCA (SIREN) project objective was to evaluate the viability of a solution based on Software Defined Network-Software Defined Radio (SDN-SDR) controllers in mapping Service Level Agreement (SLA) into slice Key Performance Indicators (KPIs) and enforcing KPI thresholds through specific network configurations.

3.1.2.2 Main Challenges

To do so the SIREN project complemented current SDN-SDR control software (e.g., Openflow, FINS) with functions of SLA mapping into KPIs, KPI enforcement, and KPI monitoring.

3.1.2.3 Description of Experiment Setup

The performed experiments evaluated the capability of the proposed solution to fulfil such requirements by means of application-level active probes. Moreover, it investigated how different KPIs contributed to the end-to-end performance.

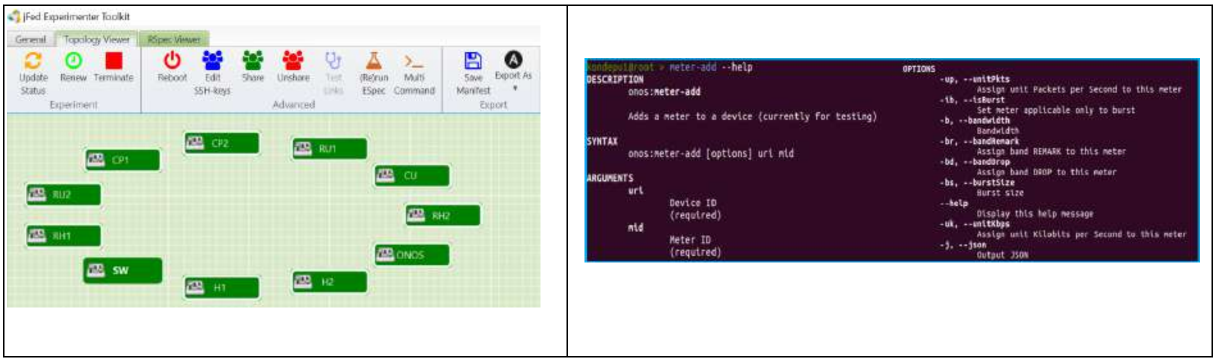


Figure 5 SIREN Experiment setup.

3.1.2.4 Main Results

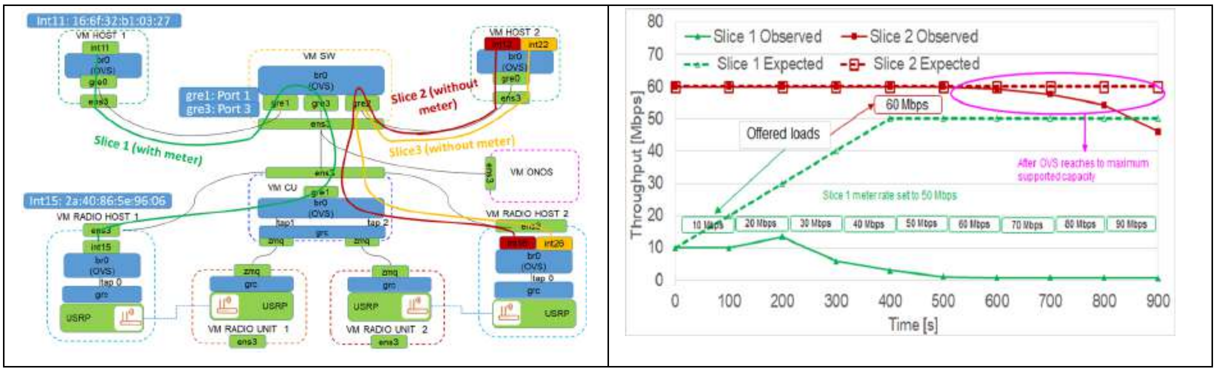


Figure 6 Main results of SIREN.

The Figure 6 shows the throughput obtained and expected when the Slice 1 meter set to 50 Mbps and Slice 2 offered load is set to 60 Mbps without meter. The experiment duration is set to 900s and every 100s the Slice 1 offered load is increased by 10 Mbps. Slice 2 provides minimum guaranteed capacity (i.e., 60 Mbps) until the overall offered load reaches the maximum supported capacity of the OVS.

3.1.2.5 Conclusions and feedback (with respect to the use of the ORCA testbed and SDR platforms)

The utilization of meters allows to guarantee to a certain slice, based on Openflow, minimum capacity by limiting the traffic of the traffic sharing the same link. The meters, which are dropping packets, are effective when the link capacity is fully utilized by the flows sharing the link.

The ORCA facilities provided by the considered testbed were very good to perform the experiment. ORCA provided a base experiment setup that we could simply modify and integrate to evaluate our proposed solutions. An important added value was the availability of sample setups that shortened the time to experiment.

3.1.3 ORCA-RAT

3.1.3.1 Goal of the Experiment

We aim to understand the complications of coupling different radio access technologies (RATs) which not only operate on different channel but also use different channel access mechanisms (OFDMA and CSMA). In particular, we aim to provide design insight into choice of RAT coupling and coordination strategies.

3.1.3.2 Main Challenges

We face two main challenges in this experiment. Firstly, we had to modify the implementation to collect additional performance metrics at different layers of network stack and defining methods to report these values back to the central controller. Secondly, implementing the necessary functionalities to enable bi-directional TCP connections.

3.1.3.3 Description of Experiment Setup

Our experiments rely on the multi-RAT capability as well as the full-stack implementation of ORCA LTE-WLAN radio aggregation (LWA) and LTE-WLAN radio level integration (LWIP). PHY layer and a portion of MAC layer functionalities are implemented in the FPGA on the SDRs. The SDRs are then connected to NS3 via the L1/L2 API to complement the rest of the network stack up to the application later.

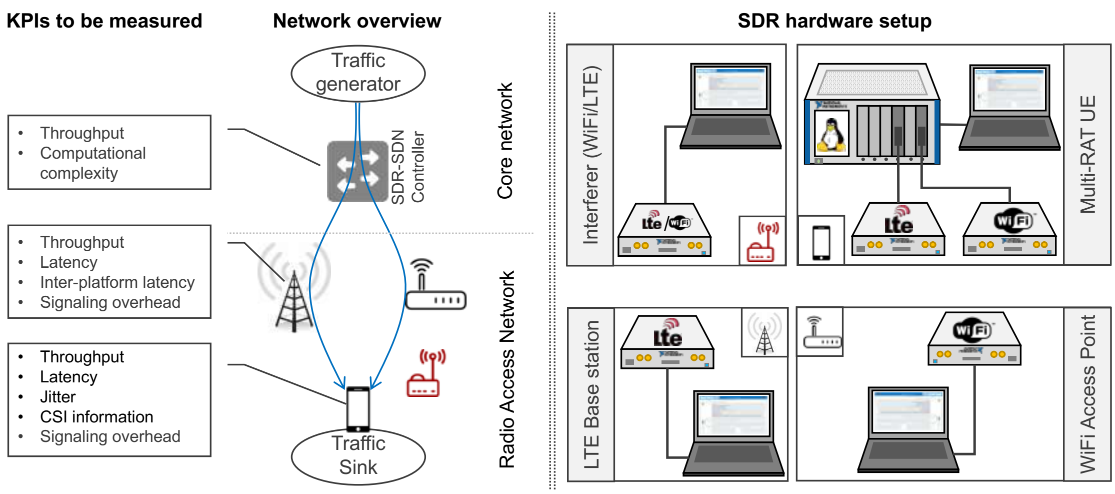


Figure 7: ORCA-RAT Experiment Setup

3.1.3.4 Main Results

ORCA-RAT aim at evaluating the performance of a real-time full-stack multi-RAT system. We have implemented a feedback mechanism to allow the eNodeB to access KPIs such as throughput and delay figures. Furthermore, we have devised a simple RAT selection algorithm which operates based on these KPIs. Our results show channel variation has high impacts on the performance of higher layer protocols (TCP in this experiment) and leveraging even simple RAT selection strategy to account for such variations can significantly reduce the delay/jitter experienced by the applications as well as increasing the throughput.

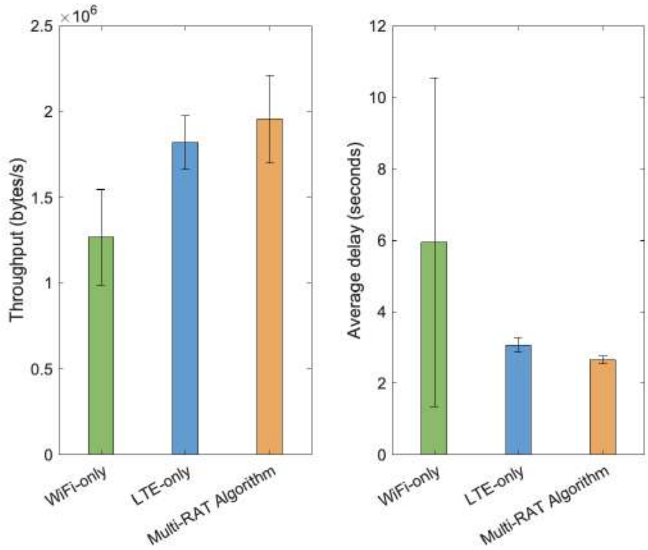


Figure 8: ORCA-RAT Main Results

3.1.3.5 Conclusions and Feedback (with respect to the use of the ORCA testbed and SDR platforms)

This is the first full-stack and real time experimental study of multi-RAT systems. In particular, we have shown how selection of RAT impacts the overall network capacity. Furthermore, we demonstrated the effect of RAT selection and rate imbalance between RATs on the higher layers of stack such as TCP congestion control mechanism. The outcome of this experiments can be used as design guideline for future multi-RAT systems in particular after integration of millimetre-wave radio which will increase the rate imbalance even further.

Our experience with ORCA consortium in general and our patron, NI, in particular has been satisfactory. None of the aforementioned results could have been achieved without access to ORCA test facility as well as the support from patron.

3.2 Industry

3.2.1 Concurrent multiple sensing for better channel utilization of Wi-Fi HaLow networks

3.2.1.1 Goal of the Experiment

Methods2Business major objective was to prove that concurrent sensing of multiple channels in a Wi-Fi HaLow network leads to a more efficient channel utilization, maximizing the throughput of Wi-Fi HaLow devices in the network. The intention was to apply the Digital Down Converter (DDC) filters provided by the ORCA project for the channel sensing and develop a mechanism for channel switching.

3.2.1.2 Main Challenges

The two main challenge were on the one side, to identify a reliable metric for classifying channels in a Wi-Fi network based on the measured wireless activity in the channel, and on the other side, to develop an efficient mechanism for channel switching that complies with the IEEE 802.11ah standard.

3.2.1.3 Description of Experiment Setup

The experiment consists of two Xilinx ZC706 Evaluation Kit - Zynq® 7000 SoC boards, from which the first one represents an Access Point (AP) and the second one represents a Station (STA). The traffic between them is captured with an SDR-based sniffer that is connected to MatLab using the libiio library from Analog Devices Inc. The figure below shows the experiment setup at the imec w-iLab.t.2 lab.

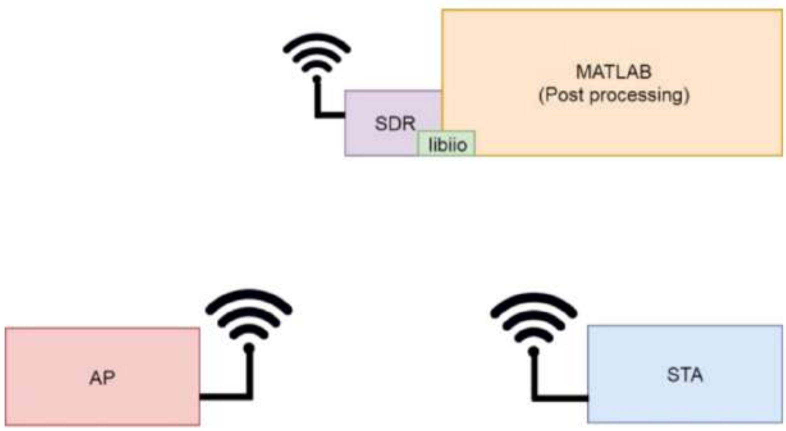


Figure 9 ConcurrentHalow experiment setup.

3.2.1.4 Main Results

Methods2Business developed two metrics for channel classification, one based upon the CCA_busy_ratio which represents the percentage of period of time that the channel is occupied and another one based upon the Traffic Saturation Metric (TSM) representing the average channel idle time. Based on these two metrics, channels could be classified.

The figures below show the CCA_busy_ratio and the Traffic Saturation Metric in function of the saturation of the network which is defined by the following formula.

Eq(1): SAT = 1- Effective throughput/Desired throughput

where Desired throughput is the sum of the throughputs STAs are trying to achieve

The numbers (1, 2 and 3) mean the following:

1: No Saturation, meaning effective throughput equals desired throughput

2: Partial saturation

3: Full saturation

As indicated by the figures below, classification based upon the Traffic Saturation Metric gives a more precise indication of the channel condition.

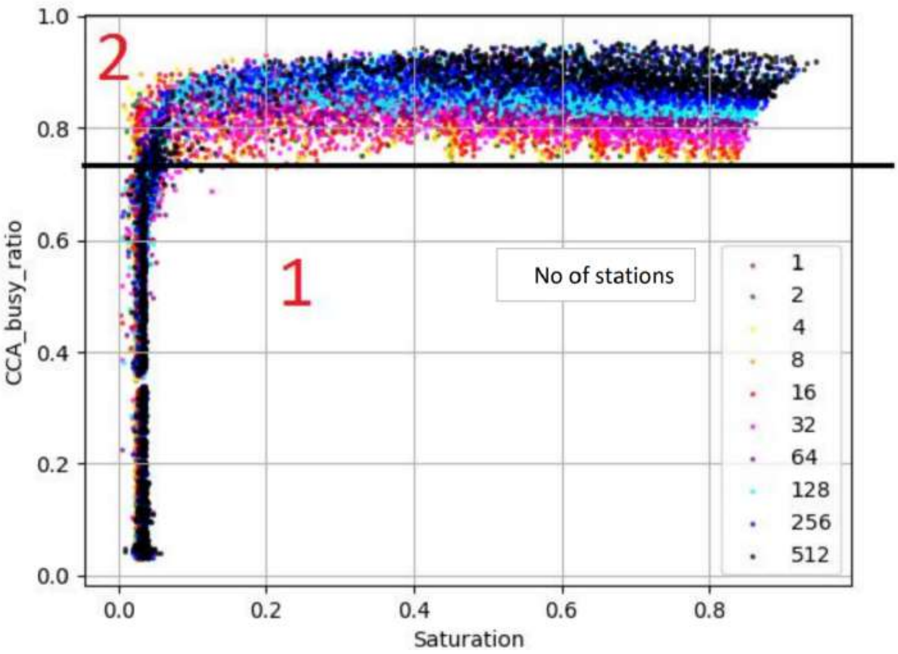


Figure 10 Main results of ConcurrentHalow, CCA_busy_ratio in function of network saturation.

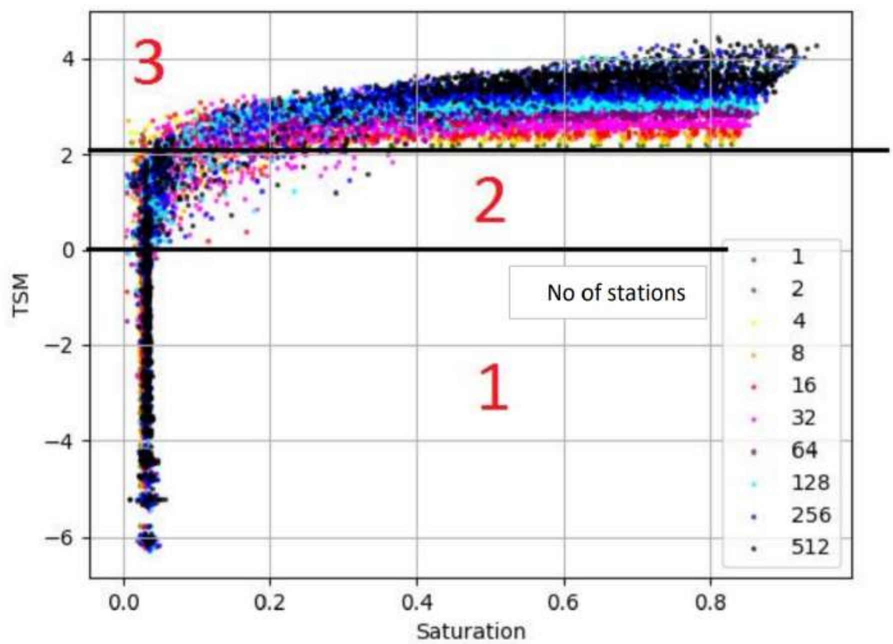


Figure 11 Main results of ConcurrentHalow, Traffic Saturation Metric in function of Network Saturation.

In addition to channel classification, Methods2Business developed two mechanisms for channel switching, one to be applied during initialization of the network and another for a network in operation.

3.2.1.5 Conclusions and Feedback (with respect to the use of the ORCA testbed and SDR platforms)

Concurrent sensing of multiple channels to enable channel switching, is a promising concept for maximizing throughput in a Wi-Fi HaLow network. The mechanisms developed for channel sensing based on ORCA's DDC filters and channel switching, were illustrated using the imec test facility and showed promising results for further implementation in Methods2Business commercial Wi-Fi HaLow access points.

3.2.2 multiRATsched

3.2.2.1 Goal of the Experiment

The goal of proposed work is to utilize and exploit ORCA tools and facility to evaluate the performance of proposed LTE MAC scheduler and SD-RAN controller in the multi-RAT environment.

3.2.2.2 Main Challenges

Testbed availability is one the biggest challenges faced during the project. Moreover, remotely accessibility of testbed was challenging as well as multiple nodes (PCs and USRPs) have to be accessed remotely with proper setting configurations.

3.2.2.3 Description of Experiment Setup

Figure 12 shows an overview of the experiment setup and connectivity of the implemented modules within TUD testbed. For the experiments, the media server is implemented within the Win7 Host PC connected to the eNB PXI controller whereas media client is made at the Win7 Host PC connected the UE PXI controller. The RAN controller modules and the database for the QoE related information exchange are implemented inside the Ubuntu PC. In order to exploit the multi-RAT use case of the testbed, noise is purposely added to the LTE link so that RAN controller can trigger automatic switching to WiFi link based on the SINR and QoE measurements. For the addition of the noise, separate Labview process is generated for noise. The noise generator output is combined with the transmission of LTE link using the combiner in the cabling setup. The experiment utilizes the testbed in the TAP bridge configuration which means that external traffic is forwarded to the NS3 generated traffic. Therefore, two packet forwarding scripts are used at PXI controllers: first at eNB PXI controller for forwarding the media traffic from media server into the NS3 TAP bridge and; second at UE PXI controller to forward the media traffic from the NS3 TAP bridge to media client.

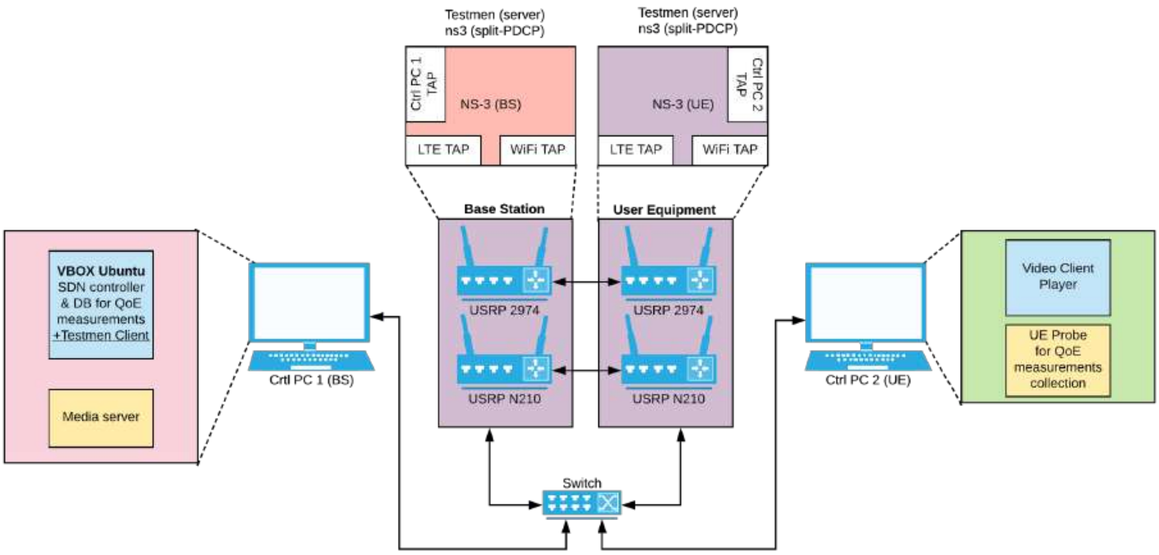


Figure 12: multiRATSched Experimental Setup

3.2.2.4 Main Results

Four different scenarios:

- Round Robin scheduler in LTE without RANC;
- Proportional Fair scheduler without RANC;
- SINR based information centric LWA switching from LTE to WiFi using RAN controller;
- QoE-aware LWA switching from LTE to WiFi via RAN controller

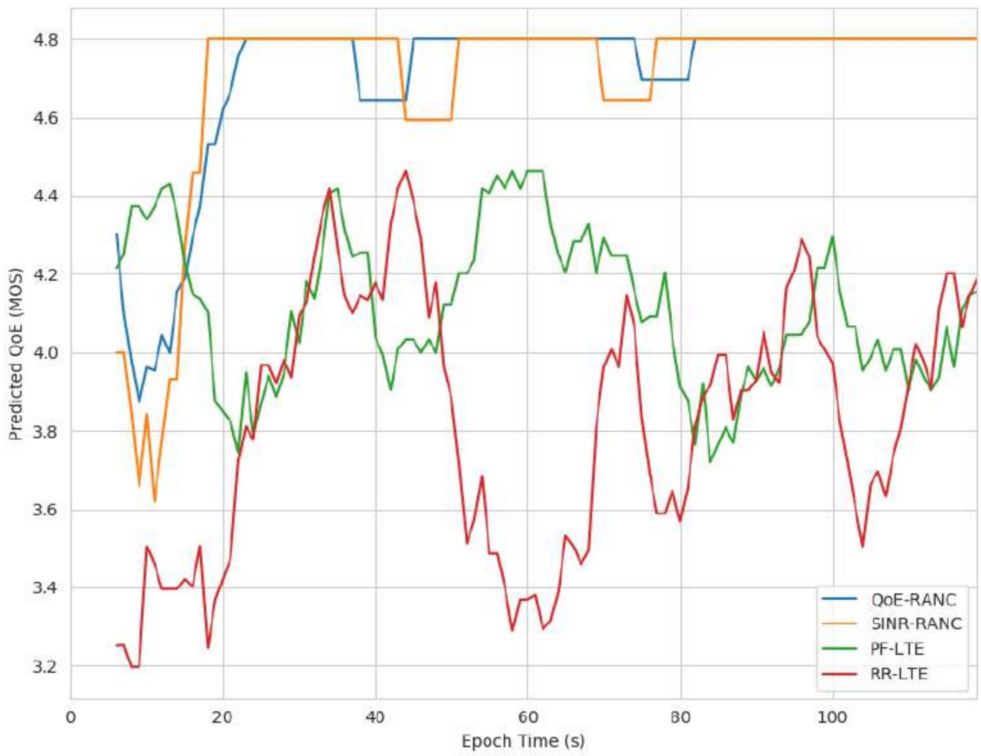


Figure 13: Predicted QoE (MOS) over Epoch Time (s)

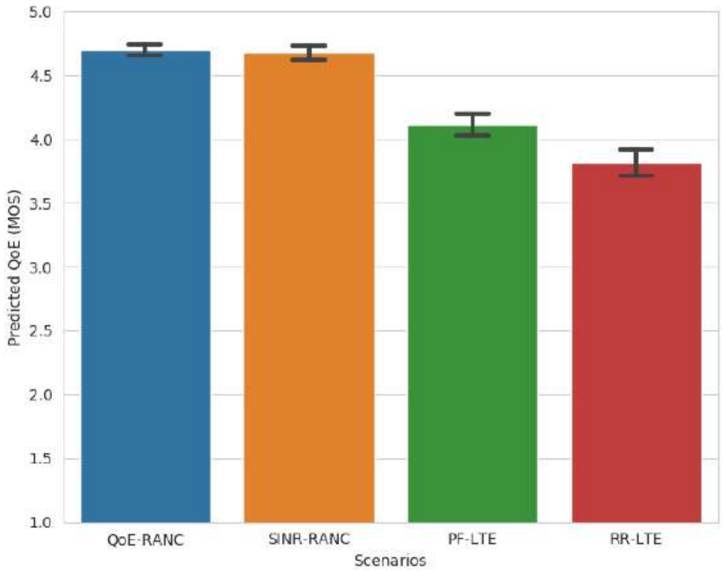


Figure 14: Accumulated average predicted QoE for each scenario

3.2.2.5 Conclusions and Feedback (with respect to the use of the ORCA testbed and SDR platforms)

With the ORCA consortium testbed, testing and validation of RAN controller product and radio resource management algorithm, both from IS-wireless, in the multi-RAT environment were possible by just focusing on the prototype design and development without caring about the underlying infrastructure implementation for the multi-RAT scenario.

ORCA experimentation testbed allows us to experiment the ideas and concepts in a realistic environment together with the support from patron and open source code availability. The patron also organized a workshop including essential training which proved to be quite useful to learn the functionalities of the ORCA testbed.

All in all, we had a great experience regarding communication and support from the testbed Patron. Moreover, with the help ORCA facility we have been able to test and experiment novel ideas that were not tested before in realistic testbed environments. This helped us to understand the concepts as well as we managed to train ourselves with testbed and issues related with real life testing.

3.2.3 ELASTIC

3.2.3.1 Goal of the Experiment

The main objective of this experiment is the validation of elastic resource management algorithms able to serve multiple Network Slice Instances (NSI) over the same physical resources while optimizing the allocation of computational resources to each slice based on its requirements and demands.

The experiment deploys a use case on top of the IRIS testbed that provides two services over two network slices, with a focus on the QoS-aware control and CPU usage. The goal is to have two competing network slices on the cloud infrastructure: one emulating a MVNO Public Safety service with high throughput and reduced latency requirements and the other emulating an OTT service provider (delay tolerant – best effort slice). A resource management algorithm is implemented and evaluated in terms of performance gains when operating under computational resource limitations.

3.2.3.2 Main Challenges

The main challenges of this experiment can be divided into two distinct dimensions: understanding how the srslte software uses computational resources under distinct eNodeB configurations and traffic profiles and how to manage computational resources so that the high priority slice can cope with stringent SLA requirements without disrupting the low priority slice.

3.2.3.3 Description of Experiment Setup

The experiment setup created in IRIS uses four computing nodes, as can be seen in the diagram shown in Figure 15. Machine A implements the EPC and eNodeB components of the LTE network, while machine B contains the UE component. Machine C is used to exchange traffic patterns with the UE through the LTE network, using the iperf tool. Finally, machine D implements the ELASTIC algorithm: it receives traffic and CPU usage data from the two probes and determines the actions to perform in order to comply with QoS requirements.

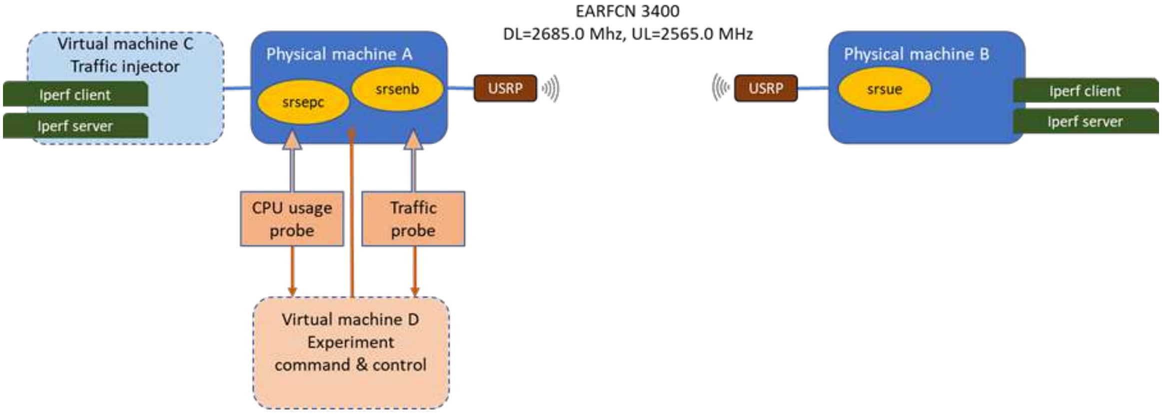


Figure 15 Experiment setup in IRIS.

The two B210 USRPs are configured in single antenna mode, using the LTE EARFCN frequencies: DL=2685.0 MHZ, UL=2565.0 MHz. Access to each virtual machine is achieved through JFED, using SSH terminal sessions.

3.2.3.4 Main Results

The ELASTIC algorithm proved to be very effective to increase the TCP throughput of the high priority slice if more CPU resources are required to comply with stringent QoS requirements. Testing revealed gains of 48% in downlink, 55,6% in uplink and 49,8% in simultaneous downlink and uplink. Figure 16 shows the results of the TCP downlink test.

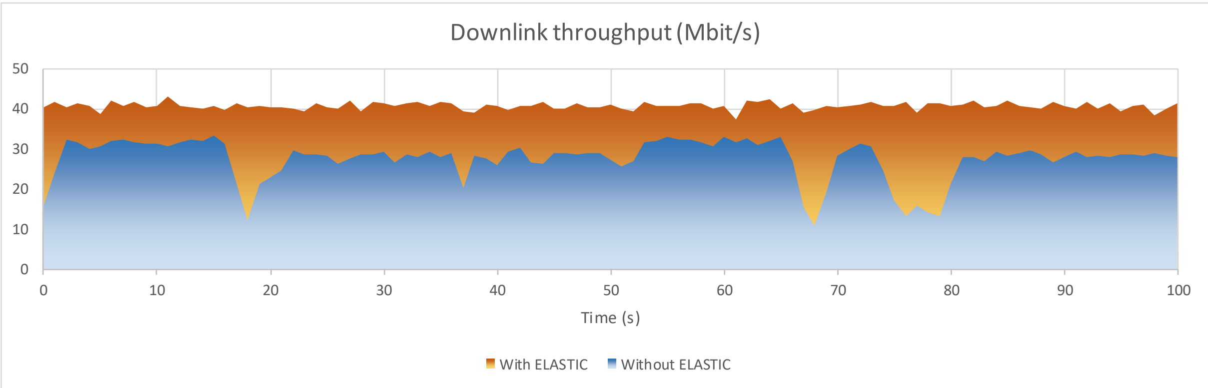


Figure 16 TCP download throughput comparison.

ELASTIC was also successful dealing with UDP traffic bursts, even with high throughput demand in both directions at the same time. Figure 17 illustrates how ELASTIC deals with UDP traffic bursts and its impact on CPU usage.

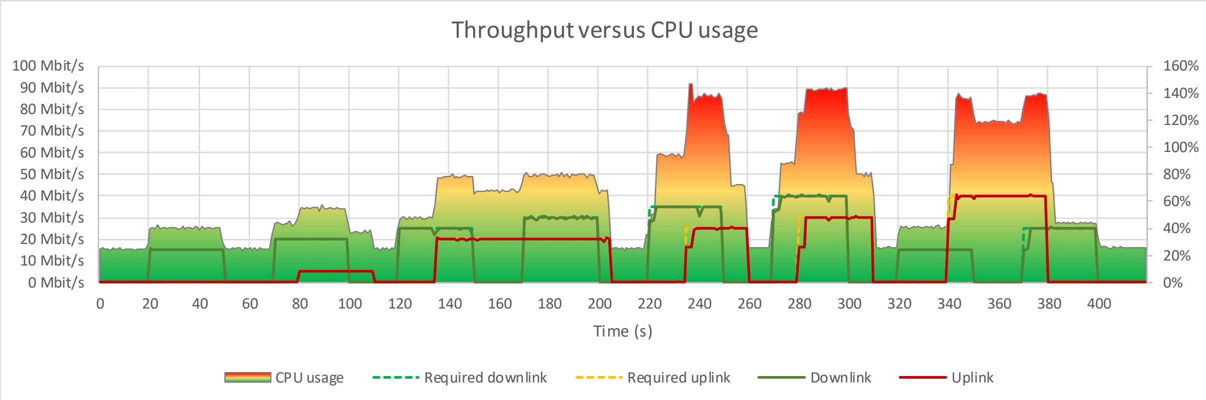


Figure 17 How ELASTIC handles UDP traffic bursts.

3.2.3.5 Conclusions and Feedback (with respect to the use of the ORCA testbed and SDR platforms)

The main conclusion of this experiment is that when two competing cloud RAN LTE slices are implemented over the same computational infrastructure, intelligent management of computational resources is an effective instrument to ensure that high priority slices can cope with demanding QoS requirements under shortage of computational resources. The ELASTIC algorithm implemented in this experiment proved to be effective to increase the performance of a high priority slice without disrupting the operation of the low priority slice.

ORCA was extremely useful to support this experiment, by allowing our company to have remote access to equipment and resources, namely USRPs and computational nodes, that are usually beyond our reach. The way how different network scenarios can be easily created within JFED, even interconnecting nodes of distinct testbeds, has been perceived as a major advantage of ORCA.

Thanks to the ORCA facility we were able to substantially increase our expertise on cloud RAN technologies and test resource management algorithms using radio equipment that otherwise would be beyond our reach.

3.2.4 BEE

3.2.4.1 Goal of the Experiment

The goal of the BEE experiment is to provide a robust wireless access infrastructure in indoor environment where emergency services should be provided. The use of the existing wireless infrastructure will permit a better use of resources as well as better indoor support and deployment.

3.2.4.2 Main Challenges

The main challenge in the BEE experiment has been to use implement QoS/QoE ideas in a novel and open SDR implementation. The support from the ORCA facilities permitted to quickly focus on the main aspects of SDR technologies and provide traffic differentiation.

3.2.4.3 Description of Experiment Setup

The BEE experiment controls the SDR device in order to support emergency scenarios. The SDR can be driven in real time via the GUI (shown in the figure below) thanks to the ORCA APIs.

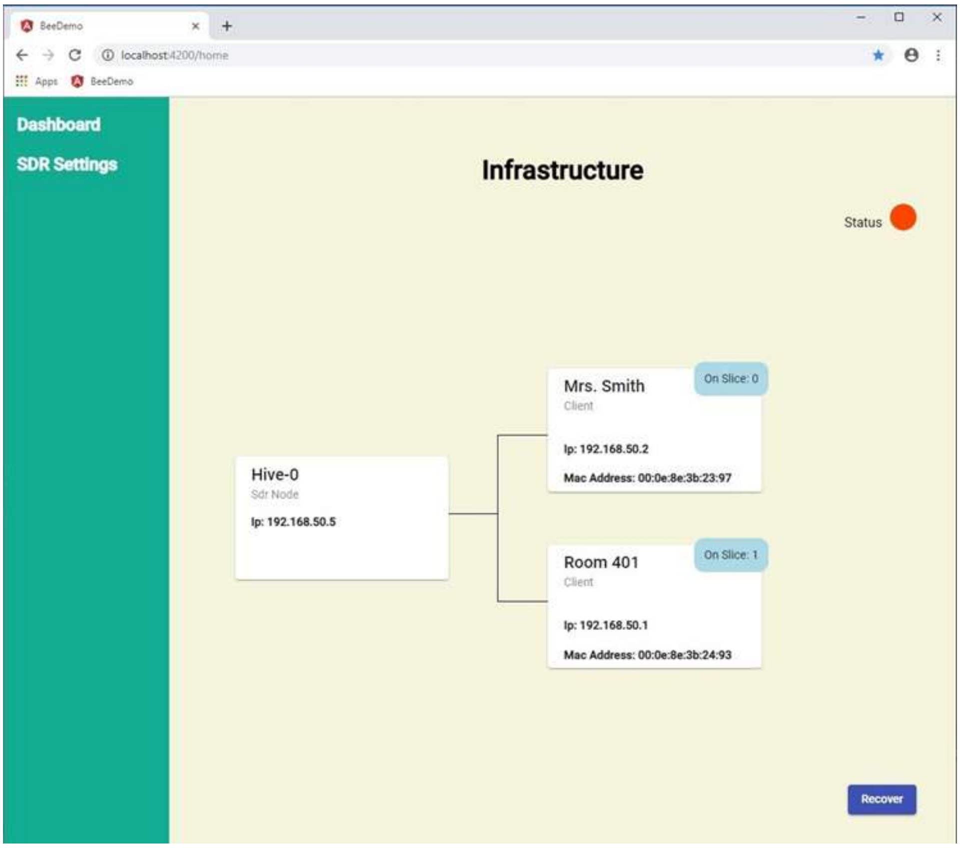


Figure 18 BEE GUI interface showing the infrastructure view.

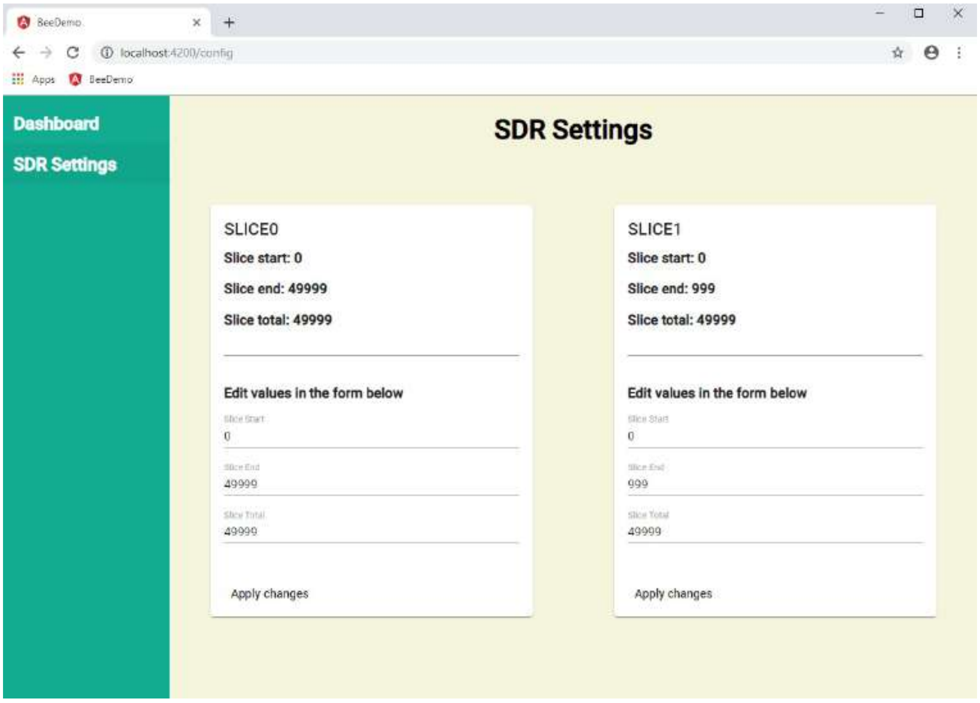


Figure 19 BEE GUI interface showing the SDR settings.

3.2.4.4 Main Results

The SDR device permits traffic differentiation and the full support of an emergency terminal that whose traffic is never degraded, while normal traffic can show degradation.

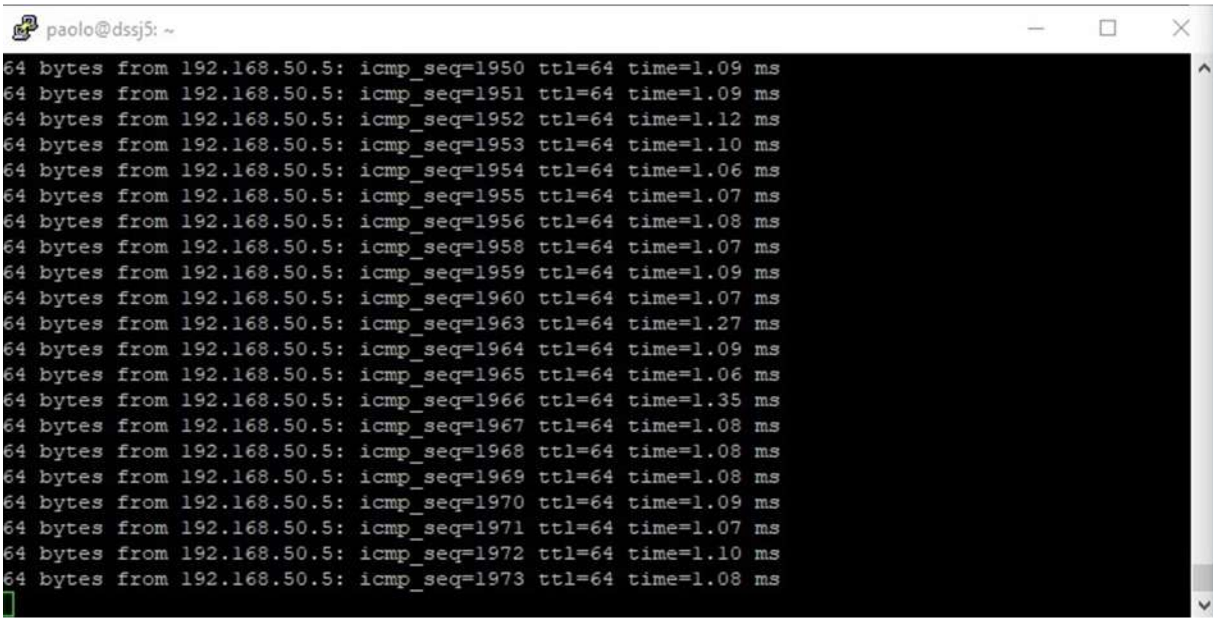


Figure 20 BEE ping results for the "panic button" terminal during the emergency status.

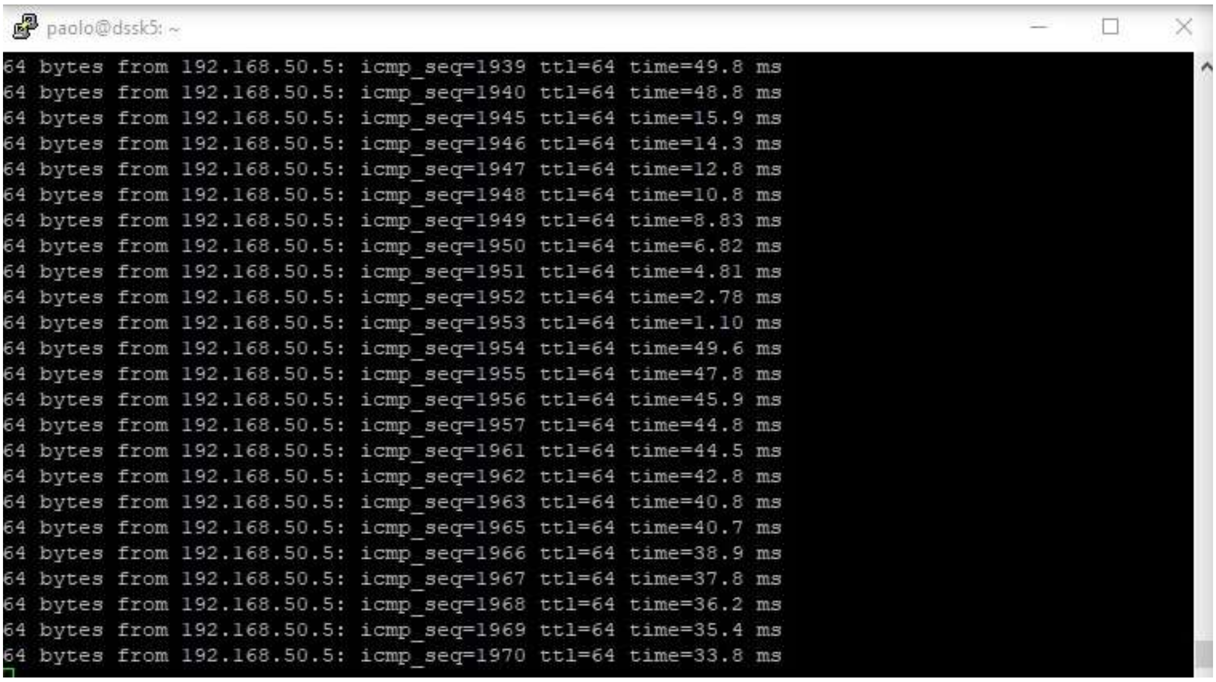


Figure 21 BEE ping results for the normal terminal during the emergency status.

3.2.4.5 Conclusions and Feedback (with respect to the use of the ORCA testbed and SDR platforms)

The ORCA facilities permitted Level7 to successfully implement the BEE experiment that will be the foundation for new added value services and novel experiments on the SDR/SDN architectures.

4 CONCLUSIONS

The OC2 EXP of ORCA has been successfully concluded by December 2019. Seven projects, three from “Scientific Excellence” and four from “Industry”, reported their overall-positive experiment process, results, feedback and indication on ORCA.

The Report of MinDFul project will be included in the next Deliverable 7.5

This will serve as a source of good reference in implementing future open call for experiment (one additional in ORCA project), and open calls in general.