Zero Touch Elastic Optical Networks using Sliceable Bandwidth Variable Transponders

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ABSTRACT

Sliceable Bandwidth Variable Transponders (SBVTs) enable transmitting from one point to multiple destinations, changing the traffic rate to each destination and the number of destinations on demand. The aim of this work is to quantify potential savings of the SBVT based architecture proposed in PASSION project calculated in relation to estimations for IP over DWDM networks using non-sliceable transponders. The techno-economic analysis considers accumulated CAPEX and OPEX costs in a 10 years period over a real network scenario in Hamburg region.

Keywords: Sliceable Bandwidth Variable Transponders, Elastic Optical Networks, Total Costs of Ownership, Pay as You Grow, Multilayer Planning

1. INTRODUCTION

Bandwidth Variable Transponders (BVTs) can adjust their transmission rate by varying the number of subcarriers and by modifying the modulation format, as depicted in Fig. 1-a. However, when a BVT is operated at lower than its maximum rate part of the BVT capacity is wasted. In order to address this issue, the Sliceable BVT (SBVT) has been proposed [1]. A SBVT can allocate its capacity into several optical flows that are transmitted to one or several destinations, as illustrated in Fig. 1-b.

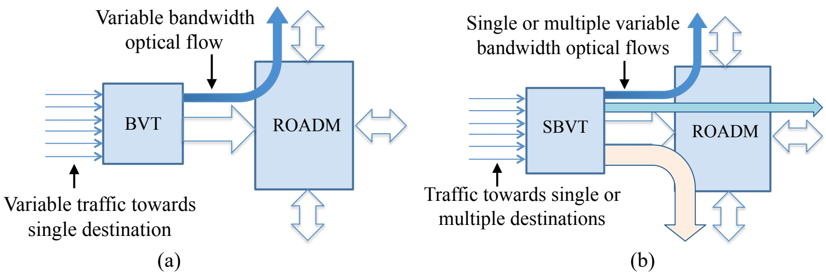


Figure 1. Illustration of the functionalities of (a) bandwidth variable transceiver (BVT) and (b) sliceable bandwidth variable transceiver (SBVT).

PASSION project proposes an S-BVT architecture which exploits VCSEL sources [2], each one operating at a different 25-GHz spaced WDM wavelength in the C-band (covering 4 THz), directly modulated to obtain up to 50 Gb/s rate, to target up to 8-Tb/s WDM aggregated capacity at a single polarization. 16 Tb/s per spatial channel are achieved exploiting polarization-division multiplexing, while the spatial dimension of 7 cores MCF or 7 fibers in a bundle allows enabling up to 112 Tb/s aggregated capacity per link. This target is pursued with a modular approach, as shown in the Fig. 2.

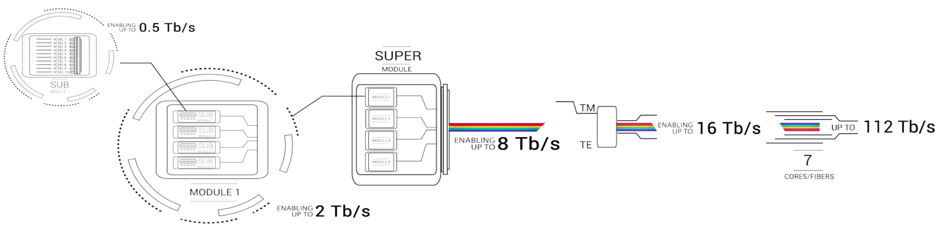


Figure 2. PASSION SBVT granularity exploiting the spectral and space dimensions

A 40-VCSEL based module is built by integrating 4 sub-modules, each one containing 10 VCSELs. The 40 operating wavelengths cover the entire C-band with 100 GHz granularity. By directly modulating each VCSEL at 50 Gbps, an aggregated capacity of up to 2 Tbps per fundamental S-BVT is obtained, as shown in Fig. 2.

PASSION SBVT combines both ultra-high capacity (2Tbps per module) and fine granularity (50 Gbps) in a single chipset, these characteristics together with automated configuration and wavelength provisioning through Software Defined Networking (SDN) could enable significant cost optimizations in telco networks. This study aims to estimate the potential savings in terms of CAPEX and OPEX by deploying PASSION SBVTs

2. TECHNOECONOMIC BENCHMARCKING

We are comparing different evolutionary scenarios over a reference network to quantify potential CAPEX and OPEX savings from PASSION SBVT architecture.

2.1 REFERENCE NETWORK

Telefónica IP network is composed by five Hierarchical Layers (HL):

- **HL1**: They are located at the top level of the IP network, in the backbone network. They are the interface between IP network and Internet/ISP providers. In the MPLS context they are PE (Provider Edge) routers.
- **HL2**: National Backbone Nodes distributed in most populated cities. They are located after the HL1 routers and carry traffic to/from the IR routers. They are P routers that do not aggregate traffic, only sends traffic toward the intended destination. Service platforms such as IP-TV or CDN catching are hosted on these nodes.
- **HL3**: This layer carries out the traffic aggregation/distribution function. It collects the traffic from the different metropolitan areas.
- **HL4**: The HL4 layer is composed by the routers located at the bottom layer of the IP network and performs functions such as traffic classification, subscriber's credentials authentication, validation of users' access policies, routing data to the respective destination, etc. Also, this layer aggregates traffic from different locations of the Metro network and from OLTs, DSLAMs and HL5s.
- **HL5**: The remote access layer comprises routers that collect the traffic from less dense areas than HL4s.

The reference network used in this study is based on Hamburg region topology and comprises 7 HL4 nodes connected in a dual-star IP logical topology to 2 HL3 routers using optical protected links over a fibre ring. HL3 nodes are connected to two HL2 nodes which are co-located in the same datacentre.

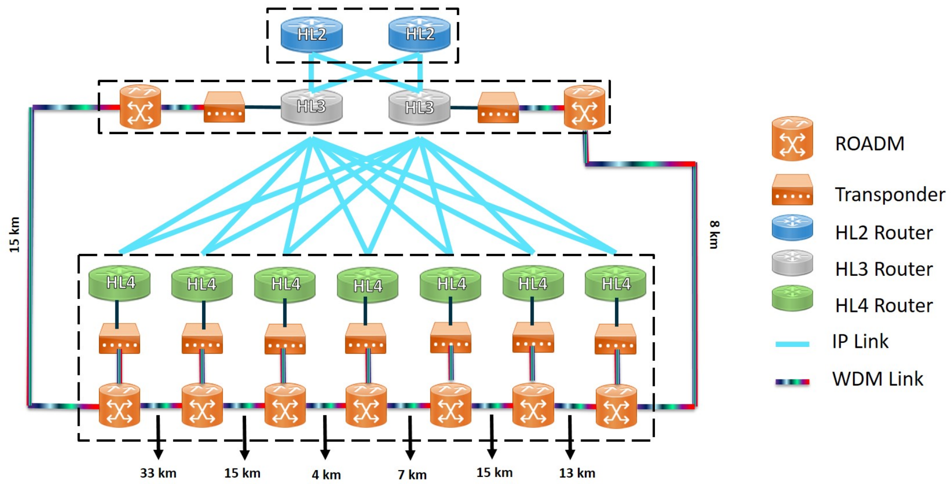


Figure 3. IPoverWDM architecture – Hamburg region

HL3 nodes are aggregating the traffic exchanged between HL4 and HL2 Nodes. The initial peak traffic per HL4 is 20Gbps, which is increased considering a Compound Annual Traffic Growth (CAGR) of 40%.
The given cost model shown in Table 1 is based on real figures from available equipment in 2020. SBVT costs are estimated based on current prices for coherent 600G and 1, 2 Tbps transponders. However, normalized prices are used in this document to preserve the confidentiality of the information.

Device	Space	Power	Price (Normalized unit)	OPEX Space	OPEX Power	OPEX Service
HL2 Router	3 RU	3,300 w	2,500.00	$22.50	$24.09	$200.00
HL3 Router	2 RU	5,000 w	1,666.67	$15.00	$36.50	$133.33
HL4 Router	1 RU	5,000 w	250.00	$7.50	$10.95	$20.00
400G Grey Optic	RU	12 w	36.96	$0.00	$0.09	$2.96
400G Breakout	RU	12 w	36.96	$0.00	$0.09	$2.96
100G Grey Optic	RU	5 w	3.33	$0.00	$0.04	$0.27

2T SVBT Optics	RU	100 w	333.33	$0.00	$0.73	$26.67
500G SVBT Optics	RU	25 w	187.50	$0.00	$0.18	$15.00
1D ROADM	1 RU	7 w	88.96	$3.75	$0.05	$7.12
1.6Tb Transport Chassis	1 RU	110 w	28.66	$7.50	$0.80	$2.29
1.2T Transponder	RU	220 w	301.67	$0.00	$1.61	$24.13
400G Transponder	RU	146 w	125.00	$0.00	$1.07	$10.00

Table 1. Cost Model Table (CAPEX & OPEX).

IP routers technical specifications for HL4, HL3 and HL2 are summarized in table below:

HL4		
Max Throughput (Gb/s)	#Interfaces	Capacity (GE)
1500	15	100
	3	400
	3	500

(a)

HL3		
Max Throughput (Gb/s)	#Interfaces	Capacity (GE)
4500	40	100
	10	400
	9	500
	2	2000

(b)

HL2		
Max Throughput (Gb/s)	#Interfaces	Capacity (GE)
4500	40	100
	10	400
	7	500
	2	2000

(c)

Table 2. Routers' technical specifications: (a) HL4, (b) HL3, (c) HL2

2.2 EVOLUTIONARY SCENARIOS

IP over DWDM

In this scenario, we assume the network evolves keeping the existing architecture shown in Fig. 3 where IP routers are interconnected using conventional transponders. Optical transponders configurations are detailed in Table 3.

Transponder 400G
4x100G Client Signals
2x100G/2x200G Line Signals

(a)

Transponder 1.2T
3x400G/12x100G Client Signals
3x600G Line Signals

(b)

Table 3. Transponders' technical specifications: (a) Transponder 400G, (b) Transponder 1.2T

Line side optics in both transponders will be considered as integrated optics in the same hardware.

HL4-HL3 SBVT based architecture

In this case, SBVTs are integrated in HL4 and HL3 routers so that conventional transponders are not needed.

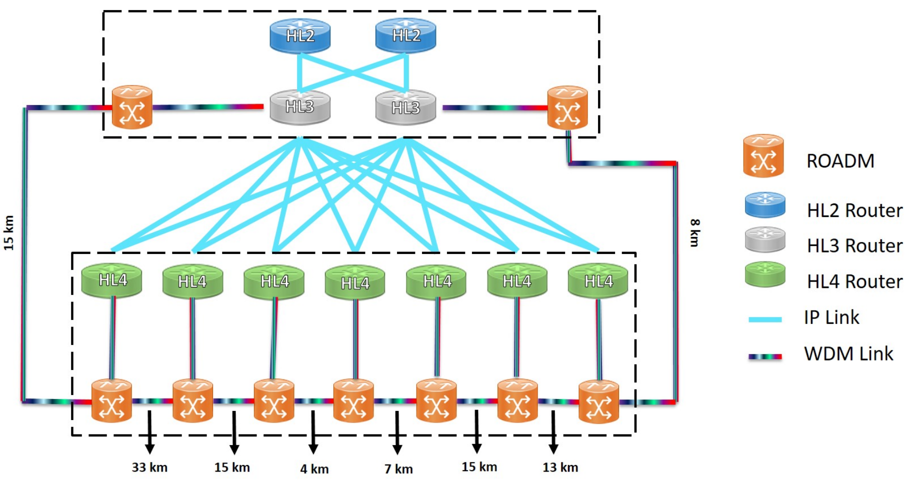


Figure 4. HL4-HL3 SBVT architecture

This architecture also all optical Point-to-Multipoint transmission and grooming since SBVTs allow to have different capacities in both ends of a link so while HL4 can be dimensioned with a single 500Gbps SBVT, HL3 node can support 2Tbps SBVT interfaces. SVBTs will tune to the appropriate place in the spectrum to pick up its subcarriers (50G subcarriers for this case study).

HL4-HL2 SBVT based architecture
In this scenario, traffic grooming is done in the optical layer so that existing aggregation HL3 nodes are replaced by SBVTs integrated in HL2.

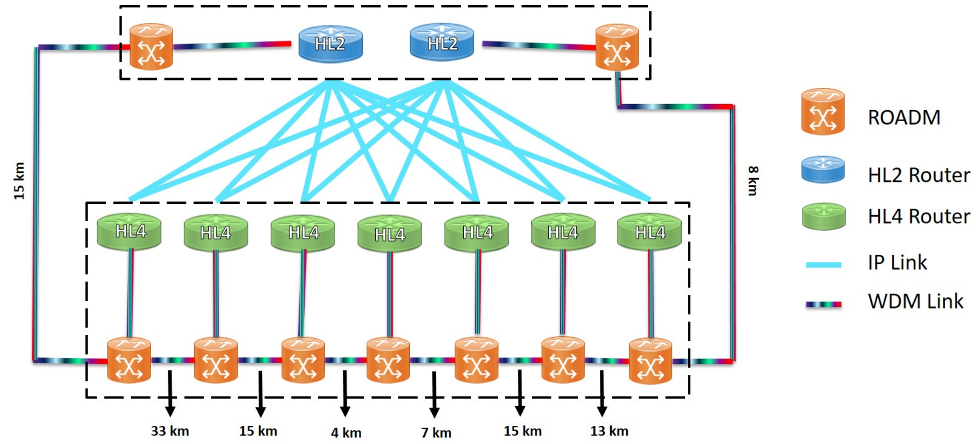
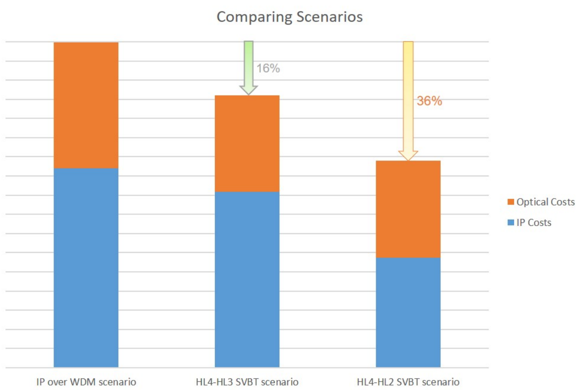


Figure 5. SVBT based architecture without aggregation layer – Hamburg region

2.3 COST ANALYSIS

According to the dimensioning results provided by a multilayer planning tool and the cost model presented in section 2.1, SBVTs based architectures can generate savings around 16% when traffic grooming is done by HL3 routers and 36% when this functionality is done by the SBVT integrated in the HL2.

Fig. 6 summarizes the cost comparison (CAPEX+OPEX) and number of accumulated items in each scenario.



Site	Device	IPoverWDM	HL4-HL3 SVBT	HL4-HL2 SBVT
HL2	HL2 Router	2	2	2
HL2	2T SVBT Optics	0	0	4
HL2	400G Grey Optic	16	16	0
HL2	1D ROADM	0	0	14
HL3	400G Grey Optic	16	16	0
HL3	HL3 Router	2	2	0
HL3	2T SVBT Optics	0	4	0
HL3	500G SVBT Optics	0	0	0
HL3	400G Grey Optic	14	0	0
HL3	100G Grey Optic	14	0	0
HL3	1.6Tb Transport Chassis	4	0	0
HL3	400G Transponder	6	0	0
HL3	100G Transponder	8	0	0
HL3	1D ROADM	14	14	0
HL4	1D ROADM	14	14	14
HL4	1.6Tb Transport Chassis	14	0	0
HL4	400G Transponder	7	0	0
HL4	400G Grey Optic	14	0	0
HL4	100G Grey Optic	14	0	0
HL4	400G Grey Optic	14	0	0
HL4	100G Grey Optic	14	0	0
HL4	500G SVBT Optics	0	14	14
HL4	HL4 Router	7	7	7

Figure 6 Scenarios' comparison (a) accumulated CAPEX and OPEX in ten years (b) accumulated network items

The next comparative table is comparing both IP over DWDM scenario and HL4-HL2 SBVT based architecture in terms of accumulated CAPEX and OPEX. These numbers are going to be the most advantageous for the SBVTs:

	CAPEX 10-years	OPEX 10-years	CAPEX+OPEX
IPoverWDM scenario	$23,413	$18,987	$42,399
HL4-HL2 SBVT	$13,574	$13,390	$26,964
SVBT Economic Advantage:	42%	29%	36%

Table 4. Cost comparative between IPoverWDM scenario and SBVT scenario without aggregation layer

The economic advantages of HL4-HL2 SBVT scenario can be improved if we consider a "Pay as you grow" model based on 50Gbps licences per wavelength activation.

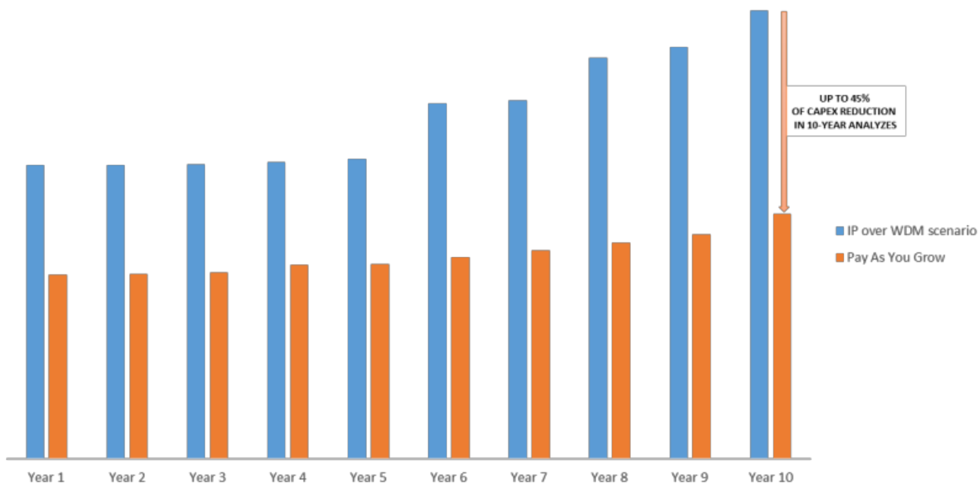


Figure 7 Accumulated CAPEX per year

3. CONCLUSIONS

The objective of SBVTs is to efficiently use the optical resources in comparison with the BVTs. This capability to redirect the traffic to the desire location provides a flexibility level that can reshape the lightpaths to the optimal location. Costs savings come not only as a reduction in the cost of IP/MPLS routers and the optical components.

This work compares three different models and assess the CAPEX and OPEX savings in the different scenarios.

ACKNOWLEDGEMENTS

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