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SODALES

SOftware-Defined Access using Low-Energy Subsystems

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D4.1 SODALES Prototype concept

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Abstract

This deliverable D4.1, "SODALES prototype concept" describes the envisioned basic SODALES architecture scenario demonstrator and the prototypes developed to implement them.

The prototype demonstrator shall provide high bandwidth pipe services to homes, Small to Medium size Enterprises (SME) and Remote Base Stations (RBS) at an open architecture suitable for multiple operators and based on Metro Ethernet Forum (MEF) services and profiles as well OAM and monitoring functions.

The demonstrator will be the testing infrastructure that will allow validating all the SODALES developments in a real production environment.

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List of Acronyms

3GPP	Third Generation Partnership Project
AAI	Authentication, Authorisation, and Identification
ADSL	Asymmetric Digital Subscriber Line
ADSL2	Asymmetric Digital Subscriber Line and Annex J
AGP	Aggregation Point
aGW	Advanced Gateway
AIS	Alarm Indication Signal
APON	ATM-PON
ARN	Active Remote Node
ARPU	Average Revenue Per User
ATM	Asynchronous Transfer Mode
AWG	Arrayed Waveguide Grating
BBU	Baseband Unit
BER	Bit Error Rate
BoF	Broadband over Fibre
BPON	Broadband PON
BS	Base Station
BTS	Base Transceiver Station
BW	Bandwidth
CAPEX	Capital Expenditure
CATV	Cable Television
CCM	Continuity Check Message
CDMA	Code Division Multiple Access
CDU	Customer Demarcation Unit
CE	Customer Equipment
CEN	Customer Ethernet Network

CFM	Connectivity Fault Management
CFP	C Form-factor Pluggable
CO	Central Office
CoMP	Co-ordinated Multi-Point
CoS	Class of Service
CPE	Customer Premises Equipment
CPRI	Common Public Radio Interface
CSI	Channel State Information
C-VLAN	Customer VLAN
DBA	Dynamic Bandwidth Allocation
DGD	Differential Group Delay
DMM	Delay Measure Message
DMR	Delay Measure Reply
DSL	Digital Subscriber Line
E2E	End-to-End
EC	Ethernet Channel
EFM	Ethernet First Mile
E-LAN	Ethernet Local Area Network
EMS	Element Management System
ENNI	External Network Network Interface
EoS	Ethernet over SDH
EPL	Ethernet Private Line
EPON	Ethernet PON
EVC	Ethernet Virtual Channel/Connection
EVPL	Ethernet Virtual Private Line
FDD	Frequency Division Duplex
FSAN	Full Service Access Network
FSO	Free-Space Optics
FTTB	Fibre-To-The-Building

FTTC	Fibre-To-The-Curb
FTTCab	Fibre-To-The-Cabinet
FTTH	Fibre-To-The-Home
FTTx	Fibre-To-The-x
GEM	GPON Encapsulation Method
GFP	Generic Framing Procedure
GPON	Gigabit-PON
GSM	Global System for Mobile
HDTV	High Definition Television
H-NID	Hybrid NID
HO	High Order
HQoS	Hierarchical QoS
HSPA	High Speed Packet Access
HW	Hardware
ICI	Inter-Cell Interference
ID	Identifier
IEEE	Institute of Electrical & Electronic Engineers
IETF	Internet Engineering Task Force
iid	independent & identically distributed
IoF	Intermediate frequencies over Fibre
IP	Internet Protocol
IPTV	IP Television
IR	Infra-Red
IRN	Intermediate RN
ISP	Internet Service Provider
ITU	International Telecommunications Union
JD	Joint Detection
JT	Joint Transmission
LAN	Local Area Network

LB	Loop Back
LCAS	Link Capacity Adjustment Scheme
LED	Light Emitting Diode
LMM	Loss Measure Message
LMR	Loss Measure Reply
LO	Low Order
LoS	Line of Sight
LTE	Long Term Evolution
MAC	Medium Access Control
MEF	Metro Ethernet Forum
MEG	Maintenance Entity Group
MEN	Metro Ethernet Network
MEP	Maintenance End Point
MPO	Multiple Performance Objectives
NID	Network Interface Device
MIB	Management Information Base
MIMO	Multiple-Input Multiple-Output
MPLS	Multi-Protocol Label Switching
NGPON	Next-Generation PON
NC	Network Controller
NMI	
NMS	Network Management System
NNI	Network Node Interface
NUNI	NID UNI
O&M	Operations and Maintenance
OAM	Operations, Administration and Maintenance
OAN	Open Access Network
OBSAI	Open Base Station Architecture Initiative
ODN	Optical Distribution Network

OFDM	Orthogonal Frequency Division Multiplexing
OLT	Optical Line Termination
OMCI	ONT Management and Control Interface
ONT	Optical Network Termination
ONU	Optical Network Unit
OPEX	Operational Expenditure
ORI	Open Radio equipment Interface
OVC	Operator Virtual Channel
P2MP	Point-to-Multi-Point
P2P	Point-to-Point
PB	Provider Bridge
PBB	Provider Backbone Bridge
PDH	Plesiochronous Digital Hierarchy
PDU	Protocol Data Unit
PE	Provider Edge
PHY	Physical layer
PM	Performance Monitoring
POI	Point of Interconnect
PON	Passive Optical Network
POTS	Plain Old Telephone Service
PPB	Parts Per Billion
PTFR	Poly-Tetra-Fluoro-Ethylene
PTN	Packet Transmission Network
PTP	Precision Time Protocol
PW	Pseudo Wire
PWE	Pseudo Wire Emulation
QoS	Quality of Service
RAN	Radio Access Network
RBS	Radio Base Station

RDI	Remote Defect Indication
RF	Radio Frequency
RF	Radio Frontend
RMON	Remote Performance Monitoring
RN	Remote Node
ROADM	Reconfigurable Optical Add/Drop Multiplexer
RoF	Radio over Fibre
ROSA	Receiver Optical Sub-Assembly
RRH	Remote Radio Head
RSP	Retail Service Provider
RT	Remote Terminal
SCN	Signalling Communication Network
SDR	Software Defined Radio
SLA	Service Level Agreement
SLM	Synthetic Loss Measurement Message
SLR	Synthetic Loss Measurement Reply
SME	Small- to Medium-sized Enterprise
S-NID	Service NID
SNMP	Simple Network Management Protocol
SOAM	Service OAM
SoC	System-on-a-Chip
SODALES	SOftware-Defined Access using Low-Energy Subsystems
SOHO	Small Office/Home Office
SONET/SDH	Synchronous Optical Network/Synchronous Digital Hierarchy
SP	Service Provider
SSM	Synchronous State Message
STM	Synchronous Transfer Mode
S-VLAN	Service VLAN
SW	Software

TCO	Total Cost of Ownership
TDD	Time Division Duplex
TDM-PON	Time-Division-Multiplexing PON
TD-SCDMA	Time Division Synchronous Code-Division Multiple-Access
TE	Traffic Engineering
T-NID	Transport NID
ToP	Time over Packet
TWDM-PON	TDM/WDM-PON
UDWDM	Ultra-Dense WDM
UE	User Equipment
UMTS	Universal Mobile Telecommunications System
UNI	User Network Interface
VCAT	Virtual Concatenation
VDSL	Very-high-data-rate DSL
VLAN	Virtual LAN
VLC	Visible Light Communication
VMEN	Virtual Metro Ethernet Network
VoD	Video on Demand
VoIP	Voice over IP
VUNI	Virtual User Network Interface
WAN	Wide Area Network
WCDMA	Wideband Code Division Multiple Access
WDM	Wavelength Division Multiplexing
WiMAX	Worldwide Interoperability for Microwave Access
XFP	10G small Form-factor Pluggable module
XG-PON	10-Gb/s capable PON
ZF	Zero Forcing

1 Introduction

This D4.1 “Prototype concept” deliverable document specifies the technical demonstrators developed up to now and planned in the next year for establishing the SODALES (SOftware-Defined Access using Low-Energy Subsystems) scenario and use-cases for technology validation.

The rise of mobile communications and the trend for seamless convergence between fixed and wireless networks is the driver for the SODALES project, which aims to converge L2 Ethernet and wireless (LTE, 60-GHz) over a unique statistical multiplexer over WDM-PON that offers interconnection to fixed and mobile subscribers in a green, simplified, optimised and easy-to-manage access infrastructure.

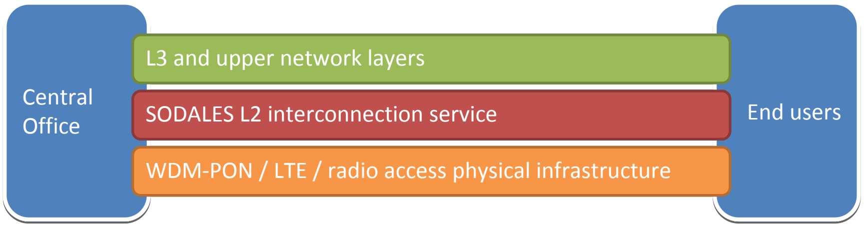

Figure 1: The SODALES vision

The T4.1 “Prototype concept” task was the first task of the work package, aiming at defining the whole prototype.

It consists of a combination of newly implemented parts combined with existing modules and off-the-shelf components and data source/sink devices, which are test generators / analyzers emulating user equipment.

The main innovations of SODALES, already described in earlier deliverables, will be incorporated in the demonstrator prototype, namely:

- The Active Remote Node (ARN) at an access network intermediate location between the central office and end-user premises, as a modular, flexible and future-proofed infrastructure topology for solving the associated bandwidth and wired-wireless convergence issues
- The bidirectional real-time optical wireless Visible Light Communication (VLC) prototype for the very low cost and energy consumption high speed final-drop link when optical fibers and additional spectrum are not available.
- The Software-defined Carrier Ethernet CPE Demarcation Unit interfacing to WDM 10G or microwave and providing multi-user, multi-port service demarcation
- The SODALES Advanced Control and Management Plane (ACMP) built over the Open Network as a service (NaaS) model for OAMP management of network infrastructures

SODALES will deliver services across a set of heterogeneous access infrastructures in the access network.

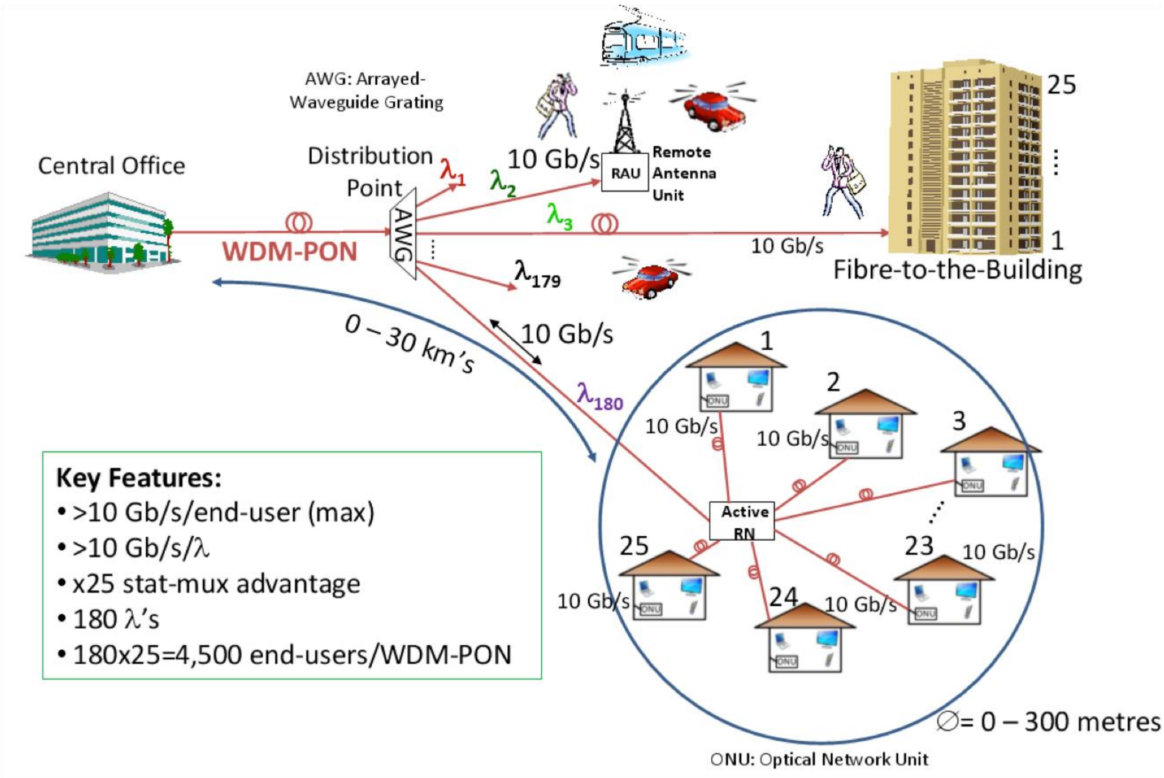

Figure 2: SODALES interconnection service in the access network

All partners' decisions on the prototype system configuration concept are based on previous experience and SODALES system requirements from WP1 and WP2 for which the work included feasibility studies, simulation and extrapolation.

This document presents a brief description for each newly developed part, as the ARN in Chapter 2 which is more detailed than the others as no previous SODALES delivery had fully covered it, the CPE in Chapter 3, the VLC link in Chapter 4 and the ACMP in Chapter 5. Then, the MEF services to be supported are enumerated in Chapter 6, before the scenario prototype and demonstrations are discussed in Chapter 7. The document concludes with an indication of the future work, in Chapter 8 and the conclusions, in Chapter 9.

2 The ARN device

Initially based on the ITU-T G.984.x OLT GPON approach, the PTI active network equipment solution is nowadays evolving for next generation PON architectures as defined by the ITU-T G.987.x, G.988.x and G.698.x recommendations. This is both for central office and customer premises as well as for Ethernet service customers addressed by P2P links and Ethernet interfaces with dedicated bit rate allocation. The OLT evolution to perform the ARN role fits into the PTI and SODALES objectives.

In the SODALES network, only very basic functionalities such as statistical multiplexing at the Ethernet level, basic bandwidth service differentiation between residential and business users, and a common backhaul infrastructure for a RBS are considered for the ARN. It is able to serve multiplay services, namely Voice (VoIP), Data (High Speed Internet - HSI) and TV at a single chassis. Wholesale and enterprise services are addressed through Business Ethernet VBES/TLS Services (VLAN Business Ethernet Services/Transparent VLAN Services).

The ARN is a reliable high availability system that uses common element 1+1 protection (Power, Switch Fabric & Processing) and load balancing LACP at the uplink interfaces. To guarantee security, the Advanced Encryption Standard (AES) is used in the system. Multicast and IGMPv2/v3 snooping with proxy reporting are both enablers for a flexible IPTV service delivery.

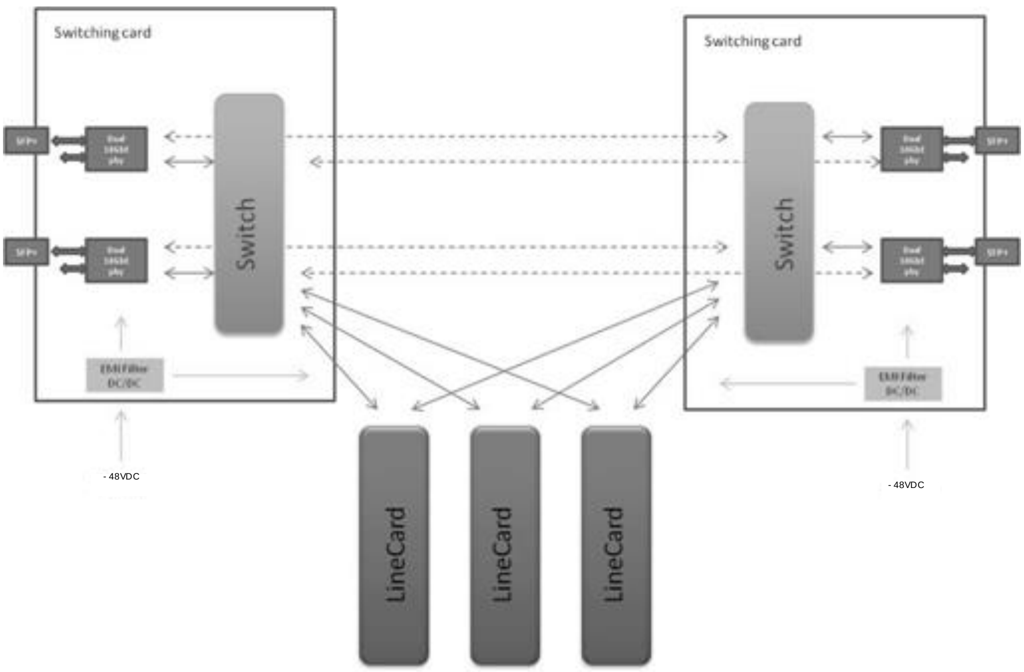

Figure 3: ARN architecture

Simulations with real traffic patterns by means of discrete-analysis tools of the ARN internal non-blocking data plane architecture confirmed its performance as well as complete resilience.

2.1 Hardware characteristics

The ARN equipment, still in a prototype state, is shown in Figure 4. This consists of a chassis for the placement of the two switching boards and a maximum of three line cards. To the left there is a replaceable fan module, responsible for the required ventilation.

In this equipment, the interface to the central office can either be implemented in a line card or in the switching board.

Figure 4: View from an angle of the populated ARN chassis

The ARN cards can be hot-swapped and inserted into the slots identified at the figure below. Slot numbering goes from 1 to 5, being slot 1 the topmost and slot 5 the bottommost.

Figure 5: Front and side view of the empty ARN chassis

The ARN system has a single cooling module with two redundant FANS. In case of failure of one of the FANs, the air supplied by the adjacent units is enough for the proper functioning of the equipment.

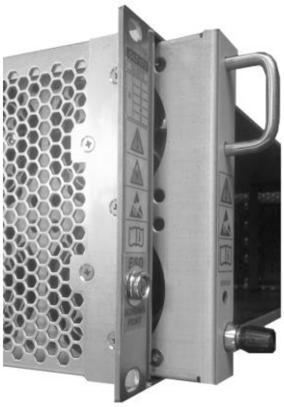

Figure 6: ARN ventilation unit

The ARN system has a single air filter located at the side of the chassis.

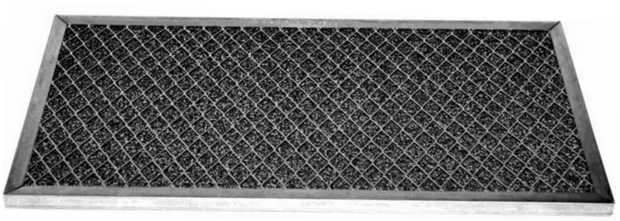

Figure 7: ARN air filter

Table 1. ARN Equipment Board Features

Board Type	**Board features**					
	Type of ports	Nº of ports	Type of pluggable module	Capacity towards backplane (Gbit/s)	MTBF (hours)	Maximum Power consumption (W)
Switch Fabric	10GE	2	SFP+	160	133.354	90
Uplink Line Card	10GE	4	XFP	40	486.874	40
Active Ethernet Line Card	GE/FE	48	CSFP	40	275.233	120

Table 2. ARN Equipment features

Features	**ARN system**
Chassis	ETSI 19'' rack 3U height 248 mm depth
Total number of slots	5

Features	ARN system
Number of usable slots for Switch Fabric cards	2
Number of usable slots for Uplink line cards	3(1)
Number of usable slots for Active Ethernet Line cards	3(1)
Backplane: Physical BW per slot	12x10GbE
Active Ethernet GbE ports (max)	144
10GbE interfaces	12

(1) Shared with the other line cards

The ARN system uses a -48VDC input voltage for its power supply. It works properly within -40.50VDC to -57VDC voltage range in compliance with the ETSI EN 300 132-2 V2.1.1 (2003-01) recommendation. The earth connections comply with the ETSI ETS 300 253: January 1995 recommendation.

This system is carrier class designed and complies with ETSI ETS 300 019-1-3 Class 3.2: Partly temperature-controlled locations recommendation.

This system will properly work within temperature ranges from -5ºC to +45ºC, and with a relative humidity between 5% and 95%.

This system is carrier class designed and suitable to work over extreme EM conditions. As such, it complies with the relevant recommendations for this type of installation, as listed in the ETSI EN 300 386 recommendation.

2.2 Ethernet features

The ARN equipment provides Ethernet access network interfaces which will meet advanced premium/business client requirements. Within each one of the ARN Ethernet ports, the following features are provided:

- VLAN provisioning,
- Range of VLAN ID per port – VLANs are configured individually; the limits are the following:
  - Switch Fabric where uplink ports are directly connected:
    - Just membership: up to 4k VLAN ID per port,
    - VLAN translation: up to 512k VLAN ID shared over existing LCs.
  - Point to Point Line Card:
    - Just membership: up to 4k VLAN ID per port,
    - VLAN translation: up to 512k VLAN ID shared over 48 GbE/FE ports LC
- Security: ACL's and IP Source Guard,

- QoS: Classification (p-bit/DSCP), Queuing, Scheduling and Rate Limiting
- Multicast: IGMPv2, IGMPv3
- Authentication: DHCP Relay Agent
- OAM: Y.1731
- MTU:
  - GPON interfaces: up to 2036 bytes
  - GE or 10GE interfaces: up to 9600 bytes
- MAC Addresses,
  - Number of learnt MAC Addresses : Up to 512K MAC addresses.
  - Learning rate per second: HW based poses no rate limitation

2.3 Protection and security

The configuration of Ethernet Uplink ports protection is a functionality that enables the 1+1 Link Aggregation (LAG/LACP) protection of an uplink port with another uplink port on a different uplink card unit, but there are also hardware and software protection features

Common element redundancy and software protection is implemented at the ARN system by means of 1:1 hot-standby features. Automatic switching to redundant units is assured without service cut off. The ARN system internal architecture (start architecture topology) guarantees that the failure of any unit does not impact the overall system. All single card units are hot swappable and switching protection features are performed without service disruption.

The central processing software features and equipment resident databases are both available at the working and at the protection processing and Switch Fabric units. Both working and processing units are synchronized to the same software version.

The ARN equipment supports also a group of features that avoid anti-DOS (Denial of Service) attacks and fake customer trojan mechanisms, namely:

- Access Control Lists
- MAC duplication prevention, with priority given to the uplink ports
- MAC/IP spoofing through the DHCP binding table verification
- Broadcast rate control
- User isolation

2.4 Synchronization

The ARN equipment implements SyncE and IEEE 1588v2/Precision Timing Protocol (PTP) synchronization schemes. Timing over Packet (ToP) enables transfer of timing over an asynchronous network. The SyncE feature requires that each network element along the synchronization path supports SyncE.

Within the ARN equipment, SyncE may co-exist with 1588 (PTP) in a hybrid configuration mode. The hybrid mode uses the clock derived from 1588 (PTP) to drive the system clock.

The ARN Equipment supports IEEE 1588v2 as the following standard type devices:

- Ordinary Clock (Can be a Master or Slave clock)
- Boundary Clock (Acts as a Master and a Slave clock)
- Transparent clock

The different clock configurations supported by the ARN are:

- Clock Recovery: System clock is recovered from the clocking source (Gbe, 10Gbe and 100Gbe).
- Clock Recovery from External Interface: System clock is recovered from clocking source or a GPS interface.
- Line to External: The clock received from an interface is forwarded to an external Synchronization Supply Unit (SSU).

2.5 The CXO160G switch fabric board

The CXO160G switch fabric boards are responsible for the forwarding plane switching of the traffic between the client and uplink boards for an overall 160 Gbps switching capacity. Besides that, they provide management, operation and maintenance functions and also powering of the ARN system.

The ARN system may be equipped with two Switch Fabric boards (in slots 1 and 5) in order to guarantee 1+1 redundancy for powering, switching and control. If only switch fabric boards are used for the uplink, an overall capacity of 40 Gb/s is available.

This board has four 10GbE internal connections and one O&M connection for each of the uplink and client boards in the system.

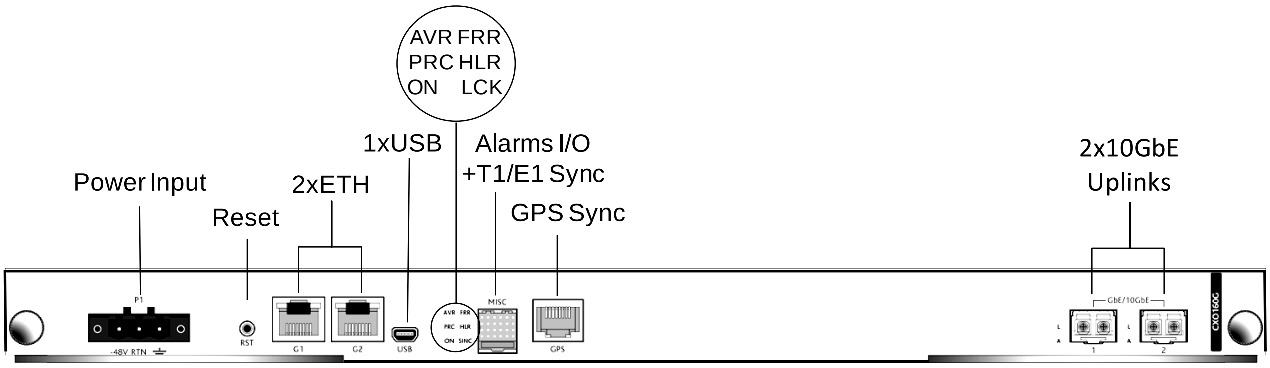

Figure 8. CXO160G Front panel

The following interfaces are provided by the board:

- 2x ETH management interfaces G1 and G2 (RJ45);
- 1xUSB serial management interface

- MISC (Alarms/conditions and ACK indicators) contacts - a Metral 2mm (FCI TM) plug is used
- 1x GPS Synchonism interface
- 2 x 10GbE uplink interfaces using SFP+ modules

The board has a number of LEDs to indicate its status:

- AVR LED - Malfunction
- PRC LED - Processing activity
- ON LED – Power supply
- FRR LED – System clock in free run state
- HLR LED - System clock in Hold Over state
- LCK LED - System clock lock state to the chosen reference.

The CXO160G is responsible for powering the whole equipment, through the power supply input connectors shown in the figure below.

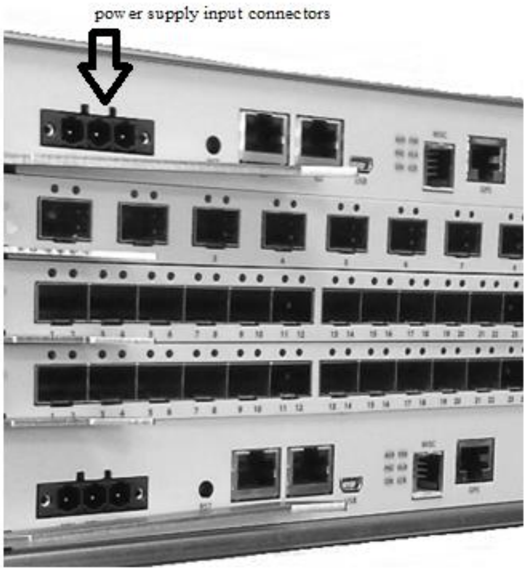

Figure 9: Power supply input connectors

The card building blocks are identified in the figure below.

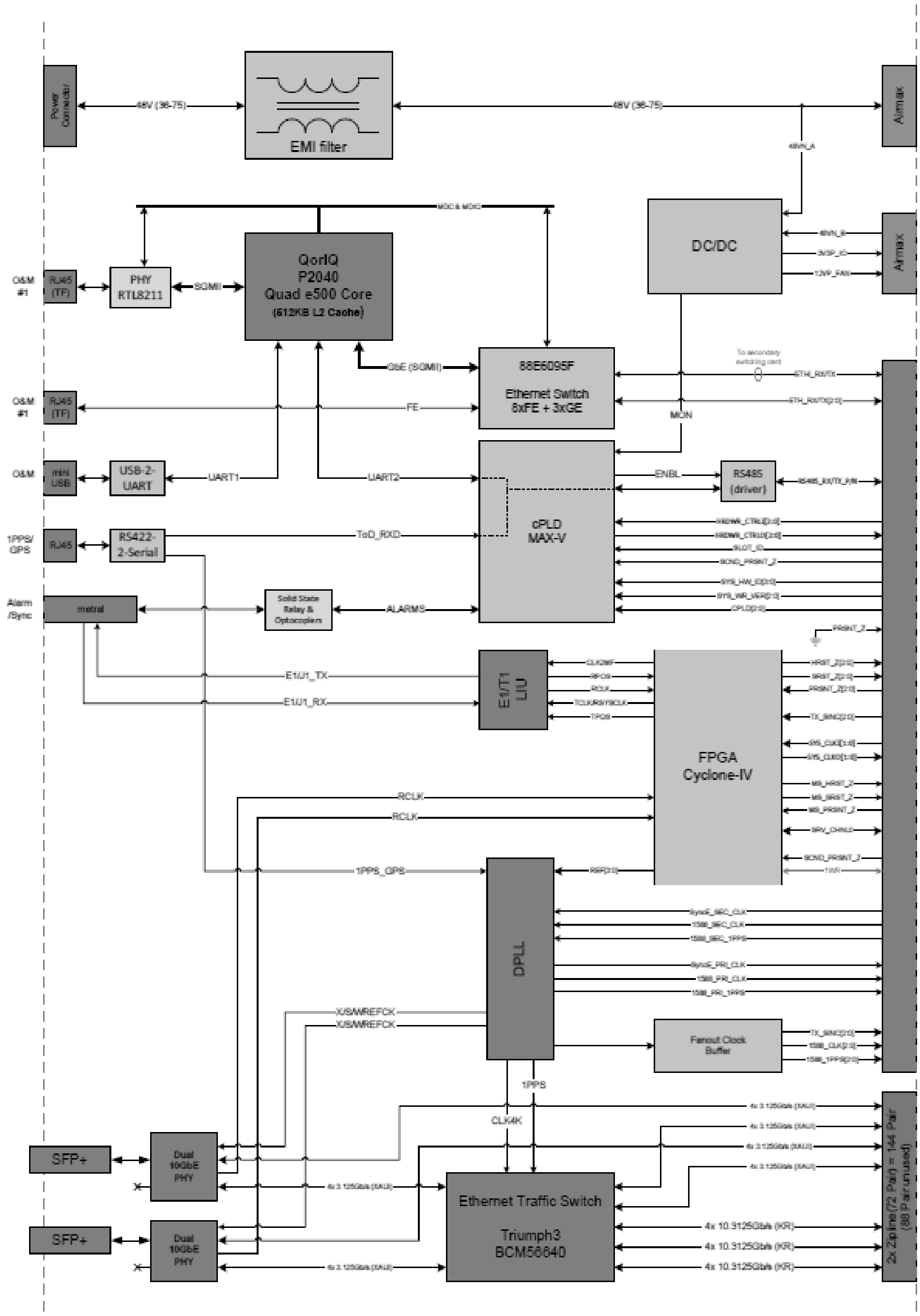

Figure 10: Switch Fabric Card diagram

All other line cards draw power from the backplane, as shown in the figure below.

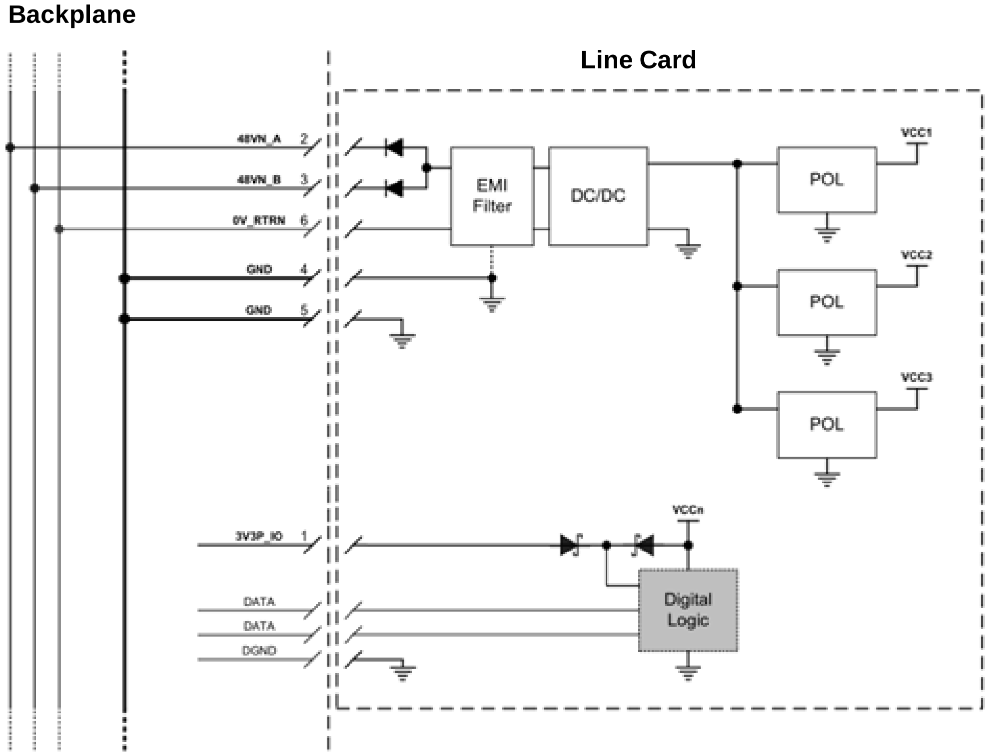

Figure 11: Line Card power connection and distribution diagram

2.6 The TU40G uplink board

The TU40Gboard is a module that interfaces with the Service Provider Network or the client network by means of four 10GE (XFP modules). This board provides LACP protection and can support P2P topology per port. It can be assembled in slots 2, 3 and 4 of the ARN.

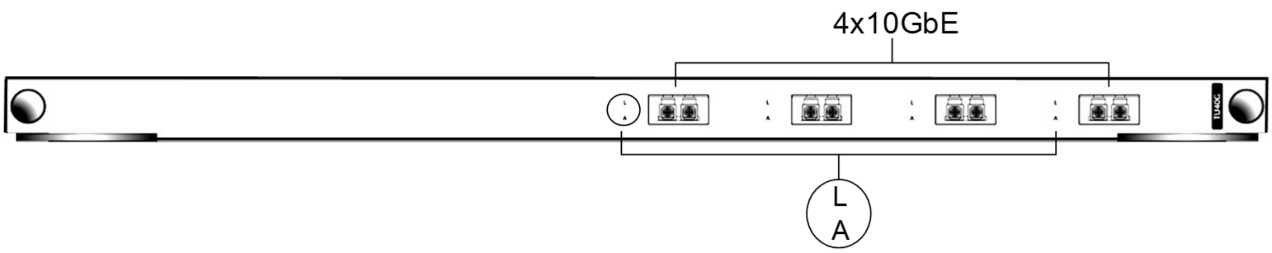

Figure 12: TU40G front panel

The connection to the 10 GE interfaces XFP modules is normally via fiber optics patch cords with LC/PC connectors.

The board provides two red/green LEDs for each of the 10G ports that indicate the interface link status and activity.

2.7 The TA48GE Active Ethernet board

The TA48GE Active Ethernet Line board provides 48 bidirectional Active Ethernet ports and supports P2P or Uplink topology per port. It can be assembled in slots 2, 3 and 4 of the ARN.

The board supports SYNC-E, IEEE 1588v2/PTP and Y.1731 OAM.

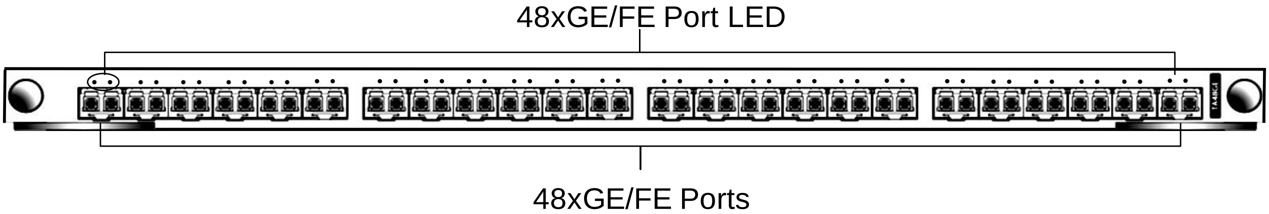

Figure 13: Active Ethernet TA48GE line board front view

The ports support Fast Ethernet and Gigabit Ethernet and use bidirectional CSFPs modules (1000BASE-BX) with LC/PC connectors.

3 The carrier Ethernet CPE

SODALES presents a Software-defined Carrier Ethernet CPE Demarcation Unit based on a single FPGA SoC, interfacing to WDM 10G or microwave connection, supporting multi-user, multi-port dedicated for the wholesale Ethernet service market. It has been fully described in the SODALES D2.2 delivery.

The CPE Demarcation Unit can operate as a Transport Network Interface Device (NID) or Service NID to provide service demarcation. It is a Carrier Ethernet MEF-compliant device and supports MPLS-TP, Deep buffering, Hierarchical QoS, user segmentation, Virtual Switch and OAM features (MEF).

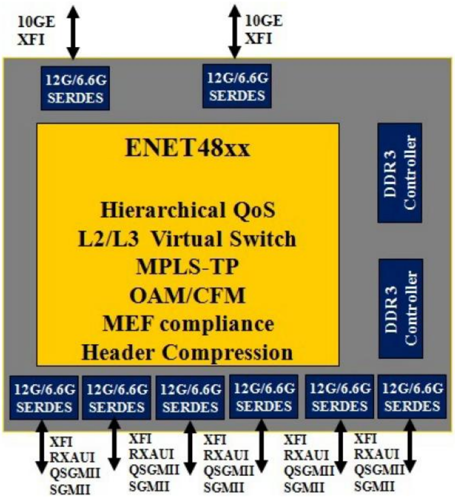

Figure 14: SODALES CPE FPGA SoC Architecture

The SODALES WDM/radio CPE demarcation unit will be used to provide intelligent demarcation to enable service providers full control on the network from UNI to UNI and can be described as a virtual Network Interface Device (NID) serving multiple subscribers. It is not the user equipment, but service provider control equipment that will enable the service provider to deliver end-to-end controlled service.

The unit allows for the complement management of the open access, where the Service Provider (SP) purchases services from the Network Provider (NP), while the subscriber remains a customer of the SP. The Service Provider Virtual Metro Ethernet Network (VMEN) is connected to the NP via the MEF E-NNI service. The Service Provider typically purchases transparent tunnel services from the Network Provider based on a Service Level Agreement (SLA) contract that can be managed using end-to-end service/flow OAM

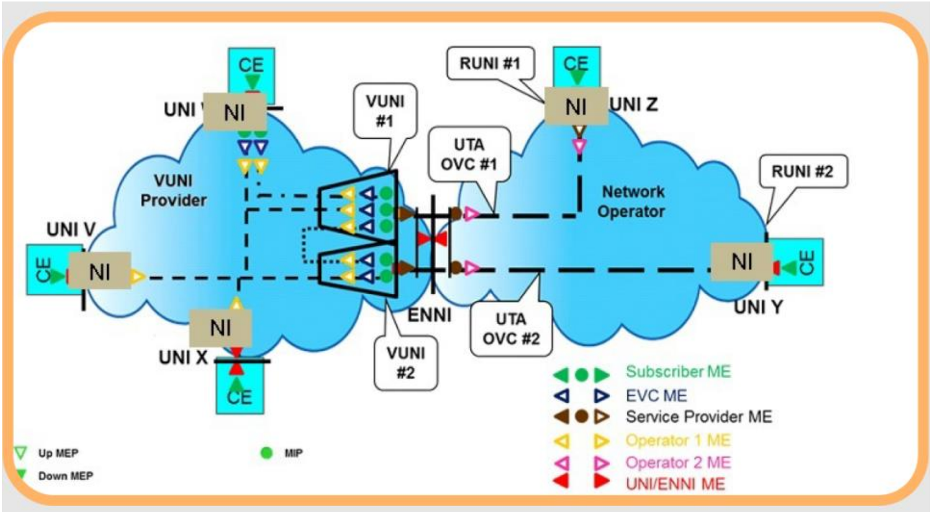

Figure 15: End-to-end service/flow OAM

The developed CPE is shown in the figure below, out of its box.

Figure 16: CPE top view

The CPE functions as a Service NID or Transport NID, with the following features:

- Supports 802.3ah Link OAM and 802.1ag Service OAM for end-to-end fault detection and Y.1731 AIS and performance monitoring
- VLAN service tagging (802.1Q), VLAN stacking (Q-in-Q) and E-Line and E-LAN service multiplexing via 802.1ad
- Hierarchical wirespeed NAT/PAT to maintain Virtual CPE routing

- MPLS-TP
- Single Rate and Two Rate Three Color Marking (srTCM & trTCM) based rate limiting
- Integrated search engine to support search of up to 128K L2/L3/L4 entries through external DDR3
- Deep buffering through external DDR3 to maintain buffering of up to 100ms
- Three Levels of policing, scheduling and shaping
- Virtual L2 switch including support for VPLS, E-LAN, E-Line and MSTP
- Sync Ethernet support
- 1588v2 TC and Optional 1588v2 BC and OC
- ERPS according to G.8032 and ELPS according to G.8031
- 10G Small Form Factor Pluggable (XFP) 10 Gigabit
- Optional E-band radio interface and header compression

4 The optical last hop network

The recent developments in Visible Light Communications (VLC) justify the SODALES interest in the technology. This area of work has been described in earlier SODALES deliverables, such as D2.1 and D2.2.

The overall principle of a bidirectional real-time optical wireless link is illustrated in Figure 17.

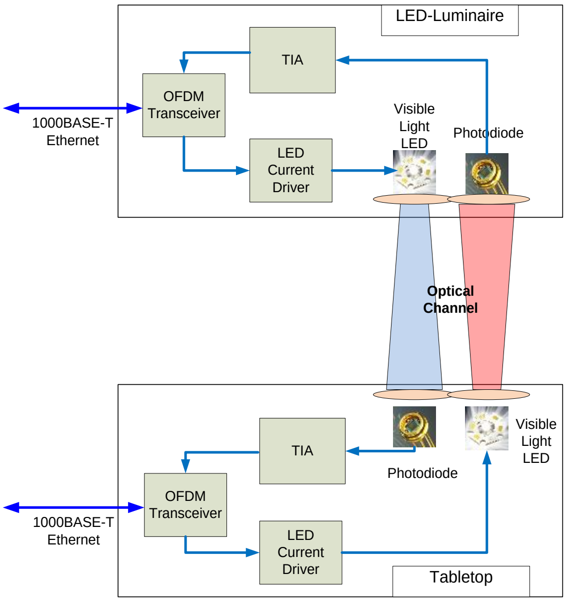

Figure 17: Principle of a bidirectional optical link

HHI has implemented a prototype shown in Figure 18, operating in half-duplex mode currently based on time division duplex and offering 1000BASE-T Ethernet interfaces.

Figure 18: VLC prototype

5 The management plane

The SODALES Advanced Control and Management Plane (ACMP) approach is targeted towards an integrated platform based on SDN and Open Access principles. This has been fully described in earlier WP3 deliverables.

Software Defined Networks (SDN) are a common model widely discussed for transport, with many advantages also for the access network.

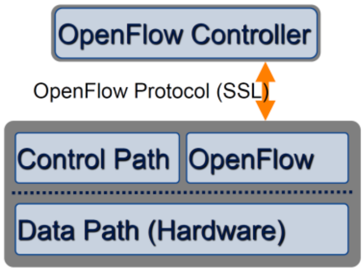

Figure 19: ARN SDN design

The CO ARN follows the SDN design paradigm:

- separate control and data planes using hardware layer abstraction into software resources
- OpenFlow functionality is used for the communication between the management platform and the devices
- standard interfaces are used

ACMP is built over OpenNaaS, the Network As A Service model.

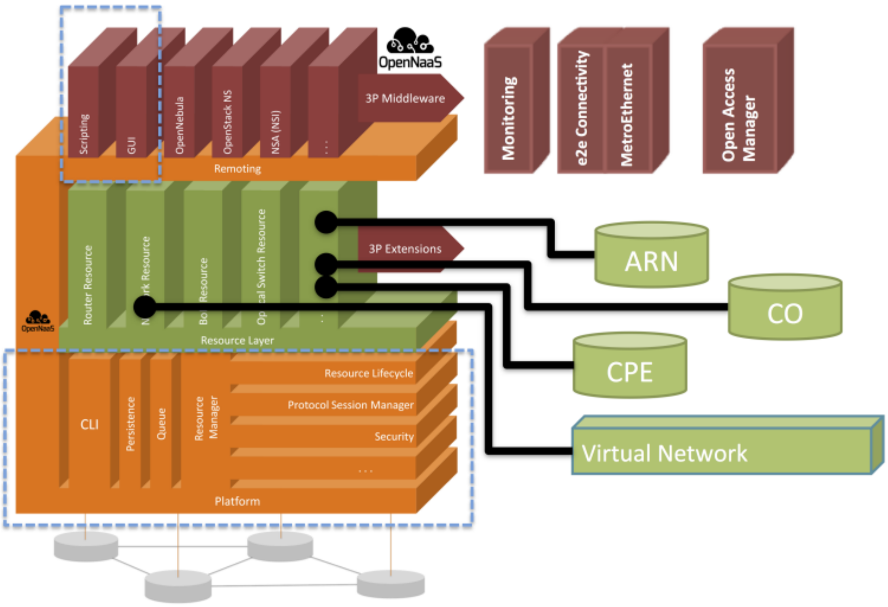

Figure 20: SODALES OpenNaaS model

On the one hand, there will be one Graphical User Interface (GUI), which will contain the basic information of the resources, connectivity, services provisioned as well as the different users. On the other hand, there will be a Command Line Interface (CLI) provided through the SODALES control and management plane, which will enable configuration through the different commands offered.

6 Services, OAM and Monitoring

The popular E-Line, E-LAN and E-Tree Ethernet services defined by MEF and used by carriers as well as standard service OAM requirements and functionalities required for Metro Ethernet Networks are to be supported in SODALES. These have been covered in earlier SODALES deliverables such as D2.2.

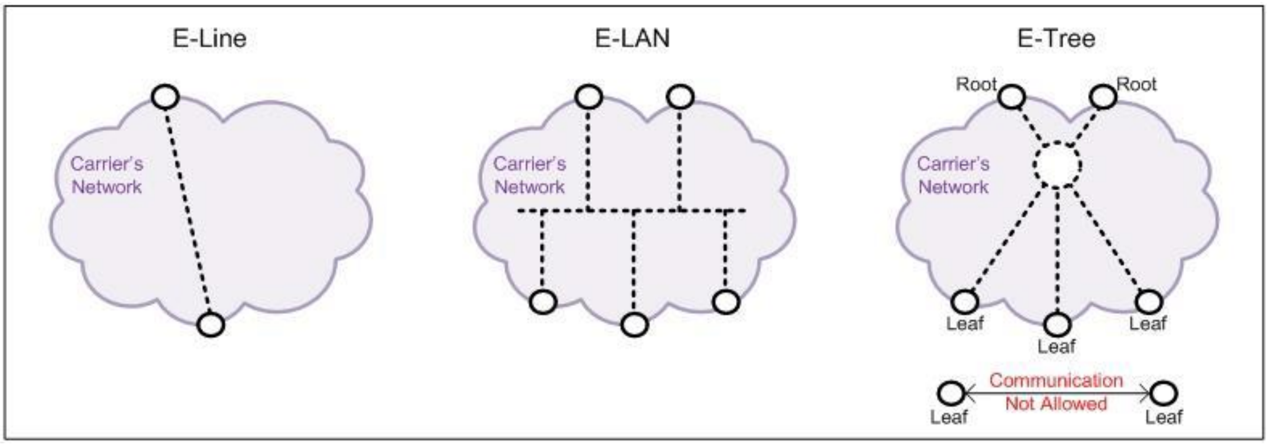

Figure 21: MEF Ethernet service types: E-Line, E-LAN, E-Tree.

The SODALES Advanced Control and Management Plane (ACMP) will enable configuration, monitoring, and controlling of the different services provided.

The OAM Fault Management features from ITU-T Y.1731 are supported:

- Continuity Check Message (CCM) for detecting connectivity failures.
- Ethernet Remote Defect Indication Signal (ETH-RDI) for an end point to indicate the presence of a defect condition to its peer.
- Ethernet Loopback (ETH-LB) to run on-demand service fault isolation/detection.
- Ethernet Linktrace (ETH-LT) for on-demand retrieval of adjacency relationships and fault localization.
- Ethernet Alarm Indication Signal (ETH-AIS) to provide indication of service interruption upstream.
- Ethernet Locked Signal (ETH-LCK) to indicate an administrative lock condition.
- Ethernet Test Signal (ETH-Test) to provide a one-way in-service or out-of-service test.

ITU-T Y.1731 OAM performance monitoring (PM) functions are also supported to measure performance parameters such as:

- Frame Loss ratio - number of service frames not delivered divided by the total number of service frames during a time interval

- Frame Delay – round-trip delay for a frame
- Frame Delay Variation – measure of the variations in the Frame Delay between a pair of service frames

7 The prototype demonstrator

The demonstrator aims at validating the SODALES concepts by setting up a system constituted also by the newly developed parts with an end-to-end service delivery and management.

The current SODALES prototype scenario demonstrator already employs the following project specific developments:

- The ARN from PTI
- The carrier Ethernet CPE from ETHERNITY
- The VLC link from HHI

There is also the intention of demonstrating the superior performance of the network when introducing the ARN, as verified in the network simulations that have been carried out earlier.

The basic demonstrator scenario is illustrated in Figure 22, where:

- There is a dedicated connection to the CO by one SME and one RBS using 10G wavelengths
- The ARN serves a customer capacity of up to 136 Gb/s
  - 96 statistically multiplexed residential customers are served using 96xGE ports from two TA48GE cards
  - 3 SME and one RBS are served using 10GE ports from one TU40G card
- In this scenario, the ARN offers 20-Gb/s uplink capacity
  - by means of 2×10Gigabit Ethernet ports in a 1+1 redundant configuration, using the a single CXO160 card ports. The uplink capacity can be increased by using a second CXO160G card.
  - The oversubscription between the uplink and the customer ports is lower than 1:7

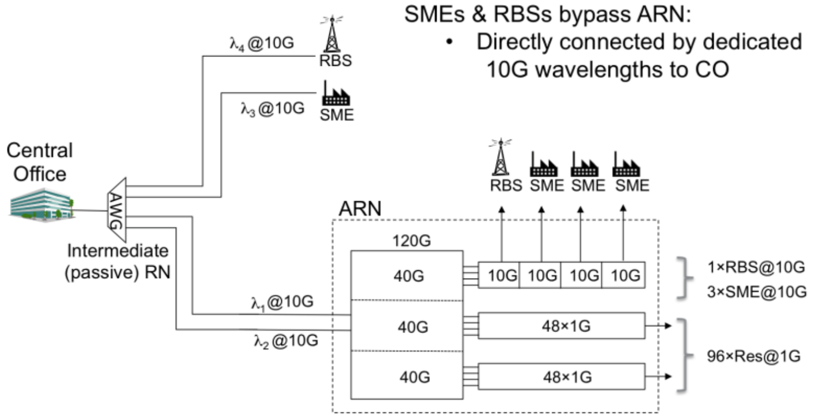

Figure 22: The basic SODALES scenario

The SODALES architecture uses a point-to-point topology DWDM fibre network configuration without add-drop multiplexers.

In case a purely residential area is being addressed and RBS backhauling does not use all ARN 10GE interfaces, there is the option to use them to connect to another switching stage, eventually using the carrier Ethernet CPE, which fans out a number of GE interfaces to increase the number of supported residential customers.

The user capacity of 1 Gb/s in the SODALES architecture is much higher than GPON, that provides a data stream of 2.5 Gb/s in the downstream direction, and a 1.25-Gb/s upstream channel typically shared by 64 users. Naturally, this exerts pressure at the uplink. But the ARN statistical multiplexing gains are high for this number of residential customers, and the burstiness of video streams traffic patterns also brings gains. Therefore, the proposed 20 Gb/s capacity are considered enough, at least with current mainstream user devices, that are not able to take advantage of data rates of 100 Mb/s or more.

Note that while upstream traffic bandwidth may eventually be limited by the ARN uplink interfaces capacity, the downstream traffic in real life networks tends to be limited by the internet or server side. The oversubscription in this scenario is considered adequate and not limiting, as discussed in a previous SODALES delivery.

The basic SODALES scenario allows for the delivery of the required services for optimal network utilization, as shown in Figure 23.

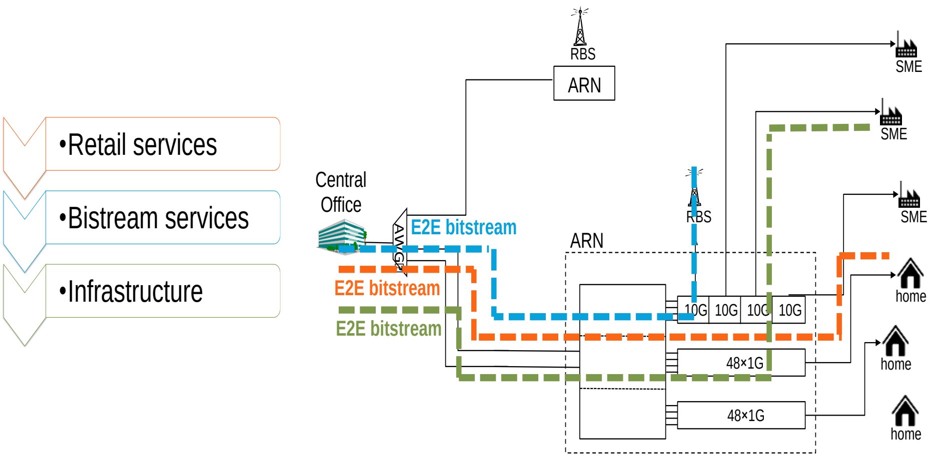

Figure 23: SODALES services

The establishment of SODADES scenario prototype trials for providing Metro Ethernet Forum (MEF) services aims at obtaining a real-life validation of the project objectives, such as

- Creating an open architecture suitable for multiple operators
- Enabling infrastructure sharing via network virtualization
- Using heterogeneous access technologies supporting different physical layers, wired/wireless feeder and access links with Ethernet as a common integration platform
- Providing Generic operation and maintenance features
- Employing a Software-defined architecture

The equipment used at the Central Office (CO) is the OLT1T3 from the PTI OLT platform portfolio, shown in Figure 24.

Please refer to http://www.ptinovacao.pt/content/BR_GPON-IN-A-BOX_PTInS_EN.pdf for further details on the PTI GPON portfolio.

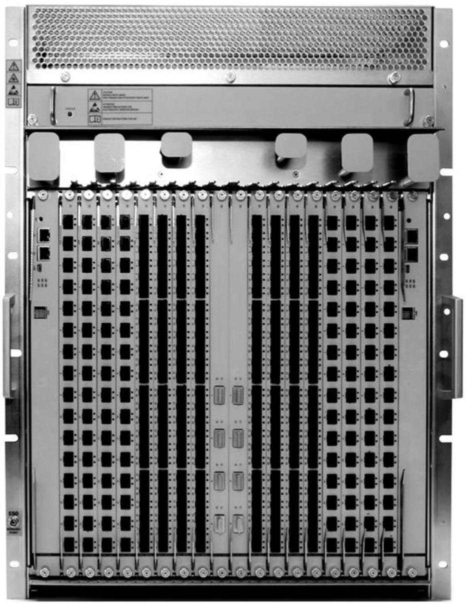

Figure 24: OLT1T3 CO equipment

The OLT1T3 connects to service providers and the ARN using 10G interfaces, to provide bit stream services for residential and corporate users and the backhaul of the mobile network radio access network.

The SODALES architecture scenario has already been demonstrated a number of times, and plans exist to deploy it in a more permanent basis, namely in the DELTA network that PTI has in operation in the metropolitan area of Aveiro, and also in a municipality near Barcelona.

In the Barcelona case, it will be a commercial deployment of SODALES, to be announced at a press conference. The control and management plane will also be incorporated when it will be ready and validated.

7.1 Initial demonstrations

For the initial validation of the SODALES project and demonstrations in Brussels and Bologna, the ARN and CO equipments from PTI and the CPE from ETHERNITY were not available yet. Consequently, a system demonstrator was built using the following solutions:

- A PC serving as a traffic source server
- A PTI PP12 MPLS equipment playing the role of the Central Office (CO)
- A PTI PP80 MPLS equipment playing the role of the ARN

- A VLC link by HHI to establish the communication between the ARN and CPE. At the time, the link had important range limitations.
- A PC serving as a CPE

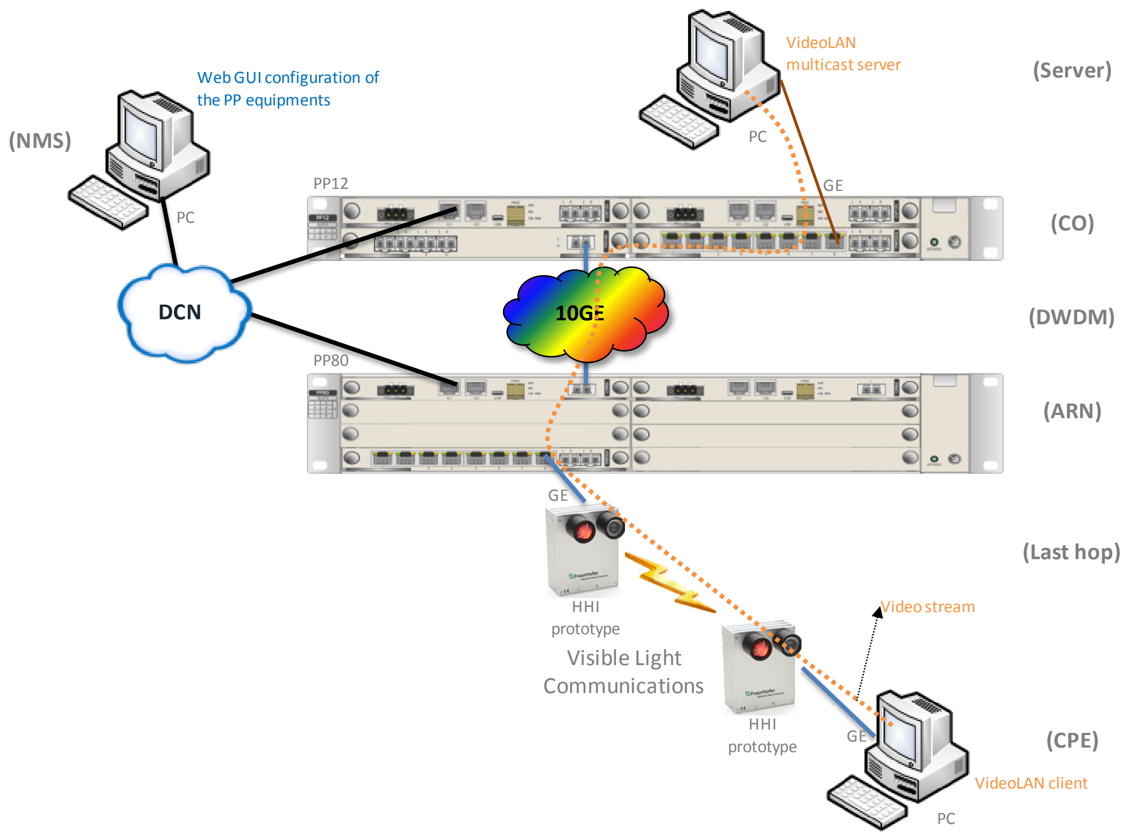

Figure 25: Initial SODALES demonstration scenario

This scenario allowed for the successful demonstration of the SODALES vision by establishing a video stream service over a Layer 2 end-to-end access solution.

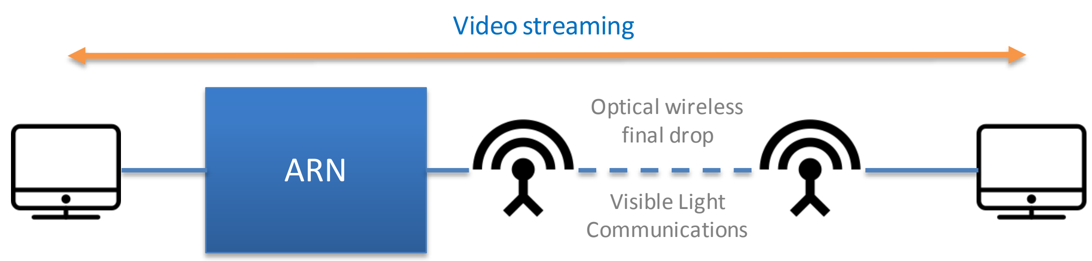

Figure 26: Video streaming demo

The scenario configuration still didn't use the SODALES control and management plane, relying instead on the PP12 and PP80 web configuration interface.

7.2 Introducing other SODALES components

The next step in the demonstration is to include both the CPE, which has already been demonstrated in a standalone way, and the OpenNaaS Advanced Control and Management Plane into the scenario. This will allow the full establishment and monitoring of services in the SODALES architecture, fulfilling the project objectives.

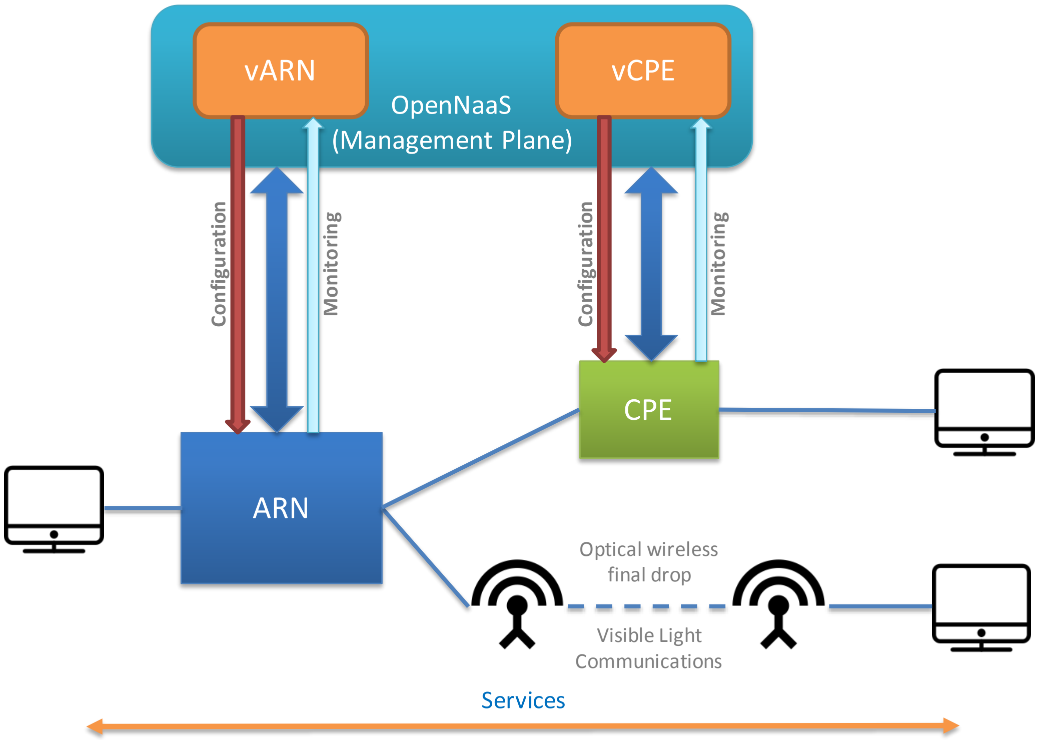

Figure 27: The SODALES service configuration and monitoring model

OpenNaaS demonstrations in Brussels are already scheduled for the beginning of 2015, preceding its introduction in the PTI DELTA platform.

The management plane based on OpenNaaS will be focused on creating a virtual slice, based on the SODALES open access principle, and then enabling the corresponding service provider to configure the slice (i.e. the virtual ARN and the virtual CPE representations). More details of the control and management plane implementation are provided in deliverable D3.4.

7.3 The SODALES prototype in the DELTA platform

End-to-end connectivity using all SODALES components will be validated using the existing DELTA platform covering PTI's own campus and three end office switch locations of the Portugal Telecom service provider in Aveiro.

This wide optical and copper network covers around 300 customers from the more than 2000 PTI employees that are provided with high speed Internet and IP TV services. A number of DSLAM units provide service over copper with ADSL2+ to Portugal Telecom customers that join the trial. The PTI campus, where most of its employees work, is covered by the OLT1T0, a low density OLT capable of delivering multi play services to 512 customers (assuming a 1:64 splitting ratio) over ITU-T G.984.x GPON. A possibility exists of expanding the DELTA trial to the *Instituto de Telecomunicações* (IT) premises in the Aveiro university campus through both existing fiber and radio links.

The GPON and DSL equipments in DELTA are managed by PTI's Agora-NG NMS solution, installed at a cluster of virtual machines in the PTI campus data center. A TR-069 Auto Configuration Server (ACS) at the data center is responsible for the provisioning of services at the GPON and DSL CPEs. Physical and virtual machines exist at the data center for the validation of an array of services other than IP TV or IPv4 and IPv6 access to the internet.

There is also an interface to the SALINA full NGN/IMS reference demonstration platform, designed as a technological showcase of the different PTI solutions in this area and enabling interoperability tests with third-party systems with the objective of encouraging synergies with industrial partners and scientific communities.

SALINA already includes an Enhanced Packet Core (EPC) for LTE, and multiple initiatives exist to install a cell site with an enhanced Node B (eNB) in the PTI campus for the introduction of the mobile service into the DELTA and SALINA demonstrators.

The SODALES scenario will introduce at DELTA the OLT1T3 large scale OLT as the Central Office (CO) equipment, a number of ARN equipments and several CPE using a variety of final drop technologies to validate all the services and functionalities that will be developed during the project.

Depending on the overall DELTA network load, its architecture may need to be adjusted in order to choose the component to be subject to traffic stressing. Thus, the OLT and DSLAM used may all eventually uplink to a single ARN, for example, in order to analyse its statistical multiplexing gains. Traffic generators may also be used to create additional loading.

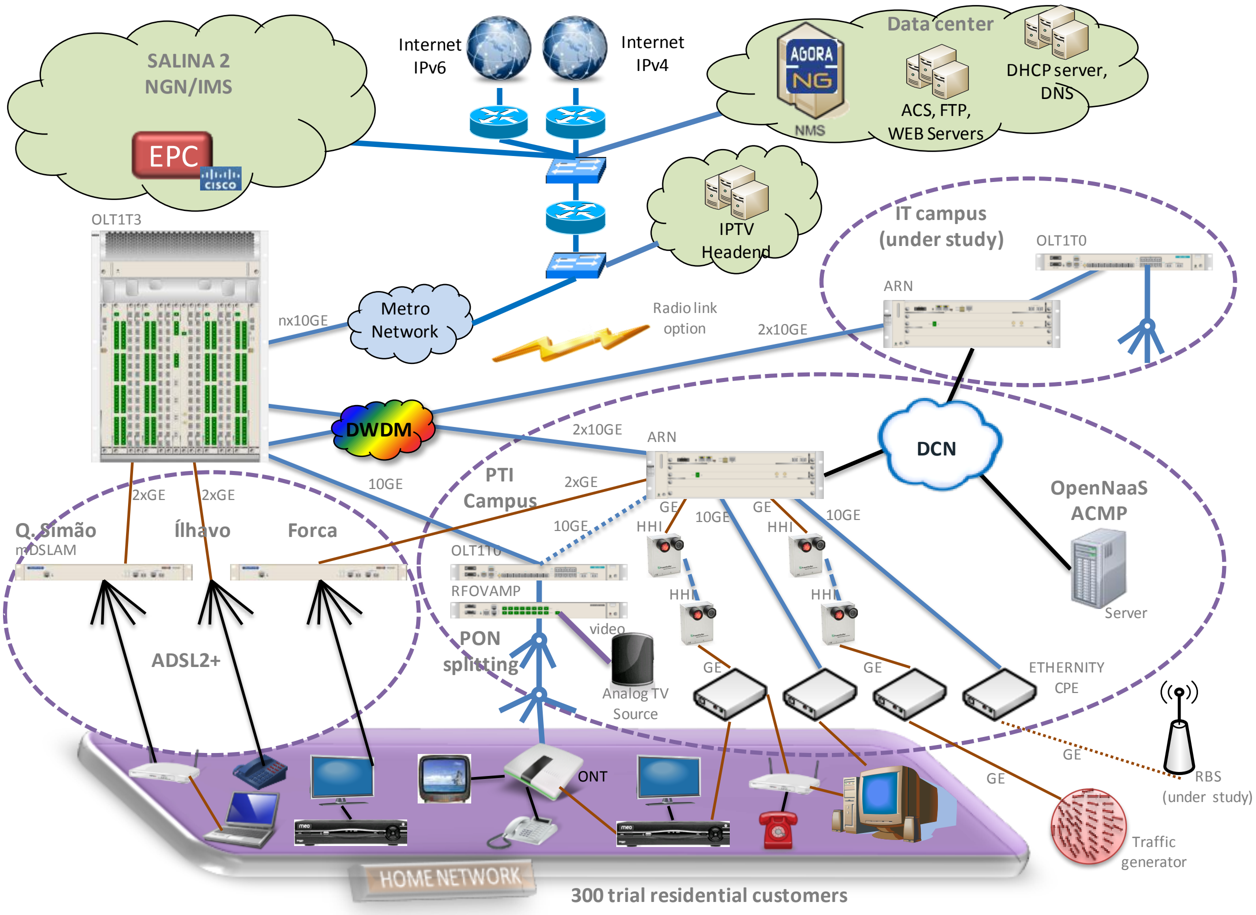

Figure 28: The SODALES DELTA scenario

At this stage, the functionality of the ARN is kept to a minimum. Nevertheless, the demonstrator will not only validate the correct working of the SODALES parts, but specially allow for a real-life confirmation of the projected architecture advantages.

7.4 Field trials in Barcelona

Validation and production trials will be implemented in Y3. Those will help to finally adapt the SODALES hardware and software for a commercial development.

Three validators will be implemented:

7.4.1 EXPERIMENTA validator

I2CAT test platform: EXPERIMENTA experimental facility offers an open experimental platform to facilitate the experimentation and validation of Future Internet services and network technologies in a real field trial to improve the quality of ICT developments. This open experimental environment aims at promoting public-private-partnership inside and outside Catalonia.

The EXPERIMENTA facility presents an ideal environment to validate prototypes for Future Internet technologies, architectures, protocols and services. One of the main innovation keys of EXPERIMENTA is the capability of the end users to reconfigure their assigned resources according to their testing, validation and research needs.

The platform offers the following equipment and services:

Connectivity and testbed Services

- Add/drop capabilities on each ROADM node
- 2.5 & 10G line connections
- L1, L2, end-to-end services
- E2E network performance monitoring services
- Collocation services at the PoPs
- Dark fibre field trial availability
- Virtual machine instances service
- L2/L3 network as a Service
- Cloud and GRID computing service

Media Services

- 10G lambda media services
- 4k media demonstration room
- Advanced Video-conference and VoIP services

Current validation & research activities

- ROADM technology validation
- GMPLS deployment tests
- FTTH Lab testbed @ UPC Castelldefels
- FTTH EPON/GPON validation & research platform
- Residential & eHealth Living Labs

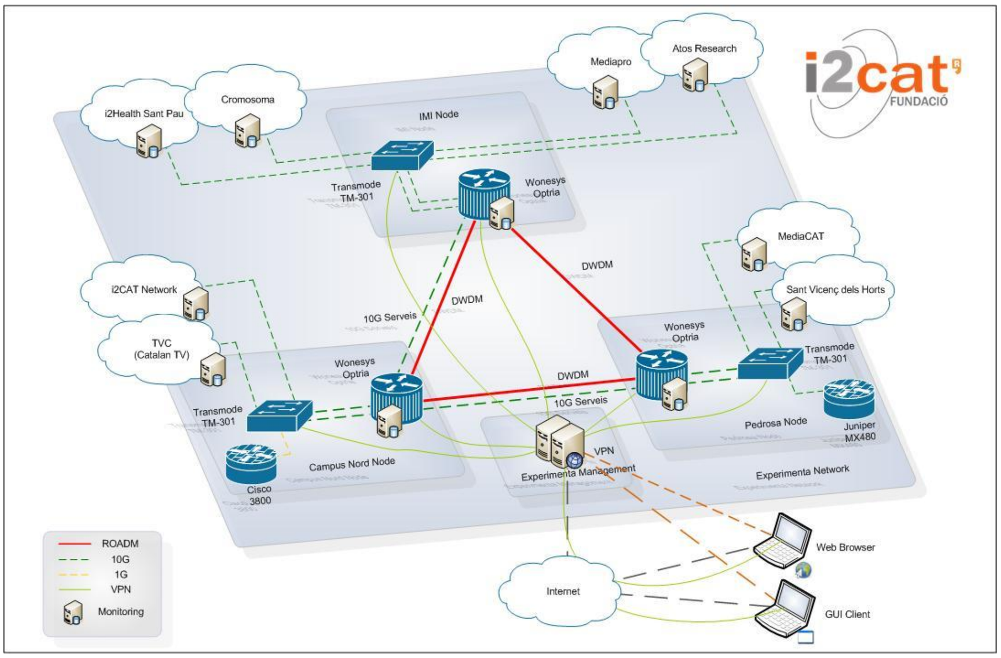

Figure 29: EXPERIMENTA infrastructure and connectivity features

This validator will be used in the context of SODALES by deploying an ARN and several CPEs and validate end-to-end connectivity in an heterogeneous transport environment.

The ARN will be deployed in the FTTH lab and media content will be distributed across the network from i2CAT datacentre to the SODALES access infrastructure. As EXPERIMENTA supports Carrier Ethernet services, this experiment will allow to demonstrate end-to-end connectivity.

Additionally, the control and management plane will be deployed to configure end-to-end services.

7.4.2 Commercial deployment in Rubí, Barcelona, Catalonia

The municipality of Rubi is engaged in several R&D initiatives to boost the productivity of the companies that have local presence in the town. There is a living lab in La Llana industrial park in which SODALES will be validated. This pilot comprises commercial exploitation so it will be the first commercial initiative of the project.

The validation will start just with the deployment of hardware equipment and end-to-end service provision in order to offer 100Mbps to each corporate customer. Depending on the location, end customers will be connected using fibre optical or radio links.

Within the scope of the project, 10 companies will be connected and the validation period will run during year 2015. Data and voice services will be provided. It is expected that commercial exploitation will continue once the project is over and that more companies will subscribe to the network.

The network is operated by APFUTURA (http://www.apfutura.net), a Spanish broadband operator.

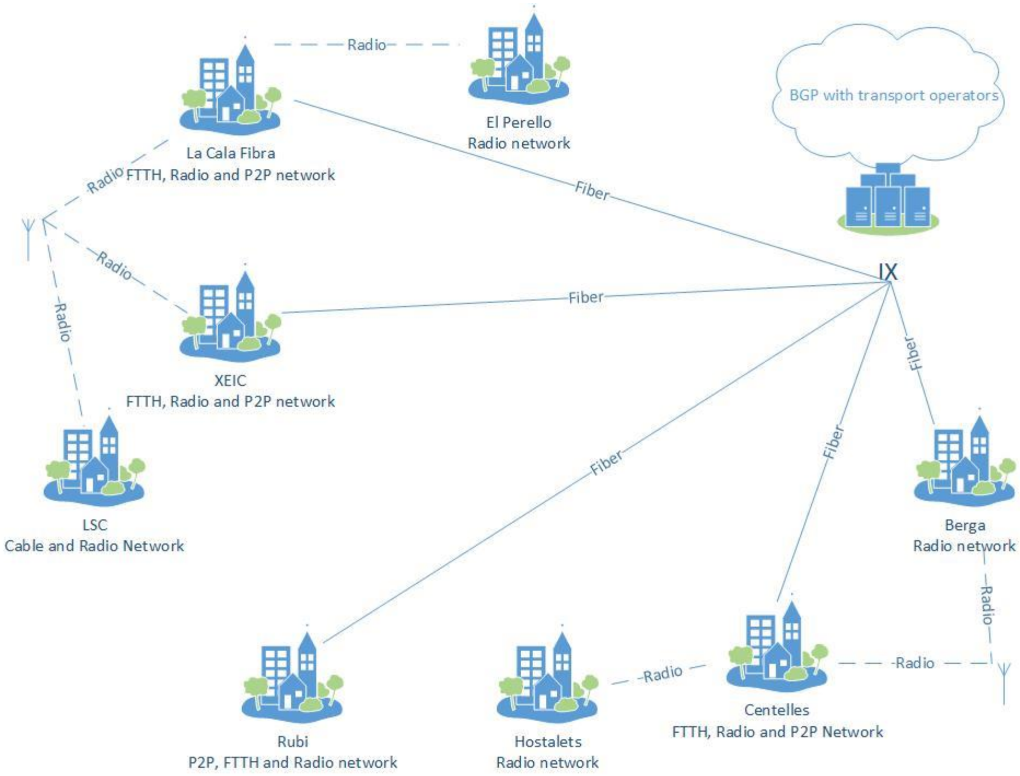

Figure 30: APFUTURA infrastructure

7.4.3 Commercial deployment in Centelles, Barcelona, Catalonia

This is a similar approach as in Rubí. The municipality of Centelles has deployed an Open Access network to connect both, residential and corporate users. There is a local operador which at present offers ultra-high speed broadband services, Fibra Optica Centelles (http://www.focentelles.net).

The OLT is from PTIS so the objective of this validation and future commercial exploitation is to develop SODALES ARN to connect end users by means of fibre or radio links. At present, there are 300 customers connected to the network.

The objective is to validate SODALES architecture and equipment to offer 1Gbps to the user. Also, as there are several corporations that are not in the fibre network range, radio links will also be deployed and validated.

The objective is to run this pilot during 3Q and 4Q 2015, as the final validation of the project.

8 Future work

There are two main directions on the future work. On the one hand, there is the issue of ARN interconnection (for resilience, and more localized traffic management), which has not yet been rigorously considered.

Thus, one approach may be to consider the use of OFDM-PON to interconnect the different remote nodes in a metro-access convergent scenario. On the other hand, and again taking into consideration the virtue of being powered, the ARN may exploit the substantial operational and economic advantages in aggregating traffic at intermediate points with standard Ethernet switching technology, together with offering Cloud Services, Content Caching within content delivery networks, and virtual CPE (V-CPE) features in order to reduce traffic aggregation at the central office

One path already in progress is the development of the ARN TU100G uplink card able to support 100 Gb/s Ethernet interfaces, as an alternative for a switch fabric card with a 100G uplink interface.

In the future, we can expect ever greater network functions virtualization (NFV) to take place at the ARN, with local caching as part of a hierarchical content delivery network (CDN), more sophisticated service differentiation (QoS/E) for a more segmented end-user base, and additional software-defined operation of the network to maximize exploitation (e.g. for energy efficiency and operational expenditure (OpEx) purposes) of available network resources.

9 Conclusions

The SODALES systems developments culminated with the establishment of a system demonstrator well capable to prove the concepts proposed in the project. Layer 2 MEF services and OAM functions supported are adequate for the future proof open access network topology envisaged.

The objective of the validators is to demonstrate the correct performance of the SODALES platform, both, from the transmission and operation perspective.

Three validators will be implemented in order to close the developments to the market. Actually, two of them, the ones taking place in Rubí and Centelles, will be commercially exploited once the project is over, so we guarantee that the project ends up with commercial results.

References

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