Impact of Protection to Converged Access Networks Planning in Rural Areas

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Abstract— Network operators are reluctant to offer broadband access in rural areas due to the high investments and limited revenues. Protection in those areas is even more unfeasible and hence, it has not been considered by operators yet. One alternative to decrease costs when offering high bitrates in rural areas is the use of new architectures such as Hybrid Passive Optical Network (HPON). These architectures offer several advantages not only from the longer reach and higher client count, but for the possibility of offering different bandwidth per end point. The recently proposed HPON architecture could be used to offer higher bandwidth to the connected Base Stations (BS) (e.g., 10 Gbps) than the bandwidth delivered to residential users (300–500 Mbps). Recent work has presented a detailed framework using real building and street data distibution provided by OpenStreetMap, which allows computing a practical fiber layout for different access architectures and splitting ratios. This approach aims at minimizing the duct length, since costs associated to ducts and trenching have been shown to be cost drivers in access deployment. This framework has been now applied in rural areas to compare the infrastructure required for a disjoint versus a joint planning. Savings depend on the building density, area size and the inter BS distance. The contribution of this paper is focused on the analysis of the cost impact of BS protection. The required availability is obtained when protection of feeder fiber and distribution fiber is guaranteed. The investment and extra fiber and duct infrastructure required for two protection schemes are compared with the unprotected scenario. The cost increase is shown to be relatively low compared with the unprotected solution.

1. INTRODUCTION

Over the years, technology has significantly changed and steered the way people communicate. Originally, the telephone replaced previous ways of communications and, nowadays mobile devices are leading the bandwidth increase of telecommunication networks. However, users are not only expecting higher bandwidth but also high reliability while avoiding increasing their monthly fee. This fact, together with the fast and huge technological progress, is forcing operators to continuously upgrade their networks. Furthermore, the number of users is significantly increasig, not only in fixed networks, but also in mobile networks, being estimated to reach 2.3 billion globally by end 2014 [1]. Due to this increasing dependency on broadband networks, redundancy and protection in the access network has started to play an important role for FTTH providers in the recent years, even for applications that were not categorized as reliability-critical, and several analysis have already been performed [2].

Nevertheless, operators have always been reticent to offer broadband access in rural areas, due to the fact that they compose the access scenarios where deployment of optical networks becomes less profitable [3]. This, however, has changed during the last years as new solutions are being proposed, becoming the Hybrid Passive Optical Access network one of the most promising alternatives. Regarding this converged solution, in which fixed users and mobile backhaul share a single access network, recent work has already shown the great savings obtained, both in urban and rural areas, with the implementation of this architecture [4]. The impact in costs that protection of HPON involves has mainly been studied for urban areas [5]. In addition, this paper contains a costs analysis of two different protection scenarios for HPON in rural areas, where several constraints such as street network topology or large distances are found.

Going even further regarding availability issues, it has to be noted that not all users connected to the access network can afford to pay a high extra cost for protection, reason why resilience has to be provided in a cost-efficient way. Due to this fact, different degrees of offering reliability to the network have already been proposed and analyzed; having concluded that the benefits of providing protection up to the first remote node (feeder fibre) are very high and low extra investment is needed [6]. In this study, feeder fiber protection in HPON is analyzed in a rural scenario, meanwhile protection of base stations is also considered in the second protection scheme for the same rural scenario.

2. OPTICAL ACCESS NETWORK ARCHITECTURES AND PROTECTION SCHEMES

This section introduces the considered architecture as well as the protection schemes.

2.1. Hybrid Passive Optical Network (HPON)

A new architecture referred to as Hybrid Passive Optical Network (HPON) has been recently proposed and studied in the OASE project [7] just for residential users. This architecture has been slightly modified so that base stations can also be connected to the same access network but getting higher bandwith than residential users and hence, obtaining a converged access network architecture.

A HPON consists of an Optical Line Terminal (OLT) at the operator's central office (CO) that is connected to several Optical Network Units (ONUs) at the end users. These end users can be either residential users or Base Stations (BS). HPON is a point-to-multipoint architecture with two splitting points. The first one, which is closest to the OLT, is an Arrayed Wavelength Grating (AWG) 1 : N, which splits the incoming WDM signal into N single wavelength signals. Each of these signals is distributed either to a BS or to a power splitter 1 : M (also referred to as second splitting point). The power splitter uses TDMA in order to share the capacity between M residential users. The HPON architecture is depicted in Figure 1, where dedicated wavelengths are directly assigned to the BS, providing them with 10Gbps peak data rates; whereas guaranteed downlink data rates for residential users after applying TDMA schemes are 300–500 Mbps (depending on whether the power splitting ratio M is 32 or 16).

In this study, four different architectures have been considered:

- **HPON(40,16)** considers a HPON with an AWG 1 : 40λ and a power splitter 1 : 16 (hence providing to each residential user with 500 Mbps).

- **HPON(80,16)** considers a HPON with an AWG 1 : 80λ and a power splitter 1 : 16 (hence providing to each residential user with 500 Mbps).

- **HPON(40,32)** considers a HPON with an AWG 1 : 40λ and a power splitter 1 : 32 (hence providing to each residential user with 300 Mbps).

- **HPON(80,32)** considers a HPON with an AWG 1 : 80λ and a power splitter 1 : 32 (hence providing to each residential user with 300 Mbps).

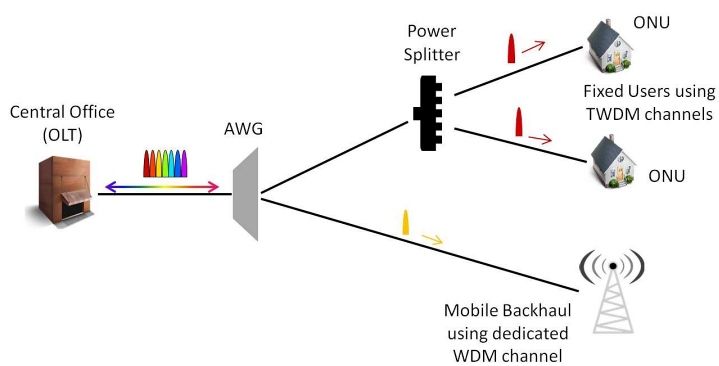


Figure 1: HPON architecture connecting fixed users and base stations.

2.2. Protection Schemes

The protection schemes addressed in this study aim at protecting the fiber infrastructure, which has been shown to be more vulnerable than equipment (due to its location, specially in rural areas).

It has been shown [5] that protection costs are directly related to the planning time and the protection approach. Let us consider in this study a greenfield scenario where both working and protection fibres are designed at the same time in such a way that the cost is minimized. As explained earlier, the infrastructure cost is driven by trenching and hence, duct sharing is encouraged. This approach is also followed for the protection fibre so that it shares as much disjoint duct as possible achieving protection while minimizing costs (as depicted in Figure 2).

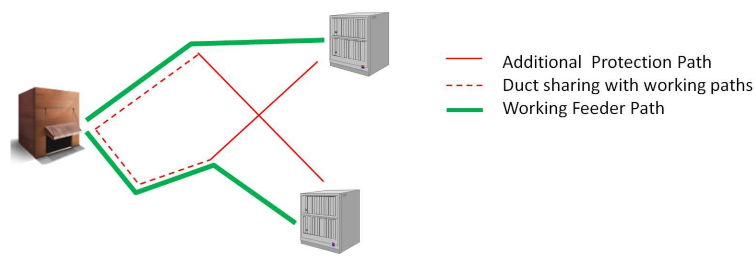


Figure 2: Greenfield-shared protection scheme.

3. METHODOLOGY

The method used in this study has as input a certain area and the splitting ratios of the power splitters and the AWGs. The methodology for the unprotected architecture shown in Figure 1 is as follows:

1. Get area database: From OpenStreetMap, an area can be selected. The relevant information for the planning such as streets, ways, buildings, etc. is extracted.
2. BS distribution: BS are distributed using an hexagonal grid, given an interBS distance. Since the obtained locations may not be realistic (e.g., in a river or in the middle of a forest), the BS are relocated to the closest street, which is consistent with the operator approach to have BS accesible for maintenance and power.
3. Clustering: Residential users are clustered based on the power splitting ratio. For this purpose, an 80% of port utilization has been considered, so that some ports are left for future use. The centroid of each cluster is considered as ideal location of the power splitter but it is realocated to the closest street (for practical reasons). Power splitters and BS are also clustered based on the AWG splitting ratio. The centroid of each cluster is considered as ideal location of the AWG but it is realocated to the closest street (for practical reasons).
4. Once the locations of power splitters and AWGs are identified, the fibre layout is computed using Dijkstra. In order to encourage duct sharing, the streets that have already been considered for routing have a lower weight.
5. Since rural areas present longer distances than urban areas, Reach Extenders (RE) may be required for ONUs exceeding the maximum reach of each network architecture. The maximum reach depends on the power splitter and AWG splitting ratios. In case RE are needed, they are indetified and the best location is found in order to minimize the cost.

The output of this methodology gives the dimensioning of the access network (i.e., the number and location of the power splitters and the AWG required) as well as the fibre layout (i.e., the number and length of the required fibres and ducts).

4. SCENARIOS AND CASE STUDY

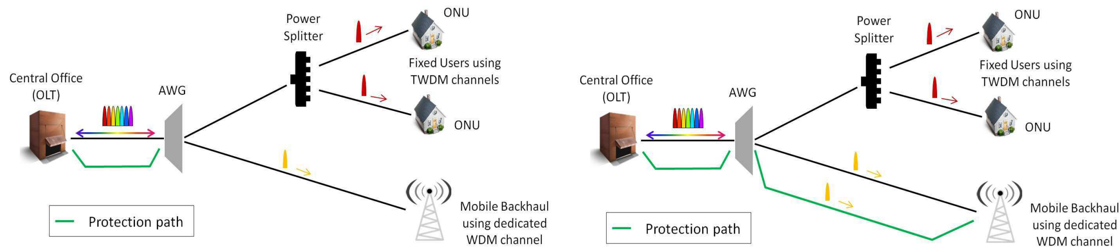
Two protected scenarios are evaluated and compared in this paper with respect the unprotected HPON previously shown in Figure 1.

4.1. Disjoint FF

In any point-to-multipoint architecture, the Feeder Fibre (FF) is the component with the highest failure impact factor [6]. Hence, FF is the first component to be protected. In this protected scenario, a disjoint feeder fibre protection path is offered in order to protect any AWGs of the HPON architecture. This protected scenario is depicted in Figure 3(a).

4.2. Disjoint FF and DF for BS

As base stations require higher availability than fixed users, additional protection for base stations should be considered when including BS in the HPON planning. In order to offer protection to the base stations, a disjoint protection fibre is deployed from the BS to its associated AWG. This disjoint protection path is established aiming at performing duct sharing by reusing sections that were already selected for working paths. One of the major advantages of this scheme is that no extra wavelengths need to be reserved for protection at the AWG as the same one can be reused for protection. The scheme can be seen in Figure 3(b).



(a) (b)

Figure 3: Proposed protected scenarios. (a) Disjoint FF protection for AWGs. (b) Disjoint FF protection for AWGs and Disjoint DF protec- tion for BS.

4.3. Case Study: Impact of Protection on Total Costs

Let us compare the two protection schemes with respect to the unprotected HPON in rural areas. For that purpose, a rural area in Germany close to Miesbach has been considered: the selected surface covers approximately 17 km^2 and has a building density of around 160 buildings/km^2.

First of all, let us compare the cost per offered Gbps for the disjoint scenario (GPON 1 : 32 to fixed users and P2P to BS) versus the HPON, as shown in Figure 4. It can be observed that for an inter BS distance of 0.5 km, the cost per Gbps decreases more than 87% when the splitting ratio of the power splitter is 16, and almost 75% when the splitting ratio of the power splitter is 32, which is the one limiting the delivered bandwitdth to the fixed users using TDM.

Focusing on the protection, let us first compare the required infrastructure of the unprotected and the protected scenarios. The infrastructure is compared in terms of fiber and duct length as

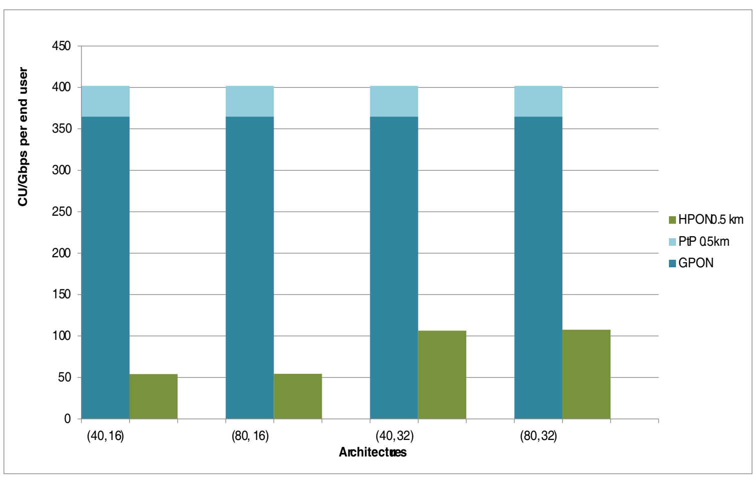


Figure 4: Disjoint versus joint planning cost per Gpbs.

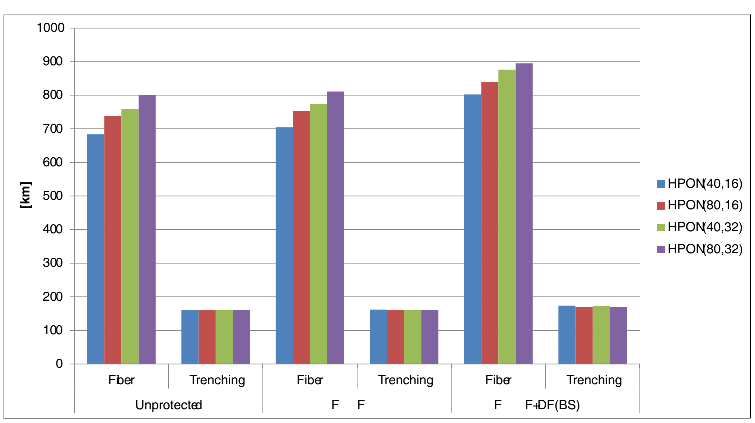


Figure 5: Infrastructure required.

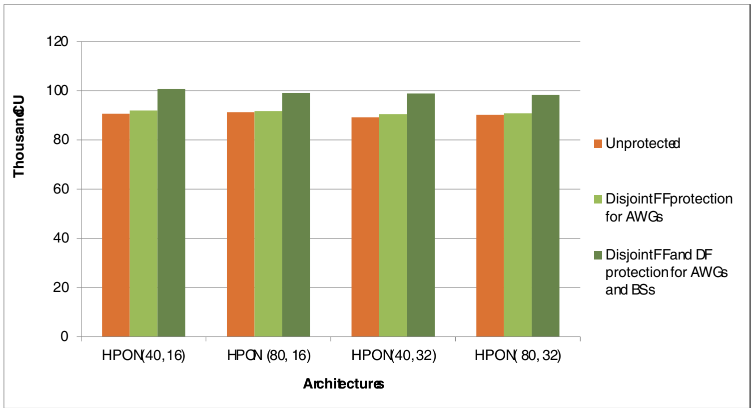


Figure 6: Costs comparison between unprotected HPON and the two considered protected scenarios.

shown in Figure 5. It can be observed that for the FF protection, only 1–3% more fiber and .1–.6% more trenching is required. Hence, the operator can protect the FF with limited extra investment. In order to protect also the DF of BS, an increase of 10–13% fiber and 5–7% trenching is needed.

Figure 6 compares the total costs of the unprotected versus the protected scenarios. It can be observed that there are not significant differences among the architectures. It has been shown that duplicating fibre only for protecting the FF paths does not require high extra investment, only about 0.5–1.5% of the total costs of unprotected HPON. This solution increases availability in a great degree and the additional costs are so low that should not become a huge restriction for operators. On the other hand, if the BSs included in the access network need to be protected too, higher total costs have been registered. Increases of approximately 8.5–11% for protecting FF and DF have been obtained respect to total costs of the unprotected solution.

5. CONCLUSION

This paper has evaluated the impact that protection of FF or FF and DF for BS schemes have on the total costs. It has been shown that in a greenfield scenario offering broadband access to users (300–500 Mbps/residential users and 10 Gbps/BS), FF protection does not require significant extra costs (less than 2%). In case operators aim at protecting the BS, an extra cost of 10% may be required.

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