Techno-economic evaluation of Optical Transport Network in metropolitan deployments

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Abstract *Optical Transport Network (OTN) technology provides multiple benefits to the network operator in backbone networks. This paper presents a techno-economic comparison of optical solutions for metropolitan scenarios to assess when OTN must be deployed.*

Introduction

In the last years, Internet traffic has increased at an unprecedented rate, with video content as the main traffic source. However, metropolitan networks were not designed to carry out the huge amount of traffic that is transported today. The network operators typically deployed metropolitan rings with 10 G technologies over dark fiber, but now, with this traffic increment, it is the time to evolve such deployments. This motivates this work, which evaluates alternatives to upgrade metro networks.

Authors in[1] present a cost comparison study of some metro architectures, but this work did not include 100 G equipment. On the other hand, we presented in[2] a comparison study with a more up to date cost model including 100 G equipment, which is necessary in the evolution for metro networks. In this paper, we extend the work in[2] considering the use of Optical Transport Network (OTN). The introduction of OTN switching technology enables traffic aggregation capabilities at intermediate nodes, which reduces the number of wavelengths and leads to an efficient bandwidth utilization. Moreover, OTN adds more flexibility, which allows the reduction of OPEX. However, it increases the complexity of the network by adding an extra layer and potentially an extra cost. In this paper we evaluate from a tecno-economic point of view if the introduction of OTN is suitable for metropolitan networks when comparing with other alternatives.

The remainder of this paper is as follows. First the network model is described with the different alternatives considered for metro deployments. Secondly, the tecno-economic comparison is done and the numerical results are presented. Finally the main conclusions are stated.

Network model description

Current metro architectures are typically composed by different levels of aggregation. At the top of the hierarchy Concentration Switches (SWC) receive traffic from Distribution Switches (SWD), which in turn receive the aggregated traffic from different mobile and fixed access users. The node architecture for the packet equipment consists of a series of common parts (switching matrix, power supply and mechanics) and the line cards (LCs) with different number of ports. Having this architecture in mind, three alternatives to deploy and update metropolitan networks are compared in terms of cost effectiveness: dark fiber, coloured transceiver and OTN.

The first possibility to update current metro networks so as to cope with the increment of traffic is based on the use of dark fiber in the transmission layer and aggregation at each intermediate node. Two options can be considered here, either to continue with the ring topology adding dark fibers as necessary or change the topology by adding fibers between each SWD to the SWCs, creating a tree topology (Fig. 1). In any case, grey transceivers are inserted directly in the LCs and they are connected to the fiber. Thus, for each transceiver a fiber has to be deployed[2].

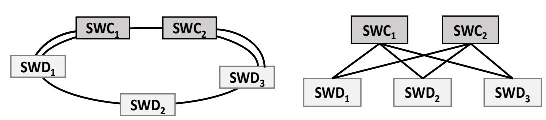

Fig. 1: Dark fiber deployments (ring and tree topologies)

The second architecture presented is based on the use of coloured transceivers and a passive filter in each node to extract-insert the corresponding wavelengths. Thus, each SWD is logically connected to each SWC by means of a different wavelength, conforming a logical star/tree topology under a ring physical topology (Fig. 2). In this case, there are not grey but coloured pluggables. The connection is done without any optical amplification. With this approach it is no longer necessary to add extra fibers and there is no use of optical transponders. To achieve this, it is necessary to include a passive filter designed for the corresponding wavelengths[2]. One of the limitations of this architecture is given by the insertion losses of the passive filters. Therefore, there is a maximum number of intermediate nodes.

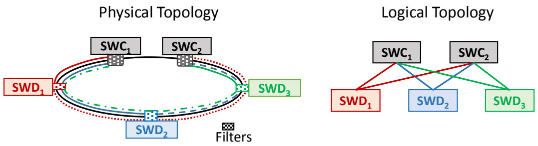

Fig. 2: Metro topology with coloured transceivers and filters

Finally, the third approach consist of using OTN (Fig. 3). Contrary to the second approach, where one wavelength is used to transmit data of just one SWD, the use of OTN allows the switching of sub-wavelength bitrates. This enables for example to add/drop at the OTN layer (without aggregating the traffic at higher levels) portions of a 100 G stream, enabling the use of 10 G interfaces at the Ethernet level. For example, in Fig. 3, SWD_2 transmits 60 Gbps in a stream of 100 G in the WDM layer (60% of occupation of the wavelength). This flow is aggregated in its way to SWC_1 with a flow of 30 Gbps coming from SWD_1, increasing the occupation of the wavelength to the 90%. As it can be observed, both flows are switched at OTN layer.

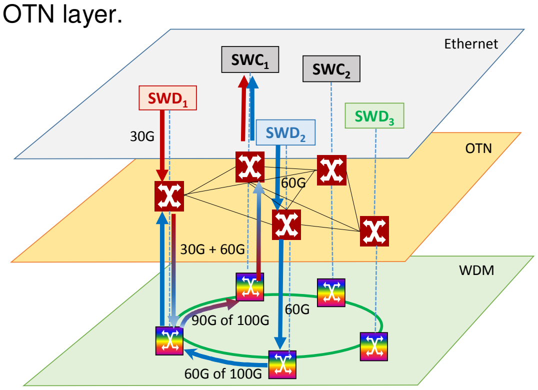

Fig. 3: Metro network with OTN layer

The node architecture adds an OTN chassis which includes the switch matrix, the tributary cards, which convert the client/Ethernet signals to Optical Channel Data Units (ODUs) and the line cards. Moreover, we have assumed that line cards include the colored transceiver.

Techno-Economic comparison of the architectures

The scenario selected to carry out the techno-economic comparison is a topology ring, the same as in[2], since it is very representative of current metro deployments for Telefonica. Specifically, 5 SWDs are connected two 2 SWCs in two rings (3 SWDs in one ring and 2 SWDs in the other). All SWDs generate traffic between 1 Gbps and 100 Gbps, which are common rates taking into account that SWDs aggregate traffic from different access networks. The cost model presented in[3] has been assumed, which is, to the best of our knowledge, the most recent cost model available in the literature. All cost values presented in this study are normalized to the cost of a grey transceiver of 100 G (Tab. 1).

Tab. 1: Cost model assumed obtained from[3]

Ethernet equipment		OTN equipment	
Description	Cost	Description	Cost
Chassis 16 slot	2.47	Chassis 8 slot	5
2x10 G Line C.	0.85	40 x 10 G tributary cards	3.04
10x10 G Line C.	3.4		
1x100 G Line C.	4.7	10 G trib. plug	0.1
Grey 10 G transc.	0.1	1x 100 G line card (including transc.)	26
Grey 100 G trans.	1		
Coloured 10G trans	0.9	FOADM 2 degree	5.2

Regarding the solution with coloured transceivers, passive filters with a normalized cost of 0.03 have been assumed. In the case of OTN approach, a Fixed Optical Add Drop Multiplexer (FOADM) of degree 2 has been considered[3].

It is important to remark that fiber deployment cost becomes a key parameter in the techno-economic study, since one of the architectures to be compared use dark fiber. For the selected metro scenario, where amplification is not needed, it can be assumed that all fiber connections have the same cost. However, its value depends on several parameters: if there are available fibers, if the fiber can be leased, if there is enough space in the trench to deploy a new fiber bundle, if a new deployment has to be done, etc. The higher cost in a greenfield scenario is given by the digging and trenching for fiber installation[4], whereas in brownfield scenarios, the cost of deploying new fiber over existent ducts can be reduced to a 25%[5]. Considering that, we have carried out a sensitivity study instead of setting a concrete value for the fiber cost. Specifically, a cost in the interval [0,4] per Km is assumed according to[4] and normalizing to the price of a 100 G grey transceiver. Therefore, we cover scenarios where there is available fiber and its use does not increment the cost, brownfield scenarios where fiber needs to be leased or fiber has to be added and greenfield scenarios where the whole plant has to be deployed. Finally, a metro network with 20 km of average (with a maximum of 40 km for any optical path) is assumed[2].

Numerical Results

For the scenario described above, we have compared the following alternatives: grey 10 G and 100 G ring and tree topologies (Fig. 1), coloured logical tree solution based on 10 G (Fig. 2) and OTN with 100 G to take advantage of the aggregation capabilities.

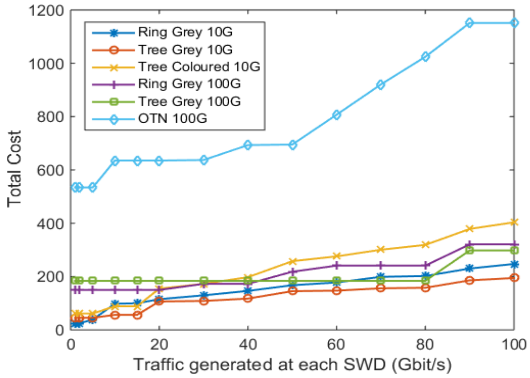

Fig. 4 Total cost vs Traffic considering plenty available fiber

Fig. 4 depicts the total cost vs. the amount of traffic generated at each SWD when considering free fiber (i.e. the operator has plenty of fiber). It can be observed that the 10 G grey deployments (both ring and tree) are the most cost-effective solutions, followed by tree and ring dark fiber deployments with 100 G. On the other hand, OTN cost is significantly higher than the cost of the other solutions. This is due to the fact that OTN requires more equipment, which, according to the cost model assumed, it is quite expensive. The solution with coloured transceiver does not bring any advantage when there are plenty of free fibers. The reason is that the cost of using a coloured transceiver is higher than a grey pluggable. The same is applicable for OTN.

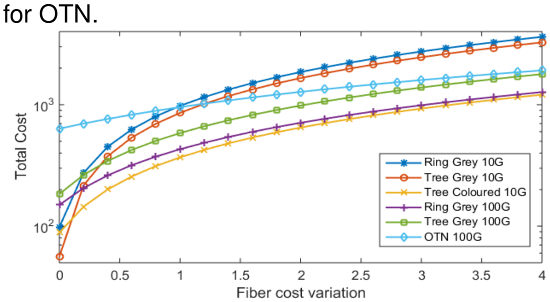

Fig. 5 Total cost vs Fiber cost variation for a generated traffic in each SWD of 10 Gbit/s

Fig. 5 and Fig. 6 present the sensibility analysis based on the fiber cost. As long as the cost fiber increases, the grey 10 G deployments are not suitable. For low network loads, (Fig. 5), we can see that coloured 10 G tree topology is the most cost-efficient, followed by grey ring topology of 100G. When traffic increases (Fig. 6), tree grey topology of 100 G is the cheapest architecture for fiber costs lower than 0.5, then the tree coloured of 10 G.

We can conclude that OTN is in general a more expensive solution than coloured and grey 100 G topologies for metro scenarios. However, OTN is cheaper than 100 G grey in scenarios with low fiber availability, where the operator is

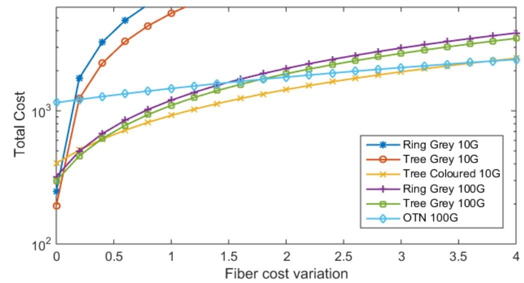

Fig. 6 Total cost vs Fiber cost variation for a generated traffic in each SWD of 100 Gbit/s

forced to deploy fiber. To have a competitive solution against coloured pluggables in such scenarios (fiber cost of 3), OTN prices have to decrease at least 60% to be cost-efficient.

From the technical point of view, let us remark that the maximum number of SWDs in the coloured solution is limited due to the number of hops and channels. On the other hand, OTN is the best candidate technology to transport legacy SDH. Therefore, there are some scenarios where the OTN solution is motivated by need of SDH transport as well as by OPEX savings.

Conclusions

We presented the techno-economic comparison of alternative technologies to evolve metro networks. Results demonstrate that there is not a unique preferred architecture, but it depends on the scenario characteristics, such as the amount of traffic or the availability of fiber.

Moreover, with the considered cost model, OTN equipment has to reduce the price at least a 60% in order to be a competitive solution for metro deployments when compared to the coloured solution.

Acknowledgements

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