Unbundling the optical access with WDM-PONs

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Foreword

Several different types of bandwidth-hungry applications and services, including multimedia-oriented applications as high-definition television, are rapidly being deployed in the access network. Hence, telecommunication operators are urged to upgrade their access networks to provide broader bandwidth to their subscribers [1]. **This growing demand of bandwidth requires the deployment of a new optical access network.** Independently of which operator will sustain most of the costs (still an open issue in many countries) the main question is how to ensure an effective cost sharing of the physical infrastructure by multiple operators. In the presence of an incumbent operator (which is the Italian case, for instance) such cost sharing is mandatory and regulated and is called Unbundling in the Local Loop (ULL).

Framework

Complete passive optical network

Passive optical network (PON) has emerged as the most flexible, scalable, and future-proof optical access technology. The flexibility of PON lies in its simple point-to-multipoint topology, low-cost implementation, and relative ease of deployment [2].

PON greenfield scenario

This work is funded by the ROAD-NGN project [3]. It includes, as a case-study, the new optical access network of the historical downtown L'Aquila, which still is to be rebuilt after the destructive earthquake of April 6th 2009. In this scenario, the requirement **of coexistence with legacy PONs is not necessary**.

Full-spectrum fiber

Historically, conventional single mode fiber had high attenuation at 1383 nm, commonly referred to as the water-peak. The International Telecommunication Union standard (ITU-T G.652.D) sharply limits attenuation at/near the water-peak, extending the range of possible transmission signals. The industry commercially refers to these fibers as "reduced-water-peak (RWP) fibers", **"low-water-peak fibers"** or **"full spectrum fibers"** [4].

Transmission technologies

Transmission technologies based upon last PON's standards XG-GPON [5] and NG-PON2 [6].

XGPON
- **Up to 10 Gbps in DS**
- **Up to 2,5 Gbps in US**

NGPON2
- **Up to 160 Gbps in DS**
- **Up to 80 Gbps in US**

Method

Bandwidth characterization

Main goal
Characterize fiber's bandwidth using wavelength dependent impairments in order to obtain a **cost curve**
$C(\lambda) = f(c_a, c_d, c_s, \lambda)$

Propagation Attenuation $c_a(\lambda)$
The primary specification of optical fiber is the attenuation. Attenuation means a loss of optical power.

Chromatic Dispersion $c_d(\lambda)$
Chromatic dispersion (CD) is caused by the fact that single mode glass fibers transmit light of different wavelengths at different speeds [7]. The conversion of chromatic dispersion effect in power penalty is known as "Dispersion power penalty problem".

Receiver sensitivity $c_s(\lambda)$
Optical receiver in digital communication system typically contains of Photo Detector. The responsivity of a photodiode is a measure of the sensitivity to light, and it is wavelength dependent [8].

Bandwidth partitioning

Main goal
Define grids and channels (several alternatives)

CWDM grid
- ITU-T recommendation G.694.2 (12/2003) specifies the CWDM grid
- Used in metro applications
- **18 channels** with centre-band wavelength spaced $20nm$ apart

PROs
- Transceiver, filter and any other hardware are available
- It is cheaper than any other DWDM alternatives

CONSs
- Few number of channels
- Channels too different with respect of cost curve

DWDM grid
- ITU-T recommendation G.694.1 specifies the DWDM grid
- DWDM grid supports a variety of fixed channel spacing ranging from 12.5 GHz to 100 GHz and wider (integer multiples of 100 GHz)

XGPON-based channel
88 channels with centre-band wavelength spaced **600 GHz** apart

NGPON2-based channel
534 channels with centre-band wavelength spaced **100 GHz** apart

PROs
- Large number of channels
- Optimized channels allocation is possible

CONSs
- HWs more expensive than CWDM solution

Bandwidth assigning

Main goal
Build and allocate **slots**
(a slot is a set of channels)

Inputs
- Number of operators
- Operators requirements (number of channels for downstream/upstream)
- Cost curves from **bandwidth characterization**
- One of the grids resulting from **bandwidth partitioning**

Algorithm selection

MIN cost
It builds and allocates slots using the best available bandwidth portion of the fiber

MAX fairness
It builds and allocates slots in such a way the operators have a portion of bandwidth very similar to each other

Final goal
Obtain a wavelength allocation plan for operators

References

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Results

Example scenario

- Different HWs for DS (downstream) and US (upstream) DWDM-grid 0,6 THz
- Four operators
- 4 channels for DS and 4 channels for US pro operator
- MIN cost algorithm