Evolution for FTTH deployment in the access network

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Abstract—This paper considers the optical access networks deployment in France and the main technical challenges which are associated to such deployments. Possible evolutions of broadband optical networks are discussed, with the need for adapting both metropolitan and access networks to the customer service demand evolution.

Keywords: Access Network; FTTH; home network

I. INTRODUCTION

Among different options for offering increased bandwidth to the customers with FTTH infrastructure, the advantages of deploying cost effective Passive Optical Network (PON) have been largely recognized. As in many countries, G-PON (Gigabit-capable Passive Optical Network) is now being deployed by FT. Figure 1 illustrates the eleven first cities which are concerned in 2008 in France by this commercial FTTH pre-rollout.

Figure 1. Initial FTTH pre-rollout in France

As a Telco operator, major issues for the next years with such deployments, besides our capacity to adapt the end to end network to the needs, are not only CAPEX but also OPEX. A lot of questions are to be solved when starting a PON deployment, taking into account, on one side, the fact that ODN (Optical Distribution Network) represents the major part of the expenses and are generally installed for a quite long period of time (probably more than 20 years), and on the other side, that metropolitan WDM networks, with the necessity to support the whole traffic (corresponding to DSL, mobile and fibre services), will impact on the access network architecture design.

Finally, because 100Mbits/ or 1Gbit/s interfaces are now feasible for FTTH users, high speed connectivity in home network also needs to be carefully considered: different solutions have been analyzed in terms of easiness and future capability.

II. LEARNINGS FROM INITIAL FIBER DEPLOYMENT

The main initial questions were:

- How to take into account the initial customer demand in a non disruptive way (all the customers probably will not ask for fibre services at Day 1) together with the future service evolution with higher bandwidth upon the time?

- As new fibre infrastructure represents a huge investment, how to maximize the re-use of the already installed underground facilities, both in the copper access (ducts, manholes…) and in the metropolitan networks (existing nodes and fibre cables…) ?

- In the ODN, what are the best splitting ratios and the most efficient location of the splitters to be installed, and what could be the impact on PON systems specification?

As concerned the ODN attenuation, a measurement campaign on the first thousands of FTTH customer links has been conducted. Such measures concerned the deployed GPON equipments with a 28 dB optical budget range (Class B+) and with a 64 splitting ratio on the ODN. Among different parameters, the optical power on the Optical Network Termination (ONT) side has been measured and is shown on figure 2: in urban very dense areas, customer eligibility for GPON technology with a 64 splitting ratio, doesn't seem to be a problematic issue.

Field observed mean value (for this sample) was around -19 dBm, with -25 dBm as a minimum value (Note that according to the ITU rec., -27 dBm minimum sensitivity is required on the ONT side.)
However, a detailed analysis of the optical field measurements (fig 3) has been conducted. Such analysis was very helpful for improving some operational installation procedures, such as the need for adapting and qualifying technician skills and tools, for modifying i.e. some fusion splicer calibration…. Such results were also demonstrating the benefit of installing new generation of fibres with lower bend losses, especially in the customer building.

Furthermore, as the distances to be covered are higher in less dense areas, some evolutions (in order to reduce the ODN attenuation) will be probably required and are under study, i.e. with "premium class splitter" selection or "improved connector product lines" opportunities. Such improvements have to be compared, from an economical point of view, with possible PON system class C or C+ options or with other alternative options like the reduction of the ODN splitting ratio (1/64). Note that, adopting a lower splitting ratio could be a straightforward option from an operational point of view (even as a curative option for specific zones), but may have a significant impact on the network costs.

III. TOWARD HIGHER SPLITTING RATIOS AND REACH EXTENSION FOR PON SYSTEMS?

Higher splitting ratio and reach extension opportunities may reduce the cost of the ODN infrastructure to be installed by the operator, mainly because of the impact on the number of optical central offices to be installed and because of the impact on the size of the feeder cables (low fibre count cables are often the only compatible option with the existing underground ducts...)

The customer demand for "FTTH based" services is somewhat unpredictable and this demand will strongly depend on the commercial offers... but if the number of customers is not so high at the beginning (for example less than 20% of the clients requesting fibre services in a first step), there is a trade-off, from an operator point of view, between the need for minimizing initial investment and the demand for avoiding, as far as possible, future technician interventions on the ODN (need for connecting/disconnecting fibres upon the time). Two main options have to be compared:

Option 1: splitters located near the customer buildings (for example in the distribution box), with the idea that most of the fibre infrastructure has to be "lighted" at the initial stage, in order to reduce the future operational works in the ODN and, for example, to lower the time for connecting a new customer

Option 2: more "centralized" splitters (i.e. in a cross connecting street cabinet), with the idea to provide a more flexible ODN. Such option may reduce the number of OLT cards to be installed in the central offices by a higher "operational filling ratio" of the Optical Line Termination (OLT) port. The drawbacks could be the additional associated cost (higher fibre count distribution cables, more technician interventions on the field, potential impacts on ODN reliability,...) together with the difficulties for this solution to be deployed in dense area or old historical cities, as it requires municipalities' agreement (a large number of new street cabinets may not be accepted on the pavement)

With option 1 (even with option 2 if splitters are fusion spliced at day one) it could be interesting to increase the ODN splitting ratio. As an example, only one 2,5 Gbits/s OLT GPON port could serve in a first step 512, 256 or 128 apartments, then drastically minimizing the number of OLT GPON port to be installed in the central office. The GPON specification doesn't need to be modified in that case, as the operator, thanks to a splitting ratio reduction, stick with the possibility to serve 32 or 64 customers only, if the customers demand growths later on,

Another major interest of higher splitting ratio and reach extension to be considered is that FTTH deployment could be a good opportunity for drastically reducing the number of central offices in the access network. Some initial studies have been conducted in order to understand the possible impact of reach extension on the number of optical Central Offices to be deployed. For very dense area (see figure 4) distances between COs are generally low. In other situation, i.e. in larger area...
mixing high and low population density, OLT backhauling doesn't represent the most significant part of the operator investment, but need to be taken into account as a part of the dilemma.

Figure 4. Possible evolution of the number of central offices, depending on the ODN reach in a very dense area.

Figure 5 illustrates six deployment scenarios where OLTs are co-localized for example with master DSLAMs only, with metropolitan edge nodes only, etc... In that study case, as the density of population could be low, the need for reach extension will clearly exceed class B+ or class C+ capability. Customer's eligibility on figure 5 is shown as a function of the optical budget (with and without a 28 dB extended module) inside the 60km maximum reach. When extender modules are used, they are sited inside an existing central office. We also illustrated the mean reach between the OLT and the users. The economical impact of such evolution could be significant as OLT locations number could be drastically reduced (i.e. from 820 existing Central Offices in our study case, to around 45 COs with "Edge nodes only" scenario). Of course, reducing the number of central Offices, probably in a less aggressive way, (from around 13 000 up to 2 000 or 3 000) is not a short term straightforward scenario, mainly because metropolitan networks need to support both DSL and fibre services, and because of existing DSLAM equipments in each CO.

In the particular case where OLT cards are localized in the metropolitan edge node only (the option that we judge at the moment at the technical limit of feasibility), figure 6 presents the evolution of these number of OLT sites (and also percentage of impacted users) as a function of the maximum distance (not the mean) between the node and the user.

Recent developments in PON technologies offer solutions to operators to increase the splitting ratio or the optical budget dedicated to the reach.

The deployment of an optical budget extension module (G.984.6) [1-3] inside the optical distribution network is one of the attractive solutions to enable the removal of high complexity active devices and reduce the overall access network cost. A first application of budget extension is shown on figure 7. It focuses on the use of extended budget module for a largest customer's eligibility area.

However, installation of new optical fibre cables in the metropolitan networks, could correspond to a significant investment for an operator, and raises some operational questions like protection and management issues. Figure 8 shows another scenario in which a remote extender box is used to multiplex "N" PON trees and to increase in parallel the optical reach. In addition, the optical path between the central office and the extender box could be protected. At the central office, the use of time and/or wavelength multiplexer extender module [5] would open a path by multiplexing several G-PON OLT ports. Furthermore this multiplex interface could also be shared between other interface types, as for example point to point Ethernet interfaces dedicated to Digital Subscriber Line

Figure 5. Eligibility and mean reach as a function of the OLT cards localization in the network.
Access Multiplexer (DSLAM) collect. This solution would allow to optimize the filling efficiency of OLT ports and to increase the FTTH customer's area eligibility. In any case, optical budget extension modules will be probably defined as a WDM demarcation device of the future access-metropolitan network of tomorrow, their design can't ignore the need for a multi-access backhauling network (DLS, fibre, mobile services).

Among different options for offering FTTH, the evolution of solutions to increase the optical budget and to multiplex signals allows a network operator to increase the number of customers accommodated in a GPON system by extending the PON reach, splitting ratio and filling ratio.

IV. METROPOLITAN AND ACCESS MERGER

In any case, by increasing the reach of optical access system and by the necessity to ensure service reliability, some metropolitan functionalities will be requested inside extended access network. Typically, a combination of ring and tree could offer superior scalability and low start-up cost with automatic protection path and supervision functions (cf. figure 9). The optical budget extension modules could be passive based on wavelength routing and remote amplification like SARDANA architecture [4] or active based on optical packet switching like ECOFRAME architecture [5].

V. HOME NETWORKS

New revenue generating services could be offered/extended/developed to fill the 1Gbit/s pipe to the customer doorway but the end-users have to manage, transport and distribute these high speed data flows within their homes into their lounges, home offices and bedrooms. This connectivity media must comply with the requirements of being highly efficient while being easily installable (and even installable by the end-user himself). "No new wire" approaches are being investigated to fulfil these requirements but, if self-installation is achievable, 1Gbit/s guaranteed bandwidth is not yet within reach. The solution today to guarantee the quality of service for Gbit/s approaching applications is to use Gigabit Ethernet over CAT-5/6 cables. However, then, the self-installation requirement is hard to fulfil as the termination of those cables is not easy to make and the cables must be installed away from power interfering sources. One attractive solution is to use Step Index Plastic Optical Fibre (SI-POF) whose core diameter (1 mm) is large enough to allow the user to terminate it by simply cutting the end with a sharp knife. An SI-POF cable has only 3 to 4mm of diameter and is very flexible making it ideal for installation in ducts, along a plinth or under a carpet. The data transmission uses visible light which has the added advantage of simplifying the installation and attractiveness of the overall system.

Transmission around 1Gbps over 50 to 100m of SI-POF has already been demonstrated using a combination of modulation and digital processing techniques [6-8]. We have chosen to use techniques derived from the Power Line Communication and VDSL arena with a combination of Discrete Multi-Tone Modulation and Bit Loading Optimisation algorithm to maximise adaptively the throughput transported in the SI-POF [9]. Using these techniques with a set-up similar to that described in [9] and improved components from Firecomms (650 nm VCSEL and PIN photodiode) we have successfully transmitted 1.5 Gbit/s over 50 m of SI-POF with a BER evaluated to be 1.2x10^-5 (cf. figure 10). Sampling frequency is set to 1GS/s in the TX side while we used a 2GS/s sampling frequency in the RX side. 1023 independent carriers are used over 500 MHz and, after channel probing, the optimum capacity allocation is found.
VI. CONCLUSION

We have shown a potential traffic capacity up to 1 Gbit/s inside the home network (for the moment over a SI-POF with 1 mm core diameter). With these new abilities offered soon in the users' home, and even if a part of these flows correspond to internal traffic between the customer premises equipments, Telcos need to anticipate a significant bitrate increase in their network. In order to do so, FT has started the deployment of an optical access network, mainly focused in a first step with very dense areas. In order to reduce the cost of initial deployment and in order to optimize both access and metropolitan networks, we have studied the feasibility of reducing the number of optical central offices. We have first concluded that a colocation with edge nodes is technically feasible with the use of extension optical budget modules. Moreover, it seems economically pertinent to use extension and mux optical budget modules in order to have as far as possible in a non-disruptive way, a common optical backhauling of the whole traffic (xDSL, mobile and FTTH flows.)

REFERENCES

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