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► To cite this version:

Andrew Lord, Albert Rafel, Michael Parker, Adrian Farrel. The Impact of the Optical Network on 5G – The Metro-Haul Project. 23th International IFIP Conference on Optical Network Design and Modeling (ONDM), May 2019, Athens, Greece. pp.62-69, 10.1007/978-3-030-38085-4_6 . hal-03200682

HAL Id: hal-03200682

<https://inria.hal.science/hal-03200682>

Submitted on 16 Apr 2021

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The Impact of the Optical Network on 5G – the Metro-Haul project

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Abstract. An overview of the current status of the EU Metro-Haul project and its impact on 5G End to End Key Performance Indicators (KPIs) together with a summary of the use cases and demonstrations intended to illustrate the technology being developed.

Keywords: 5G, optical networks, KPIs, SDN, orchestration, slicing

1 Introduction

Metro-Haul is an EU project in the 5G-PPP cluster that has been running since June 2017. It is focused on building the metro side of a future End-to-End (E2E) 5G network. The rationale behind the project is simple – we assume that an intelligent, dynamic and most importantly 5G-aware optical transport layer will assist far better in terms of performance and cost-effectiveness in the delivery and operation of 5G services, than a dumb and inevitably over-provisioned transport layer. Figure 1 [1], provides an overview of the Metro-Haul network architecture, showing how it acts as the intelligent interface between the 5G access (fixed & wireless) and photonic core of the overall telecommunications network.

In this paper, we focus on the major benefits that Metro-Haul technology brings to 5G, and we describe them in terms of so-called Golden Nuggets (GNs). Once these are highlighted, we go on to unpack Metro-Haul's contribution to the crucial 5G E2E Key Performance Indicators (KPIs) – indicators that are effectively our project's measure of the effectiveness of Metro-Haul technology. Note that this technology extends from the physical layer to control plane and monitoring layers – in other words, improving the underlying physical performance, introducing dynamic service level monitoring for individual slices and finally implementing a Software Defined Networking (SDN) based orchestration capability that can dynamically provision existing and new 5G slices on demand. The monitoring is handled by a key Monitoring and Data Analytics function developed within the project which is built into the overall SDN framework as well as capitalizing on recent AI developments for complex decision making / autonomous operation.

Finally, we look at the planned Metro-Haul demonstrations designed to illustrate our impact on the KPIs. Although Metro-Haul still has more than a year to run, with many

of the demonstration-based results still to come, we already can see the very wide ranging and deep impact that the project will have on E2E 5G-sourced networks in the future.

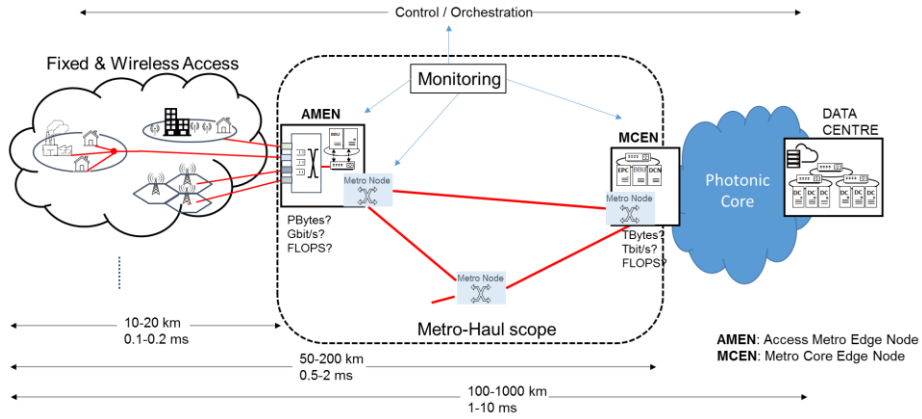


Figure 1: The Reference Metro-Haul Network Architecture

2 Metro-Haul key innovations (Golden Nuggets)

As an ambitious 5G research project, Metro-Haul distinguishes itself through a set of three key technical innovations. These have been referred to elsewhere as Golden Nuggets and can be understood to be the key “take home” messages offered by the project, representing its unique selling point (USP) amongst the other 5G projects being investigated around the world. These key technical innovations centre around the optical technologies that Metro-Haul is investigating to cater for the enhanced bandwidth and network operation requirements that the 5G use cases are expected to exploit. In addition, Metro-Haul is also investigating open, multi-layer disaggregation as a means to offer economies of scale, simplify network inventory, and offer enhanced network operational agility and flexibility. Finally, related to parallel developments in the artificial intelligence (AI) control of complex and adaptive systems, Metro-Haul is also testing technologies that offer real-time performance monitoring and analytics, and a network planning tool to assist in optimised investment and deployment of network resources. These key innovations are summarised as follows:

1. High capacity & flexible Metro optical network with edge computing

This provides for a dynamic data plane with an intelligent control plane involving multiple network segments and layers, spanning multiple geographical Data Centre (DC) locations, and addressing resource heterogeneity including, notably, the optical transport. Without these data and control plane architectures, network resources supporting future 5G services would require enormous over-provisioning of both optical transport capacity across metro and core networks, and edge Data-Centre resources such as compute and storage.

Aspects of this first Metro-Haul innovation are being demonstrated in Berlin (Germany) in a use case scenario consisting of real-time video surveillance and low-latency object tracking.

2. Open multi-layer disaggregated network

A systematic and unified approach based on model-driven development enables the SDN control of multilayer disaggregated and open transport networks, while allowing flexibility in deployment choices, extensibility for the integration of new technologies and agility in migration processes without vendor lock-in.

This particular aspect is being demonstrated in the city of Bristol (UK), featuring a crowd-sourced video broadcast use case scenario.

3. Real-time performance monitoring and analytics, and planning tool

A telemetry/monitoring framework that provides a global, real-time view of the E2E network performance. This new technology enables service configuration and reliable autonomous operation. It provides pro-active actions on early detection of issues. Machine-learning within the decision engine allows this new Metro-Haul technology to continually learn and improve as real network data is collected. It includes tools for state-of-the-art advanced planning, resource placement, and network re-optimization/re-configuration, enabling holistic optimization across heterogeneous resources.

Aspects of this third innovation are to be found in the Metro-Haul “portable” control plane demonstrator, where all software components from the project partners are integrated into a single platform.

3 Metro-Haul KPIs

5G is well recognised as a disruptive technology with wide impact on a broad set of vertical industries (automotive, health, media, public safety, energy, IoT, and Industry 4.0), social infrastructures (entertainment, education, leisure activities), as well as impacting on the more conventional telecom players (operators, manufacturers/vendors, and service providers etc.) associated with communications technology. Critical to ensuring the social, environmental, and techno-economic success of 5G (as indicated by an associated widespread take-up and seamless interoperability between different 5G technologies) are a successful suite of emerging 5G standardisations, as well as an objective means of benchmarking the developing 5G technologies. This latter aspect will be based on a set of Key Performance Indicators (KPIs) and Key Quality Indicators (KQIs) appropriate for both the physical (PHY) and service (i.e. QoS/QoE) levels.

Reaching a common understanding and consensus of the 5G KPIs is now a critical aspect of 5G research – especially with many groups and projects around the world working on competing or complementary visions. Initially, 5G was conceived as a Radio Access Technology (RAT) providing an enhanced and upgraded technical solution to the earlier 3G and 4G mobile telephony and data technologies. However, as is always the case in technology evolution, convergence of disparate and independent technology areas also frequently provides an attractive opportunity to also improve end-user experience (e.g., via seamless and ubiquitous interconnectivity and new services) This convergence also achieves economies of scale on a unified platform (CapEx savings), improves overall efficiency of operation (OpEx savings), and enables new business models.

The Metro-Haul project is no exception to such a 5G trend – except that it is principally looking to understand 5G beyond the conventional RAT space, that is to say, to make the telecoms network that is closer to the core (i.e., the metro network) ready for the huge technical demands that new 5G services (i.e. eMBB, URLLC, mMTC use cases) will place on the overall network. Thus, Metro-Haul (as the name implies) is a metro-centric project.

Reflecting its metro-network emphasis, as well as its reliance on exploiting optical technologies to achieve the massive capacity increases with increased flexibility and efficiency of network operation, we have defined nine KPIs in the Metro-Haul project (Table 1) to assess the success of the Metro-Haul architecture to support vertical services enabled by 5G RAT technologies.

TABLE 1: Metro-Haul KPIs

KPI	Category	Target
1	Optical Point-to-Point connection set-up time	≤ 1 min
2	Metro-Haul E2E Point-to-Point connection set-up time	≤ 2 min
3	Set-up time of network service slice across Metro-Haul	≤ 1 hr
4	Capacity of Metro-Haul Controller	Control of 10 – 100 nodes (AMENs/MCENs *, i.e., Open Disaggregated ROADMs)
5	Fault/degradation detection time	To be defined
6	Capacity of Metro-Haul infrastructure	100x more 5G capacity supported over the same optical fibre infrastructure
7	New Optical Components/Systems	To be defined
8	CapEx Reduction	To be defined
9	Energy Consumption	To be defined

* AMEN – Access Metro Edge Node, MCEN – Metro Core Edge Node

We now discuss the Metro-Haul KPIs in greater detail, describing how the KPIs are defined, their context and use case application, and how they are to be measured. It is worth noting that aspects of these KPIs (e.g. targets, or how to be measured) is still work on progress and hence have yet to be completely defined.

KPI#1. Optical Point-to-Point connection set-up time (control plane across optical transport layer)

This KPI is the configuration time in the Optical Layer to set up or reconfigure services handling 5G applications enabled by the SDN-based management framework. The new optical nodes use disaggregated solutions. This KPI is composed of the following elements:

- Control plane latency and optical node reconfiguration delay.
- Time required to instantiate a network connection through the optical layer

This KPI will be measured using traces from the SDN controller, and time stamps and protocol analysers. The target is under one minute.

KPI#2. Metro-Haul E2E Point-to-Point connection set-up time

This KPI is the connection set-up time between two Virtual Network Function (VNF) elements as part of a service slice, using the SDN-based management framework. It includes Packet over an Optical Point-to-Point Connection.

This KPI is composed of the following elements:

- The VNFs, which are already available in the Virtual Machines (VMs)
- Control plane latency and device reconfiguration latency
- Time required to instantiate a network service
- Time required to create and install all required flow entries

The target time for this KPI is under two minutes.

KPI#3. Set-up time of network service slice across Metro-Haul

This KPI is the time to set up a network slice as a set of interconnected VNFs, and the target is under one hour.

KPI#4. Capacity of Metro-Haul Controller

This KPI is the maximum number of Netconf devices that a single SDN optical controller can support. The target is the control of 10 – 100 nodes (AMENs/MCENs, i.e., Open Disaggregated ROADMs (Reconfigurable Optical Add Drop Multiplexers)).

KPI#5. Fault/degradation detection time

This KPI is the time between the instant a fault/degradation actually happens (e.g., some threshold is violated or an unexpected trend is confirmed) until it is detected. The target for this KPI is still to be defined.

KPI#6. Capacity of Metro-Haul infrastructure

This KPI is measured as the number of service instances that can be supported. This capacity combines the optical connections and AMEN capacities (throughput, storage, and computing). The specific services that are used to assess the capacity and the specific services configuration are still to be defined.

KPI#7. New Optical Components/Systems

This KPI relates to the new components being defined in the Metro-Haul and are still to be defined.

KPI#8. CapEx Reduction

This KPI relates to the relative cost reduction with respect to baseline network cost to support a predefined set of vertical services. The baseline network costs represent the costs of supporting the vertical services using current technologies and will be defined during the course of the project using techno-economic modelling comparisons.. The target is still to be defined.

KPI#9. Energy Consumption

This KPI is the reduction of energy consumption achieved using new node technologies (e.g., Photonic Integrated Circuits, filterless technology) and the dynamic service infrastructure (set-up/tear-down of services) relative to the energy use made by technologies that make the Baseline Metro Network (based on current network technologies). The target for this KPI will be defined during the project.

4 Use Case Scenarios

Having defined the Metro-Haul KPIs and the key technical innovations being investigated within the project, we now describe some of the important 5G use cases and scenarios for which we expect these 5G innovations to be particularly of advantage. The use case scenarios also provide an opportunity to measure, calibrate, and verify the Metro-Haul performance in a realistic 5G networking context by examining the performance of the technologies against the project KPIs.

The Metro-Haul project is focusing on three demonstration testbeds. These will exercise the key use case scenarios and will provide valuable test and measurement information with respect to the emerging Metro-Haul 5G optical technologies and network architecture solutions.

1. Crowdsourced Video Broadcasts

The Crowdsourced Video Broadcast demonstration testbed will be hosted at the University of Bristol. The setup demonstrates the ability to provision low-latency compute resources and connectivity at the AMEN locations.

The overall architecture of the crowd sourced video broadcast demo is shown in Figure 2. It consists of 2 AMEN as aggregators and 1 MCEN node for core network access. The nodes are placed in active node locations of the UK National Dark Fibre Infrastructure so that the demonstration can run over this network.

The Bristol-based AMEN node has connection to the stadium and will aggregate crowd-sourced video stream traffic to client connections to transponder client ports. The site will also host compute nodes needed for VNFs and software components. The Reading node will use an emulator to generate similar high bandwidth video streams of the order of multiple 100G. Multiple wavelengths from AMEN node will congregate at MCEN node which will connect to the crowdsourced video app software hosted in a cloud. Both the BT Adastral and Bristol Labs have the capability to host MCEN and AMEN nodes, with BT Adastral site hosting the MCEN.

The use case follows the partial disaggregated optical network scenario. Here, the Optical Line System (OLS) is managed as a single black box supporting different mux/transponders. This OLS “black box” transport system, is open to support Optical Channels from external Terminal Points (TPs) as client signals, whose characteristics are specified by the Single Wavelength Interfaces (SWI). An OLS North Bound Interface (OLS-NBI) API is needed to configure and report events from the OLS. This OLS-NBI should be standard to help in the process of vertical integration with the Open WDM Transport Controller of the whole WDM system.

2. Real-time Low-Latency Object Tracking

The Real-time Low-Latency Object Tracking demonstration testbed will be hosted in Berlin. This demonstration will show the ability to provision low-latency compute resources and connectivity at the AMEN locations. Utilizing these resources, real-time object tracking is performed by automatic control of PTZ (Pan-Tilt-Zoom) cameras based on analysis of video streams from fixed and mobile cameras as well as from thermal cameras.

The network constructed in support of this demonstration is shown in Figure 3. It is a metro-ring with three semi-filterless nodes (one MCEN and two AMENs) based on coherent transponders, filterless add/drop paths and wavelength blockers in the express path of the nodes. At the edge of the network are compute units integrated with AMENs and with locally attached IP cameras and Remote Radio Heads (RRH). The RRH is driven by a BBU (Base Band Unit) located in the MCEN’s metro data centre, where the Core Node or EPC (Evolved Packet Core) is also located. Note that for practical reasons 4G technology will be used for this demo. Remote Participation Demonstration.

3. Remote Control Plane Demo

While the first two demonstrations require hardware to be physically located at the test sites, the remote participation demonstration is designed to facilitate inclusion of equipment that is not sited at the central demonstration site, and in particular is intended to allow testing of software components that can be hosted on computer equipment that is interconnected over the Internet.

This environment is known as the Metro-Haul “portable” control plane demonstrator, where all software components from the project partners are integrated into a single platform.

The SDN architecture of the demonstration is based on the concept of hierarchical orchestration, serving data connectivity to an OSM-based NVF-O. The parent controller acts as the single entry-point for systems to request network resources, with two Metro-Haul nodes interconnected via the optical networks, with NFVI at each node to support VNFs according to the placement constraints. In addition, monitoring and data analytics are demonstrated in a testbed in Barcelona with monitoring probes incorporated in a Madrid-based testbed.

5 Conclusions

The paper has presented a snap shot of the current state of development of the EU Metro-Haul project. This project has identified key benefits of designing and operating a fully orchestrated E2E solution for 5G, including the optical transport layer as well as compute and storage functions. These key benefits have associated KPIs which provide a mechanism to quantify the benefit. Finally the paper has presented some of the demonstrations designed to prove Metro-Haul technology. The remaining, crucial techno-economic aspect will develop models designed to calculate performance, CAPEX and OPEX benefits – and this will be the topic of further work.

References

1. Metro-Haul deliverable D2.2 “Functional Architecture Specifications and Functional Definition”, October 2018, <https://metro-haul.eu/deliverables/>

Acknowledgment

The research leading to this paper has received funding from the European Commission for the H2020-ICT-2016-2 METRO-HAUL project (G.A. 761727). The authors would like to acknowledge the support of the partners of the Metro-Haul project.

More information about the Metro-Haul project can be found on the project's web site <https://metro-haul.eu/>