

5G-XHaul

***Dynamically Reconfigurable Optical-Wireless
Backhaul/Fronthaul with Cognitive Control
Plane for Small Cells and Cloud-RANs***

D6.3 Smart wireless/optical testbed demonstrations via on line and work- shop demonstrations

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Executive Summary

The objective of the demonstrations given in several events, described in this deliverable, was to showcase the diverse technologies the project 5G-XHaul considers for implementation in an optical-wireless 5G infrastructure. By means of these technologies, this infrastructure will be able to offer converged fronthauling/backhauling functions to support both operational and end-user services. Technologies such as WDM-PON, millimetre wave (mmWave) and Sub-6, as well as massive MIMO radio units, were demonstrated to support the fronthaul and backhaul high capacity and low latency demand of 5G use cases. To address the challenge of managing and operating this type of complex heterogeneous infrastructure in an efficient manner, 5G-XHaul adopts SDN as the technology for network control and for providing slicing and virtualisation capabilities to the transport network resources.

1 Introduction

The key motivators for 5G are to provide ubiquitous, high-speed, high-quality wireless broadband coverage to meet societal and industrial needs beyond 2020. The 5G-XHaul project contributes to these goals proposing a converged optical and wireless network solution supported by a flexible and scalable control plane with the aim to form a flexible transport infrastructure. The main goal of the 5G-XHaul project is to develop novel converged optical/wireless architectures and SDN-based network control and transport slicing mechanisms for offering fronthauling/backhauling functions to support both operational and end-user services.

This deliverable describes the various demonstrations of the technologies developed within the project given in various events, namely the Global 5G event [1], Mobile World Congress [2] and EuCNC 2017 [3].

The technologies by the project that were demonstrated are:

Optical: A key enabler supporting the feasibility of this approach is the adoption of a high capacity, flexible optical transport comprising a combination of passive and active solutions. Passive Optical Network (PON) solutions are based on WDM-PONs, while active solutions adopt more flexible and dynamic WDM technologies such as the Time-Shared Optical Network (TSON).

Wireless: The high deployment cost of optical fibre will be alleviated in 5G-XHaul with the use of mmWave communications for both backhaul (BH) and fronthaul (FH) purposes. The goal is to deliver high capacities with the operation in unlicensed or light- licensed spectrum. In our case the selected frequency is 60 GHz.

Sub-6 technologies, such as 802.11ac, are also considered as one of the key building blocks of the 5G-XHaul wireless BH. Future mobile networks employing massive MIMO techniques incorporate a large number of transmitting and receiving antennas. This will linearly scale up the FH data rate since the data rate is proportional to the number of antennas.

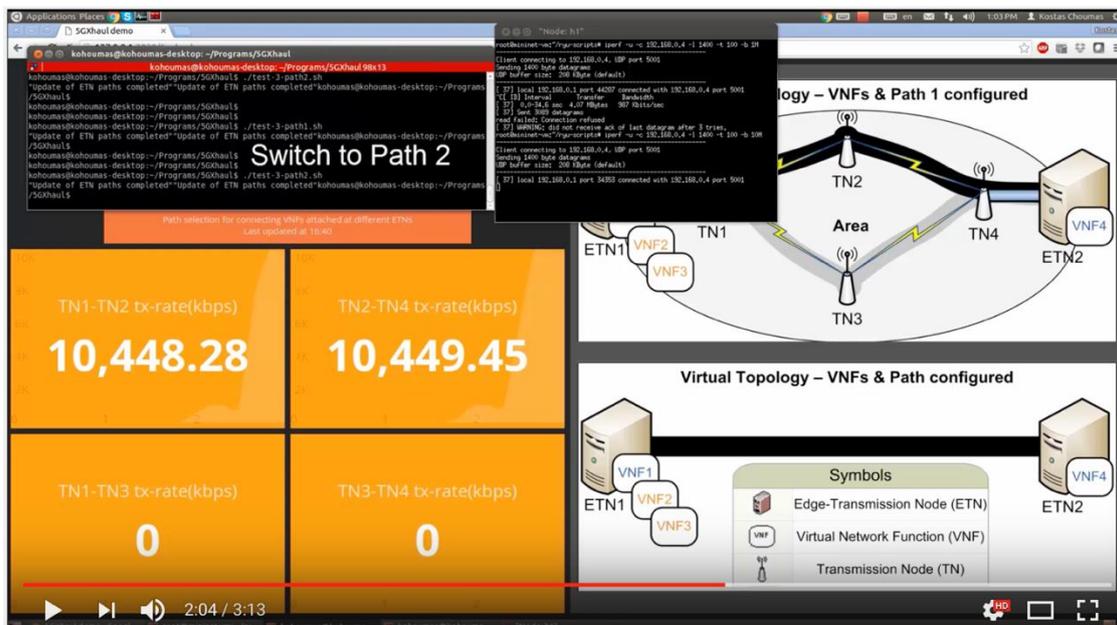
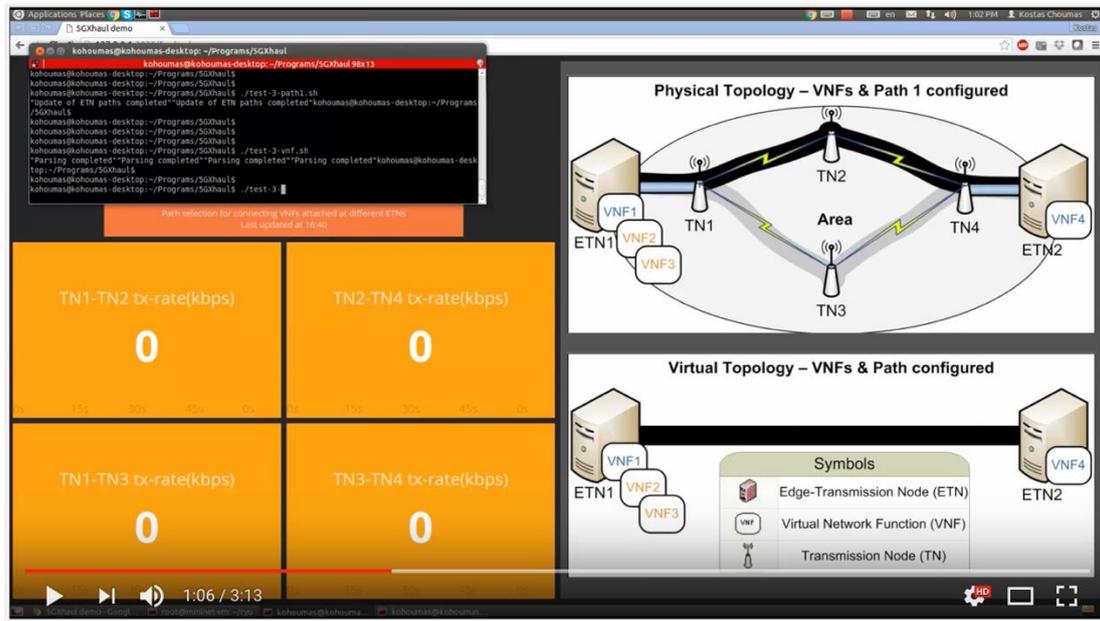
SDN Control Plane: Taking advantage of the SDN concept and the benefits of cross-technology virtualisation, 5G-XHaul proposes a control plane that is decoupled from the data plane and comprises a logically centralised controller that has a holistic view of the network, offering transport slicing capabilities.

2 Demos at the second Global 5G Event, Rome 2016

This chapter presents the different demonstrations showcased at the 2nd Global 5G Event held in Rome, Italy, in November 2016.

2.1 SDN support for Slicing Demo

The demo was targeted at showing the operation of network slicing at the edge of the transport network and encapsulation of tenant traffic into transport specific tunnels. All the nodes of the network were controlled by the 5G-XHaul Level-0 Area Controller. 4 VNFs were installed in the two nodes, Edge Transport Node (ETN) ETN1 and ETN2, belonging to two different slices. In the implemented GUI the physical topology as well as the virtual topology (tenant view) were shown while a change in the physical topology was demonstrated where a path switch at the physical topology took without affecting at all the tenant view of the network as well as the traffic between the Virtual Network Functions (VNFs). Snapshots from the demo are depicted in Figure 2-1.



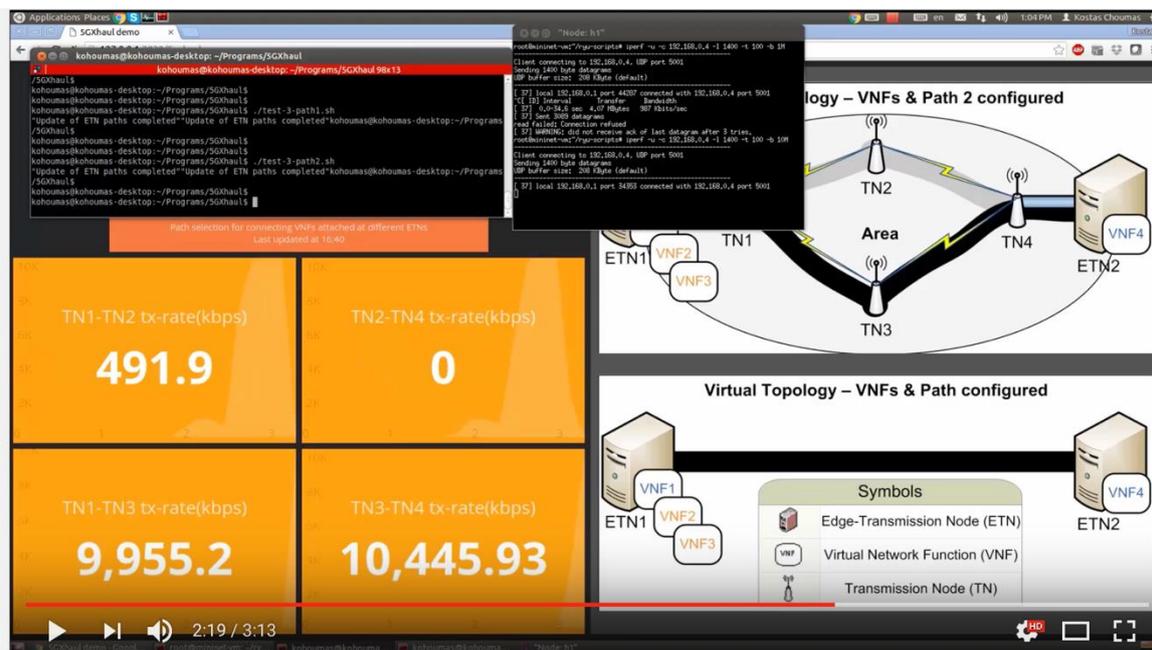


Figure 2-1. Snapshots from the Transport Slicing demo by UTH.

This demo has also been captured in a video available in the 5G-XHaul YouTube channel:

<https://www.youtube.com/watch?v=ITBZH-1pDGY>

A poster has also been presented in the booth describing the demo shown in Figure 2-2.

Hierarchical SDN Control Plane and Slicing Support over Heterogeneous Technologies



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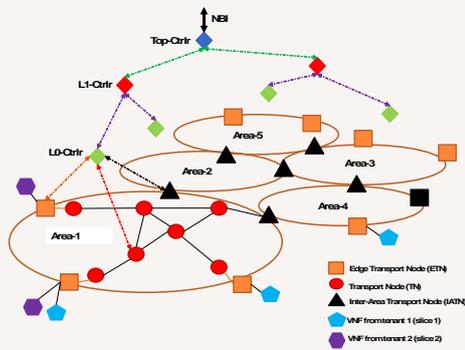
November 09-10, 2016

Global 5G Event, Rome

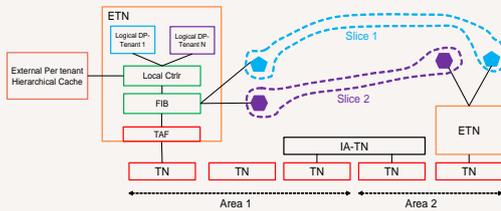
Control Plane Architecture

Challenges:

- Network slicing over heterogeneous technologies (2G/3G/4G, Wi-Fi, etc.).
- SDN-based control plane, hierarchical & distributed controllers.
- Network function virtualisation (NFV) to execute network functions on commodity hardware.
- Tenants are allowed to connect to 5G-XHaul virtual slices through standard workloads (VNFs)
- Deployment and experimentation in NITOS



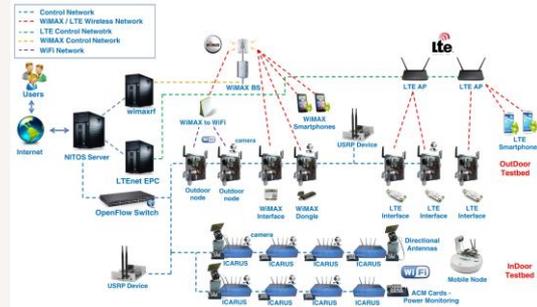
5G-XHaul Hierarchical Control Plane Architecture



Detailed overview of ETN and Slicing Support

Hierarchical Control Design

- Top controller** is responsible for provisioning per tenant slices, and orchestrating the required connectivity across different 5G-XHaul areas and domains.
- Level-1 controller** is in charge of maintaining connectivity between the underlying level-0 areas, and maintains state at the area level. It does not need to be technology specific since it operates at a higher abstraction level.
- Level-0 controller** is responsible for the provisioning and maintenance of transport tunnels between ETNs and IATNs for given 5G-XHaul area. It is assumed to be in charge of area instantiation of single type of transport technology, i.e. mmWave area, in Ethernet area, or in active optical area

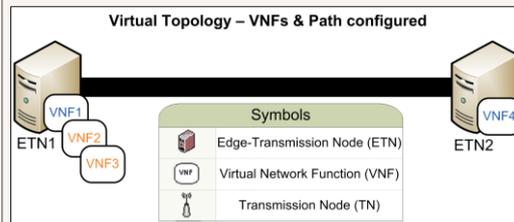
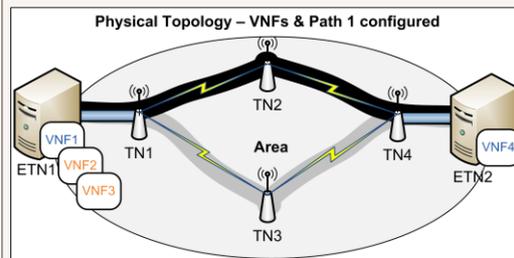


The NITOS testbed for 5G experimentation

Development of L0-Ctrlr

- Development of L0-Ctrlr in top of a WiFi area.
- The WiFi area is deployed in the NITOS testbed.
- The area consists of two ETNs hosting the VNFs and four TNs connecting the ETNs.
- The TNs connection is **virtually abstracted as a stable link**, while at the bottom layer the utilized wireless links are changing seamlessly.
- Half of the VNFs belong to a different slice of the other half, and the **communication between the two slices is not allowed**.

The Demo Topology deployed in NITOS



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Figure 2-2. Poster showing the Transport Slicing demo by UTH.

2.3 SDN controlled mmWave Demo

A millimetre wave communication mesh with SDN control was demonstrated at the Rome 5G Event. The configuration of the demo is sketched in Figure 2-3. A photo of the booth setup is shown in Figure 2-4.

A laptop is connected to a video server over a single 60 GHz wireless link, “main path”, and video traffic is streamed to the laptop (and displayed using VLC). A second redundant path is held on standby, using two wireless links. The wireless links exploit BWT Lightning II modules, either vertically or horizontally polarised, and using either IEEE 802.11ad channel 2 or 3. Monitoring information is captured by SDN agents running on the Lightning units and passed to the remote Software Defined Network (SDN) controller using OpenFlow extensions developed by i2CAT.

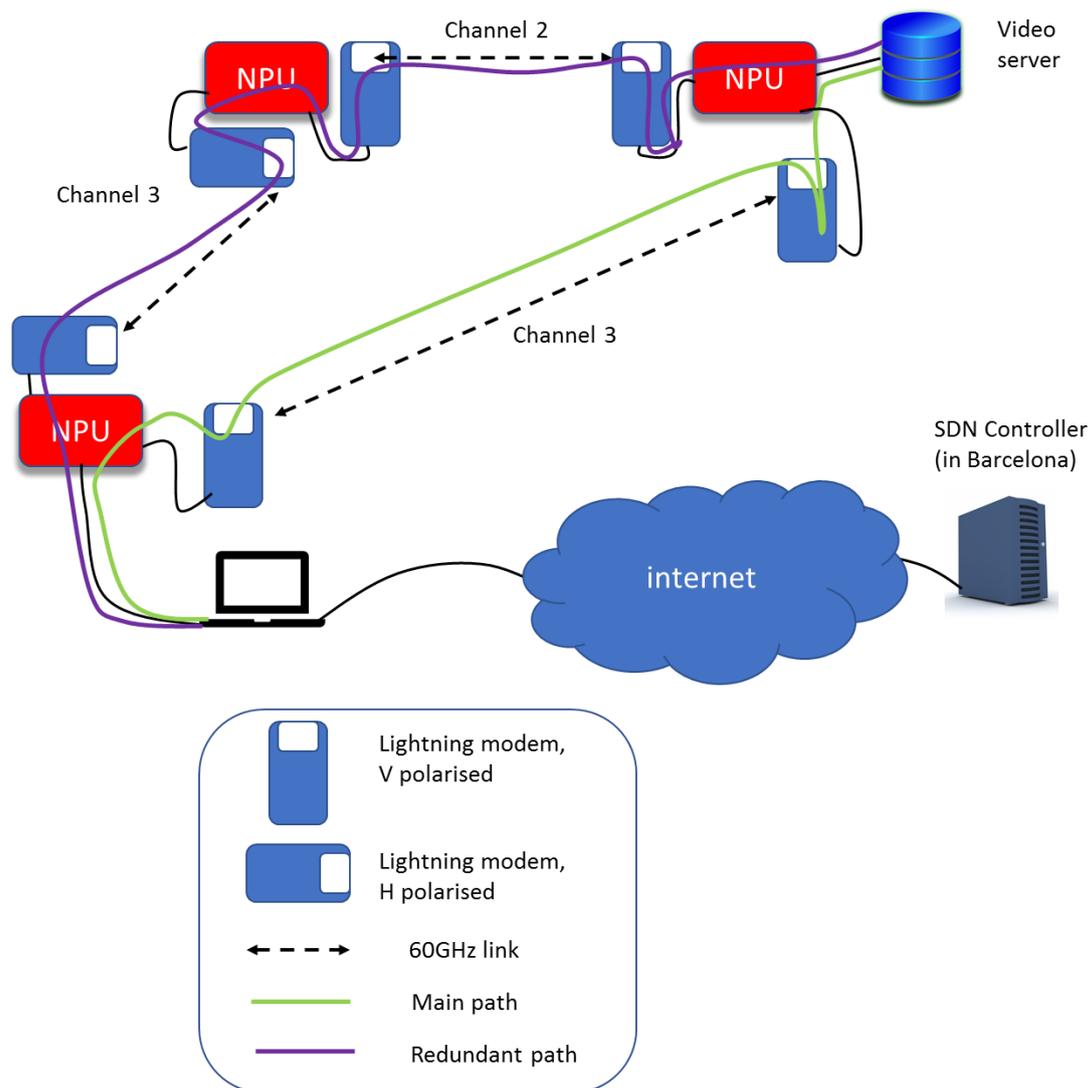


Figure 2-3. Millimetre-wave mesh demo arrangement.



Figure 2-4. Photo of the demo booth and equipment. The orange boxes are the NPUs.

When the wireless link of the normal path is broken, the traffic may be switched to the redundant path after detection by the SDN controller.

2.4 Prototyped ONU and system features of WDM-PON

We have presented the Optical Network Unit (ONU) prototype which is under development for the WDM-PON system, which are the two white devices on the booth table as shown in Figure 2-5. The key component in the ONU is a tuneable laser which can be remotely controlled via the out-of-band (OOB) communication channel, such that the expensive wavelength locker is no longer needed. It can be seen that the SFP+ module is assembled on a sub-board with the control circuit.

The autonomous wavelength tuning of this prototyped ONU is illustrated in a video clip (available online in the 5G-XHaul YouTube channel: <https://www.youtube.com/watch?v=s9RaS1wjv-s>). The video demonstrates that the ONU under test could automatically adapted the emitting wavelength, when it is connected to a different de-/multiplexer port.



Figure 2-5: Photo of the WDM-PON exhibition at the booth

In addition, a poster introducing the general concept and features of WDM-PON was also presented at the booth, as shown in Figure 2-6.



Tunable Access WDM for 5G

Flexible WDM-PON for Back- and Fronthaul Services

Due to the booming demand for mobile data, it's become essential to find innovative ways to increase capacity in the future 5G mobile network. Converged metro-access networks are key to this, but also are reducing complexity and improving operational efficiency. That's what ADVA Optical Networking's WDM-PON system is able to deliver.

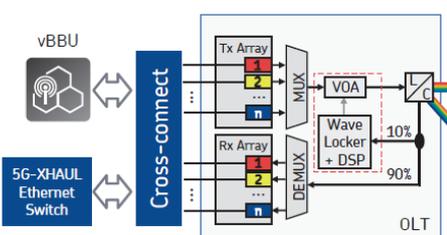
In the Horizon 2020 project "5G-XHaul", we are continuing to develop the prototype to achieve these efficiencies and ensure low-latency performance, while the innovative new architecture significantly increases fiber capacity in backhaul and fronthaul applications.

The prototype technology, which is currently defined by the ITU-T G.metro standard, directly distributes DWDM wavelengths to remote radio units or base stations. This enables up to 40 DWDM wavelength channels with a grid of 100GHz. Each channel is able to transmit data at 10Gbit/s over a 20km fiber distance without optical amplification. With a centralized wavelength locker at the head-end, cost and complexity at the tail-end are significantly reduced. This enhanced efficiency will be crucial for converged metro-access and for 5G networks. The prototype also proved to be fully compatible with current commercial wireless technology, paving the way for imminent real-world deployment.

Features & Benefits

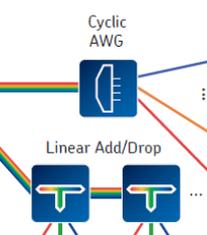
Shared trunk fiber	➔	Less fiber & installation cost
Up to 40 channels, single fiber option	➔	Fewer systems
10Gbit/s capacity per channel	➔	Ready for higher CPRI throughput
Cross-connect	➔	Flexible resources allocation
Tunable DWDM transceivers	➔	Fewer spare parts, auto-configuration
Optical layer monitoring	➔	Service assurance & troubleshooting

Optical Line Terminal (Head-End)



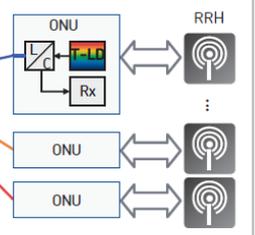
1G-10G wavelength services
Pay-as-you grow (T-SFP+)
Central λ -control and auto-tuning
Flexible BBU resources configuration
Optical layer monitoring

Passive Remote Node(s)



Passive filters
C/L-band single fiber option

Optical Network Units (Tail-End)



Remotely controlled T-SFP+
For use in ADVA products and 3rd party equipment





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Figure 2-6: Poster of general introduction of WDM-PON.

3 Demos at Mobile World Congress 2017

This chapter presents the different demonstrations showcased at the Mobile World Congress 2017, held in Barcelona, Spain, in March 2017.

3.1 SDN in wireless mmWave backhaul

At MWC'17 BWT and i2CAT demonstrated the integration of the SDN agent developed by i2CAT on the 60 GHz wireless devices developed by BWT. This technology has also been used within the framework of the 5G-XHaul Work Packages (WPs) WP3 and WP5. Figure 3-1 illustrates one of the BWT 60 GHz nodes, and Figure 3-2 provides the detailed demo setup.



Figure 3-1. BWT & i2CAT mmWave SDN demo at i2CAT's booth in MWC'17.

The purpose of the demo was to demonstrate the integration of the SDN agent. For this purpose the 5G-XHaul SDN controller, based on OpenDayLight, was installed in a laptop, and the SDN agent was deployed in two 60 GHz devices forming a point-to-point (P2P) link. The choice of the simplistic P2P topology was driven by the limited space available in the booth.

The SDN feature that was demonstrated in the event was the automatic topology discovery. For this purpose the controller dashboard depicted the P2P topology. However, when someone would wave his hand over the 60 GHz link, the link was breaking due to the high penetration losses of the 60 GHz signal through the human body and the controller was depicting a link break in the topology.

In addition, the demo also illustrated the performance of the BWT Lightning platform with throughput of around 1 Gbps.

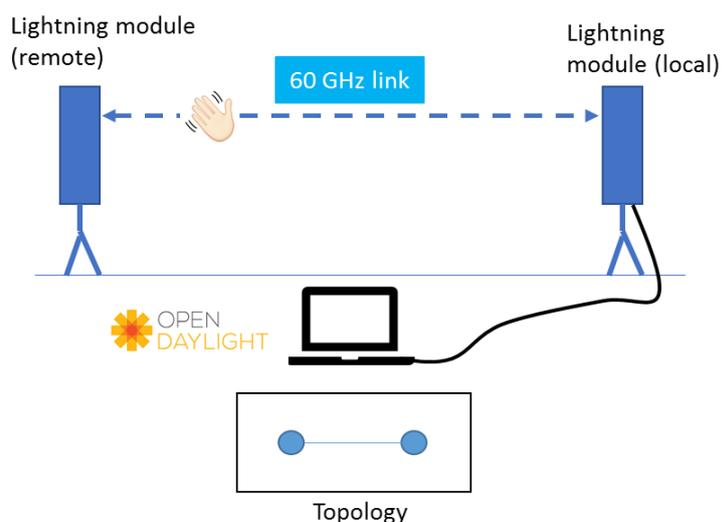


Figure 3-2. MWC'17 demo setup.

3.2 Massive MIMO Radio Unit

Airrays (AIR) attended the Mobile World Congress 2017 with a functional demo of a massive MIMO radio unit prototype) as described in 5G-XHaul deliverable D4.12. The AIR radio unit on display featured 96 transceiver in a 12x4 cross-polarised configuration. This proof-of-concept radio unit is designed for operation at 2.6 GHz in FDD (Band 7. Conducted transmission of a 256 QAM downlink signal was shown on one of the 96 transmit paths.

The purpose of this activity was to present the proof-of-concept platform to potential customers and gather feedback on key parameters such as transmit power, steering ranges, number of simultaneous beams, etc. that are relevant for a perspective productisation.

The radio unit was showcased at the company Booth 7C17 of Amphenol Antenna Solutions, which is a cooperation partner of AIR for development of this platform. Figure 3-3 shows the radio unit demonstration with the acknowledgement of the Horizon 2020 program and the 5G-XHaul project.

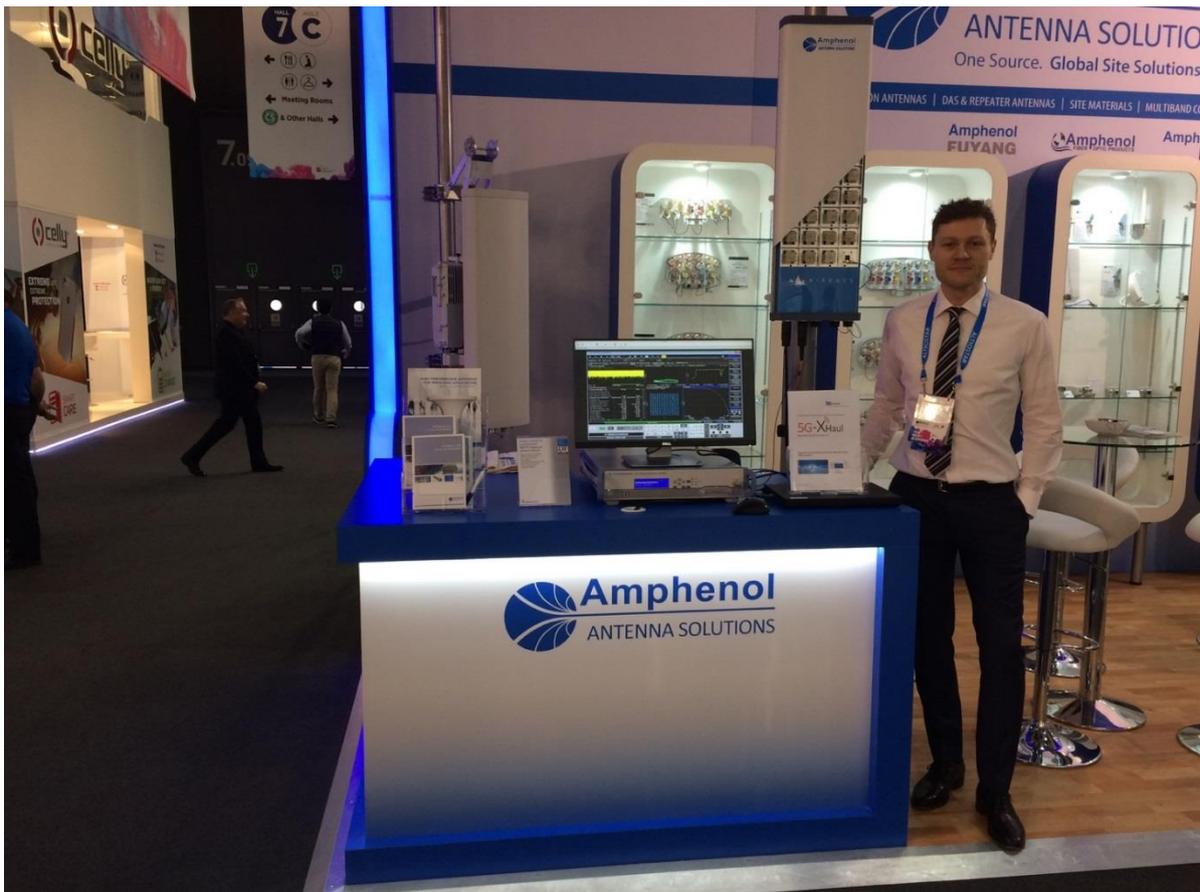


Figure 3-3: AIR Massive MIMO Radio unit demo at Mobile World Congress 2017.

4 New x-haul solutions for the 5G transport challenge – A joint workshop of the iCIRRUS, 5G-Crosshaul and 5G-XHaul projects

Future Radio Access Networks (RAN) call for transport networks with unprecedented flexibility and performance. The stringent requirements on bandwidth, latency, and timing, as well as the mandatory support of heterogeneous technologies and different functional splits, create the necessity for next-generation x-haul solutions.

The workshop “New x-haul solutions for the 5G transport challenge – A joint workshop of the iCIRRUS, 5G-Crosshaul and 5G-XHaul projects” was one of the workshops organised in EuCNC 2017. The workshop spanned for half a day and, as was already done the previous year, is a joint effort of the projects iCIRRUS, 5G-Crosshaul and 5G-XHaul, and discussed 5G transport challenges and new solutions being currently developed by these Horizon 2020 projects. The Agenda of the workshop is shown in Table 1.

The workshop consisted of two sessions, entitled ‘Architectures and Implementation’ and ‘Testbeds and Trials’ respectively. The former explored different architectural solutions for specific layers. The topics encompassed from infrastructure layer on optical and Ethernet technologies, to network virtualization and application-level architectural aspects. The latter, focused on projects’ demonstration work, described the different testbeds each project is developing, also including validation of the technologies and their implementations.

Part of these contributions was showcased remotely and/or live at the EuCNC booths of the three projects. The photos below were taken during the workshop.



Figure 4-1. Photos from the EuCNC workshop.

Table 1: Agenda of the EuCNC 2017 Workshop 8.

<p>EuCNC 2017 Workshop 8 - Oulu University, Monday, 12.06.2017, 09:00-12:30h</p> <p>New x-haul solutions for the 5G transport challenge – A joint workshop of the iCIRRUS, 5G-Crosshaul and 5G-XHaul projects</p>	
<p><i>Future Radio Access Networks (RAN) call for transport networks with unprecedented flexibility and performance. Stringent requirements on bandwidth, latency, and timing as well as the mandatory support of heterogeneous technologies and different functional splits create the necessity for next-generation x-haul solutions. The workshop will discuss 5G transport challenges and new solutions developed within the Horizon2020 projects iCirrus, 5G-Crosshaul and 5G-XHaul. An active participation from the audience will be encouraged.</i></p>	
<p>Organizers: Jörg-Peter Elbers (ADVA Optical Networking), Eckhard Grass (IHP - Innovations for High Performance Microelectronics), Antonio de la Oliva (Universidad Carlos III de Madrid)</p>	
9:00	<p>Session 1: Architectures & Implementations (Moderator: Antonio de la Oliva, Universidad Carlos III de Madrid)</p> <ul style="list-style-type: none"> 1.1: Introduction by the workshop organizers 1.2: Ethernet in the evolved fronthaul: synchronization and speed challenges - Nathan Gomes, Uni Kent 1.3: Packet network virtualization in 5G-Crosshaul – Thomas Deiss, Nokia 1.4: Low-cost passive WDM technology for high-capacity mobile fronthaul - Jim Zou, ADVA Optical Networking 1.5: 5G-Crosshaul applications: Resource orchestration for the integrated fronthaul and backhaul – Xi Li, NEC
10:30	<p><i>Coffee Break</i></p>
11:00	<p>Session 2: Testbeds & Trials (Moderator: Eckhard Grass, IHP)</p> <ul style="list-style-type: none"> 2.1: Ethernet in the evolved fronthaul: measurement and joint optimisation of RAN and transport - Howard Thomas, Viavi Solutions 2.2: The 5G-Crosshaul testbed: Experimental validation of an integrated fronthaul and backhaul – Josep Mangués, CTTC 2.3: iCirrus field trial: Transporting diverse radio technologies over an Ethernet x-haul network - Volker Jungnickel, HHI 2.4: Demonstrating the 5G-XHaul architecture in Bristol is Open (BiO) - Daniel Camps Mur, i2CAT
12:00	<p>Panel discussion with all speakers (Moderator: Jörg-Peter Elbers, ADVA Optical Networking)</p>
12:30	<p>Lunch</p>

5 5G-XHaul Exhibitor at EuCNC 2017

5G-XHaul participated also as an exhibitor in EuCNC 2017 having a booth showcasing all the important technologies developed within the project. More specifically three demos were shown: a) a fronthaul demo integrating a Massive MIMO RU and a BBU by AIR, WDM-PON by ADVA and a UE receiver by TUD, b) mmWave nodes by BWT and c) a SDN control plane demo for supporting live VNF migration and slicing which has been remotely executed at the NITOS testbed located in University of Thessaly. The demos are described in more detail in the following subsection.

5.1 Fronthaul Demo – ADVA, AIR, TUD

The fronthaul link between the baseband unit (BBU) and the remote radio head (RRH) is based on the wavelength-agnostic WDM-PON system from ADVA, and the BBU and RRH comes from TUD and AIR, respectively. This live demo showcased a successful joint integration of BBU, WDM-PON and massive-MIMO RRH. The setup is depicted in Figure 5-1.

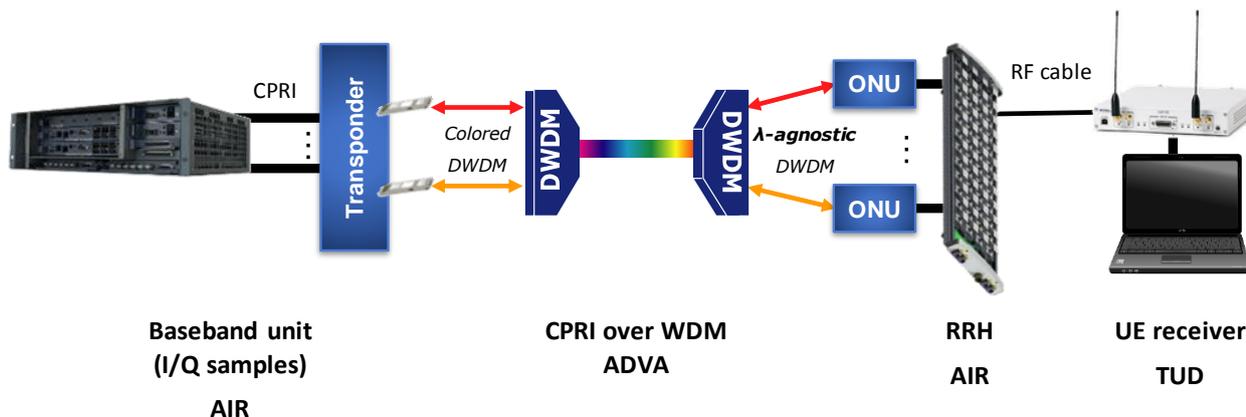


Figure 5-1: Demo setup of integrating BBU, WDM fronthaul and massive-MIMO RRH.

The setup consisted of TUD’s BBU connected to the AIR’s massive-MIMO RRH over the ADVA’s WDM-PON transport link, and TUD’s USRP served as a UE receiver after the RRH. We demonstrated a cellular downlink, where the BBU generated I/Q samples from 64QAM constellation, which were then mapped onto the LTE subcarriers spanning over a bandwidth of 20 MHz. These IQ samples were then forwarded via the WDM fronthaul to the RRH by employing the CPRI protocol.

The transponder received the CPRI streams from the BBU at grey wavelength, and converted them onto the DWDM wavelengths with 100 GHz spacing, which were later multiplexed into a single optical fibre. In the demo. We used two C-band 10G SFP+’s in the transponder to carry two independent CPRI streams at two different wavelengths. After demultiplexing at the remote node, two ONUs received the individual CPRI stream and converted the DWDM wavelength back to the grey one, feeding to one of the available optical ports of the RRH. The RRH supports 8 x 8 antennas and incorporates Split A. For the uplink, each ONU used a tuneable 10G SFP+, of which the uplink wavelength differed from the downlink wavelength, yet still in the C-band. Therefore, the upstreams were also transmitted over the same trunk fibre. As proof of concept, we used another two spare paired ports of the transponder to emulate the ONU functionality.

The RRH recovered the LTE signal from the CPRI frames and performed antenna processing before up-converting the signal to the carrier frequency 3.55 GHz. The radio signal was then sent to the antenna elements. In reality, the radio signal is transmitted wirelessly to the UE; however, in this demo we refrained from radiating the signal over the air due to licensing issues and hence we employed an RF cable to feed the signal to the UE.

Figure 5-2 shows this demo setup at the booth (inside yellow frame). More details including test results can be found in deliverable D5.2.

The autonomous wavelength adaptation of remote ONUs was also demonstrated in a video clip (available online in the 5G-XHaul YouTube channel: <https://www.youtube.com/watch?v=O4PC2rCnc0>). This was a latest implementation by employing the VCSEL laser technology.



Figure 5-2: Booth photo of 5G-XHaul fronthaul demo.

5.2 mmWave nodes demo – BWT

The following test configuration was used at EuCNC 2017 to demonstrate high speed data transfer over a millimetre wave using BWT Lightning modules. Figure 5-3 sketches the setup for the demonstrations.

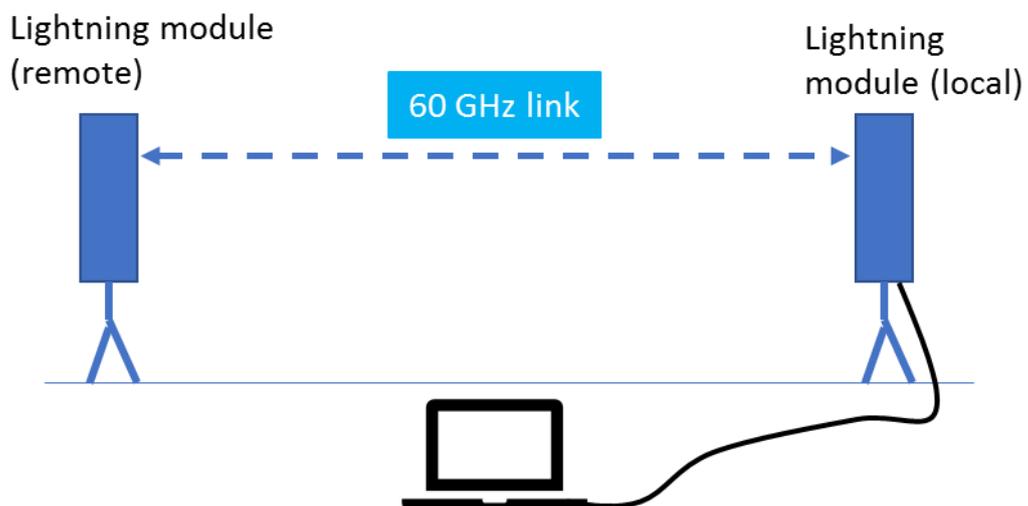


Figure 5-3. Test configuration.

Two tests were run:

1. File transfer from the remote Lightning to the local Lightning
 - a. Result: data transfer approximately 1 Gbps.
2. VLC video stream from remote Lightning to the local Lightning (see Figure 5-4)
 - a. Result: video running on laptop (rate 30 Mbps).

When the beam is interrupted by a hand, the file transfer or video playback stalls (there is a few second delay because of the depth of the playout buffer). Removing the blocker leads to a restart of the file transfer or video playback.

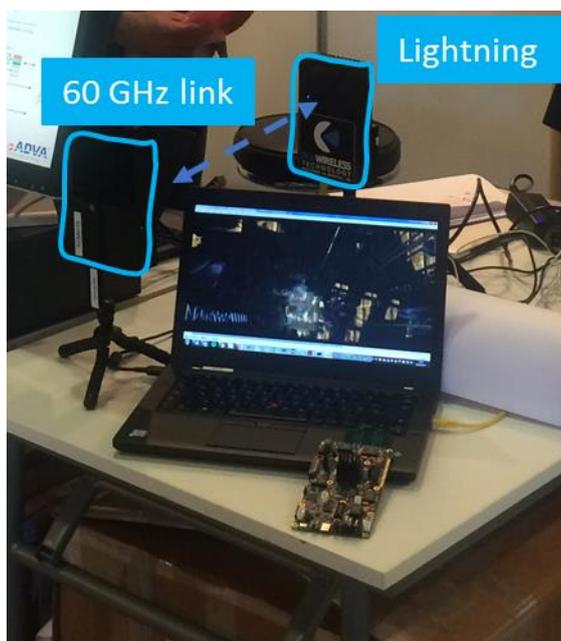


Figure 5-4. Video Stream over mmWave link

5.3 VNF migration and slicing – UTH, I2CAT

In this demo, we showcased the operation of the 5G-XHaul SDN control plane in order to support seamless VNF migration and transport network slicing in order to satisfy the tenant and operator requirements. The demo was remotely executed at the NITOS testbed [4] from the EuCNC booth.

Our demonstration started with two UDP streams, which are initiated from VNF :02 to VNF :04 and from VNF :02 to VNF :05 as depicted in Figure 5-5. The two streams feature throughput requirements that are 5 Mbps and 30 Mbps respectively. The tenant who owns the VNFs (the ‘blue’ tenant) is flexible on the location of the VNFs, enabling their placement in the ETNs that are connected with the less loaded tunnels. Thus, the orchestrator decides to place VNF :02 at ETN1, VNF :04 at ETN2 and VNF :05 at ETN3, since ETN1 is connected with ETN2 and ETN3 through tunnels that have capacities almost 10 Mbps and 50 Mbps respectively.

Then, a new tenant (the ‘purple’ tenant) brings its VNFs, VNF :01 and VNF :03, and requires these VNFs to be placed at ETN1 and ETN2 respectively. The purple tenant also requires the two VNFs to be able to stream each other with throughput of 8 Mbps¹. This new event forces the orchestrator to relocate some of the VNFs of the blue tenant, in order to be able to satisfy both the blue and purple tenants. As it is obvious from the network topology (Figure 5-5), the only solution is to live migrate the VNF :04 of the blue tenant from ETN2 to ETN3. Live migration means that VNF will be transferred from the one ETN to the other, with its state and all network connections. After the migration takes place the SDN area controller configures the forwarding tables at ETN1 so that traffic follows the path to the new location of VNF :04 at ETN3.

¹ Notice that this traffic is scaled down to adapt to the capabilities of the testbed, since the main purpose of these experiments is to validate control plane functionalities. The interested reader is referred to D5.2 for an evaluation of the data-plane capabilities of the technologies developed in 5G-XHaul.

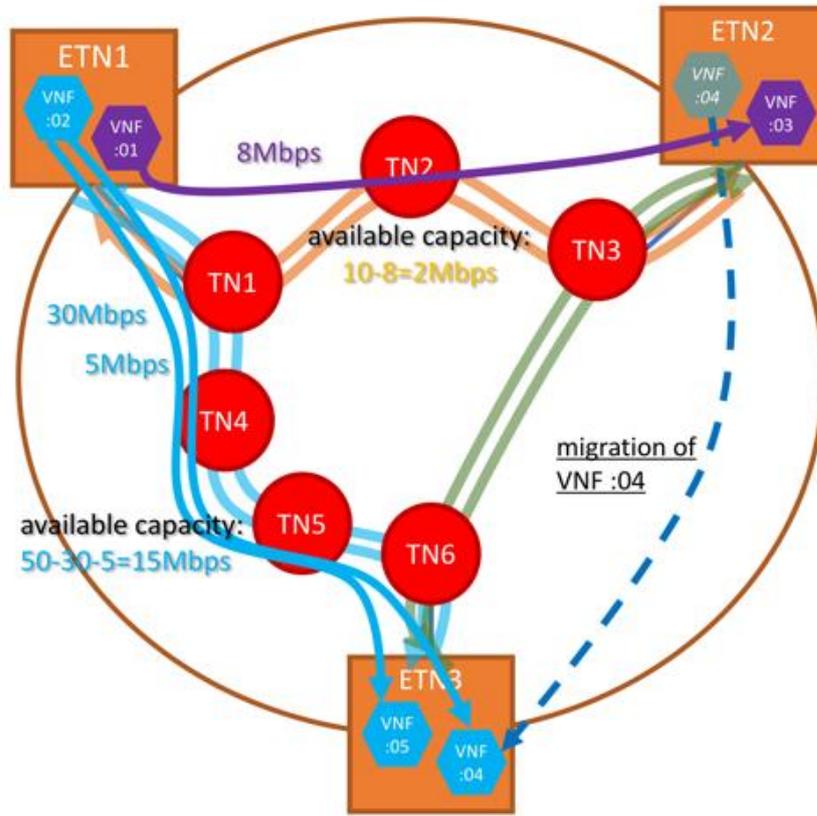


Figure 5-5. VNF migration Demo.

The demo has also been captured in a video available in the 5G-XHaul YouTube channel: <https://www.youtube.com/watch?v=XkLF-KXWN2w>

A poster has also been shown at the booth that describes the demo, shown in Figure 5-6.

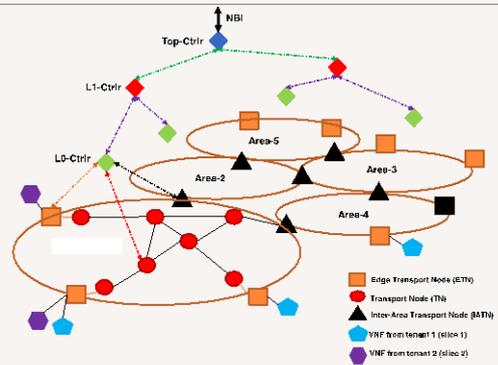
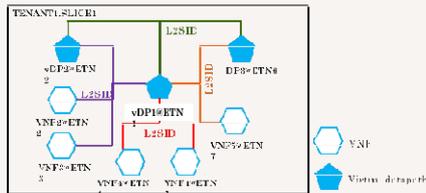
5G-XHaul SDN Control Plane Support for Transport Slicing and VNF migration

June 12-15, 2017

EuCNC 2017

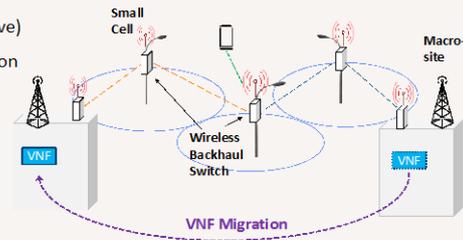
5G-XHaul Control Plane

- Per tenant full address virtualization.
- Data plane scalability: edge tunneling + control plane areas.
- Control plane scalability + resiliency: combination of replica and hierarchical controllers.



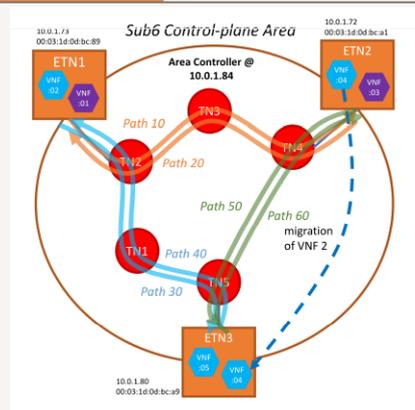
Mobile Edge Computing Application for Gaming

- Users connect to Small Cells at lamp posts with their smartphone.
- Lamp posts also host wireless backhaul switches (sub-6 or mmWave)
- Processing and Storage Resources to support the gaming application provided by compute nodes hosted at macro-sites, as VNFs.
- Traffic spike at a macro site causes increased latency. Tenant network control application detects the event and triggers migration of the VNF to another macro-site.
- The 5G-Xhaul control plane handles the tenant request and reconfigures the datapaths.
- The tenant virtual network configuration remains unaffected.



Demo setup at NITOS testbed at University of Thessaly

- The NITOS RF Isolated Indoor Deployment consists of 50 Icarus nodes with multiple wireless interfaces (Wi-Fi, WiMAX, LTE) deployed in an isolated environment at a University of Thessaly's campus building.
- 8 ICARUS testbed nodes used in total, featuring two 802.11n interfaces.
- Nodes are running OpenvSwitch, and are configured via OpenFlow using the 5G-Xhaul control plane architecture providing slice isolation.
- REST API used to trigger VNF installation, migration and gather statistics.



Funding/Acknowledgment/

<http://nitlab.inf.uth.gr>

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Figure 5-6: Poster for the VNF migration Demo.

6 Summary and Conclusions

In this deliverable, we described the demonstrations given by the project in various events that showcase the diverse technologies the project 5G-XHaul considers for implementation in an optical-wireless 5G infrastructure. By means of these technologies, this infrastructure will be able to offer converged fronthauling/backhauling functions to support both operational and end-user services. Technologies such as WDM-PON, mmWave and Sub-6, as well as massive MIMO radio units, were demonstrated to support the fronthaul and backhaul high capacity and low latency demand of 5G use cases. To address the challenge of managing and operating this type of complex heterogeneous infrastructure in an efficient manner, 5G-XHaul SDN control plane was demonstrated as the technology for network control and for providing slicing and virtualisation capabilities to the transport network resources.

7 References

- [1] <https://5g-ppp.eu/event/second-global-5g-event-on-9-10-november-2016-in-rome-italy>, 2nd Global 5G Event, “Enabling the 5G EcoSphere”, 9-10 November 2016, Rome, Italy
- [2] <https://www.mobileworldcongress.com>, Mobile World Congress 2017, Barcelona, 27 February – 2 March 2017
- [3] European Conference on Networks and Communications, EuCNC 2017, 12-15 June, Oulu, Finland, <http://www.eucnc.eu>.
- [4] NITOS testbed, <http://nitlab.inf.uth.gr/NITlab/nitos>

8 Acronyms

Acronym	Description
5G	Fifth Generation Networks
5G-PPP	5G Infrastructure Public Private Partnership
ADVA	ADVA Optical Networking (Partner)
AIR	Airrays GmbH (Partner)
BB	Baseband
BBU	Baseband Unit
BH	Backhaul
BS	Base Station
BWT	Blu Wireless Technology (Partner)
CPRI	Common Public Radio Interface
C-RAN	Cloud Radio Access Network (aka Cloud-RAN)
DL	Downlink
e2e	end-to-end
ETN	Edge Transport Node
FH	Fronthaul
GUI	Graphical User Interface
I2CAT	I2CAT Foundation (Partner)
ONU	Optical Network Unit
OOB	out-of-band
PON	Passive Optical Network
RAN	Radio Access Network
RRH	Remote Radio Head
TSON	Time-Shared Optical Network
TUD	TU Dresden (Partner)
UC	Use Case
UE	User Equipment
UL	Uplink
VM	Virtual Machine
VN	Virtual Network
VNF	Virtual Network Function
VNO	Virtual Network Operator
VNP	Virtual Network Provider
WDM	Wavelength Division Multiplexing