Techno-economic Analysis of Transmission Technologies in low aggregation Rings of Metropolitan Networks

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Abstract: A techno-economic comparison of dark fiber and passive architectures to evolve low aggregation metro rings of 1G is presented. Results demonstrate that there are alternatives more cost-effective than just migrating to 10G.

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1. Introduction

In the last years, Internet traffic has increased at an unprecedented rate, with video content as the main traffic source. In fact, the IP video traffic will be the 82% of all consumer Internet traffic by 2020 [1]. The use of Content Delivery Networks (CDNs) or transparent caching minimize the traffic in the backbone segment, but the metro and mobile backhaul networks have to transport all this traffic. Consequently, metropolitan networks have to be updated since they were not designed to carry out the huge amount of traffic that is transported today.

Metro architecture is typically composed by three main levels of aggregation. Beginning at the bottom of the architecture, the components that can be found are Gateway Terminal (GWT) and Switches Terminal (SWT), which are devices that aggregates the traffic from the mobile and fixed subscribers. Specifically, the GWT aggregates traffic from different base stations (BS), which in turn aggregate traffic from mobile subscribers. Similarly, the SWT aggregates traffic from the Digital Subscriber Line Access Multiplexers (DSLAMs) and the Optical Line Terminals (OLT). The traffic from multiple GWTs and SWTs is received by the SWD (Distribution Switches). Finally, at the top of the hierarchy the traffic is sent to the Concentration Switches (SWC).

In [2] we present a techno-economic study of some metro architectures and we extend that work in [3] considering the use of Optical Transport Network (OTN). Both studies focused on the upper levels of aggregation (SWC-SWD). On the contrary, this paper explores the alternatives to evolve the lower aggregation level of the metro network, i.e. from the SWTs to the SWDs. This low aggregation levels are usually deployed as low capacity rings of 1G over dark fiber, but with the increment of the traffic they must evolve to 10G. This motivates this work, which evaluates alternatives to upgrade low aggregation metro networks.

2. Metro architecture and evolution alternatives

Traditionally low aggregation levels of metro networks have made use of restrained transmission technologies, which are acceptable for these scenarios, where distances are usually short and the capacity is small compared to other network segments. In this way, the most common architecture to deploy metropolitan networks does not use an optical transmission layer. That is, traffic is aggregated in the electrical domain in each intermediate node from the source to the destination and transmitted via grey interfaces directly over dark fiber (Fig.1). Consequently, it is necessary as many fibers as grey interfaces. In the case of low aggregation levels, these interfaces are typically of 1G. To increase its capacity, it is required to incorporate more interfaces of the same technology according to the amount of traffic. However, in this solution the number of necessary dark fibers is incremented, which may be a serious inconvenient if fiber is scarce. Another possibility to upgrade the network is to use grey interfaces with higher performance (i.e. 10G instead of 1G ports), which will be analysed from an economical point of view in the next section.

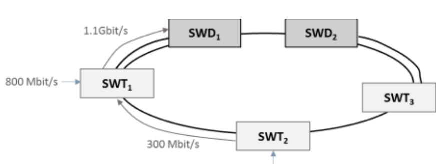

Fig.1. Grey ring deployment

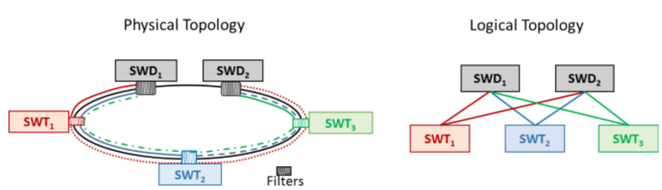

Fig.2 Physical and logical topologies for passive colored ring deployments

Other possibilities to evolve the network are based on the inclusion of an optical transmission layer using Wavelength Division Multiplexing (WDM). In this sense, each SWT is logically connected to each SWD by means of a different wavelength. That is conforming a logical star/tree topology under a ring physical topology. One option to deploy this type of solution is based on the use of new optical nodes with active equipment. This active equipment can include the possibility to comprise OTN to efficiently aggregate the traffic and an additional network management system for the optical layer. However, this type of solution results in more complexity and the extra cost does not pay off their advantages [3]. An alternative simpler approach to deploy logical trees is based on a passive architecture. This consist of the direct use of colored interfaces at the data equipment, using simple passive filters for the sake of adding/dropping signals. Fig. 2 shows the physical and logical topology of this solution where it can be seen that, using the same ring fiber infrastructure, the logical topology is a star with all SWTs connected directly to the SWDs. With this approach it is no longer necessary to add extra fibers and there is no optical amplification. One of the limitations of this architecture is that there is a maximum number of nodes in the ring, which depends on the insertion losses of the passive filters and the fiber attenuation.

An intermediate solution suitable for scenarios where traffic is not distributed uniformly between all SWTs (i.e. the majority of the ring traffic is generated by a reduce number of SWTs), consist of introducing colored pluggables in those SWTs with high traffic and keep the grey ring of 1G in the remaining SWTs (gradually convert the 1G ring into a logical tree of 1G).

3. Techno-economic analysis

To carry out the techno-economic analysis of the grey ring deployments and the passive one, a typical scenario for low aggregation metro segment has been assumed. Specifically, it is a ring topology with 2 SWDs and 10 SWTs, with a fiber length between the nodes with a mean of 4 Km, so the distance for any optical path does not exceed 40 Km. Based on Telefonica internal information, this ring is feasible for the passive solution using filters with low pass-through insertion losses.

The deployments considered in the analysis are: the 1G grey ring (RG1), the colored passive architecture that gradually deploys a logical tree of 1G but keeping also the 1G grey ring (RG + TC 1G) and the 10G grey ring (RG10). It has been supposed a brownfield scenario, where the initial equipment consist of a grey ring with interfaces of 1G. Thus, the different architectures can use this initial equipment in their upgrade. Specifically, the RG1 and RG+TC 1G will reuse all the equipment and the RG10 can reuse only the chassis. Moreover, in the case of RG+TC 1G, a threshold of 40 Mbit/s in the SWT to migrate to the colored solution has been set.

It has been assumed a non-uniform scenario where each SWT generates a different amount of traffic, but the initial traffic in the network is fixed to 800 Mbit/s with a traffic increment of 35% per year during seven years (leading to a final traffic of 6.53 Gbit/s in the whole ring). The cost model presented in [4] has been assumed, which is, to the best of our knowledge, the most recent cost model available in the literature. Since in [4] the cost of the colored pluggable is not presented, we have assumed the same relationship in the cost as in the case of 10G grey and colored transceivers. In addition, passive filters with a normalized cost of 0.03 have been assumed [2, 3].

Table I. Cost model considered obtained from [4]

Description	Normalized Cost
Chassis 16 slots	2.47
Line card 20x1G	0.51
Line card 32x1G	0.6
Line card 2x10G	0.85
Line card 4 x10G	1.70
Grey 1G transceiver	0.02
Grey 10G transceiver	0.1
Colored 1G transceiver*	0.18
Colored 10G transceiver	0.9
Passive filter**	0.03

* approximation done with same ratio as in 10G grey colored
** used in [2, 3]

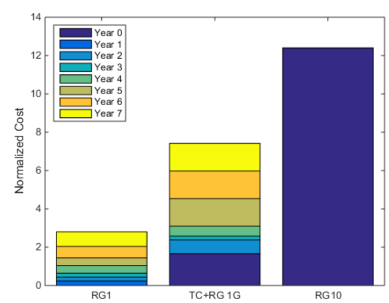

Fig. 3. Incremental cost per year for the different architectures when fiber is available (cost of fiber equal to 0)

It is important to remark that fiber deployment cost becomes a key parameter in the techno-economic study, since two of the architectures 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. Nonetheless, its value depends on several factors: 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 [5], whereas in brownfield scenarios, the cost of deploying new fiber over existent ducts can be reduced to a 25% [6]. Bearing all these in mind, we have carried out a sensitivity study considering a normalized fiber cost in the interval [0,4] per Km as in [3] to cover all possible scenarios.

Fig. 3 depicts the incremental cost per year for each alternative when plenty of fiber exists. As it can be observed, the most cost-effective solution is the grey ring of 1G. This solution does not need an initial investment (year 0), and year by year the increment in the cost is given by the new grey pluggables. However, the number of fibers (showed in Fig.4) increases up to 160 for the highest traffic considered, which to some extent will cause technical limitations and an increment on the operational complexity as the number of interfaces increases.

On the other hand, the ring grey of 10G require a high initial investment but no more upgrades. The inversion is due to 10G pluggables and its corresponding cards. In contrast, the gradually deployment of the colored solution does not present a high initial investment, since only some SWTs are upgraded with colored pluggables. Moreover, it has the advantage of a progressive inversion as the traffic increases.

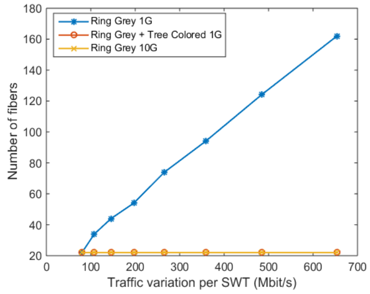

Fig. 4. Number of needed fibers vs traffic in the SWT for the considered architectures

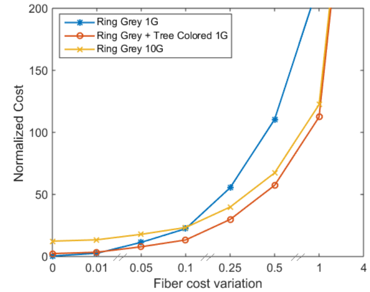

Fig. 5. Total cost vs Fiber cost variation for a generated traffic in each SWT of 196.6 Mbit/s (3^{rd} year)

Fig. 5 presents the sensibility analysis based on the fiber cost for the highest traffic considered. As long as the cost fiber increases, the grey ring of 1G is not suitable. This is due to the fact that the number of fibers needed in the 1G grey ring increases with the traffic (Fig. 4), whereas for the remaining architectures this do not happen. Therefore, the ring with 1G grey interfaces becomes the most expensive technology when there is no plenty of fiber for even small fiber costs (higher than 0.01).

4. Conclusions

In this paper we present a techno-economic analysis of alternative technologies to evolve low aggregation metro rings. Specifically, three architectures have been compared: dark fiber with grey 1G and 10G grey interfaces and the passive architecture based on colored interfaces of 1G and passive filters. Results demonstrate that there is not a unique optimum architecture, but it depends on the scenario characteristics. In this way, the 1G grey rings seems to be the most cost-efficient when plenty of fiber exist. However, the large amount of interfaces and fiber needed is its main inconvenient. On the other hand, the passive deployment is more cost-efficient compared to the grey ring of 10G. This is due to the fact that both cards and pluggables cannot be reused in the 10G ring from the initial scenario. Moreover, it can be gradually updated, so that the inversions are progressive. However, this architecture has its own limitations, since there is a maximum number of intermediate nodes determined by the filter losses and fiber attenuation.

5. Acknowledgment

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