Update on WDM-PON

Klaus Grobe
ADVA Optical Networking SE, Fraunhoferstr. 9a, 82152 Martinsried, Germany, Mob.: +49 177 685 1001
KGrobe@ADVAoptical.com

Abstract—We present a status update on WDM-PON, with respect to current implementation trends and standardization. Relevant aspects of WDM-PON are being standardized in the ITU-T G.989 and G.metro Recommendation series. This is complemented by the availability of first tunable lasers with cost reduced to long-haul lasers which support bit rates of 10 Gb/s. This allows WDM-PON as a cost-effective infrastructure solution for broadband services, covering distances of up to 80 km. This can be used, for example, to connect geographically dispersed research and education sites to termination points of national networks.

Index Terms—WDM-PON, access network, tunable laser.

I. INTRODUCTION

WAVELENGTH-DIVISION-MULTIPLEXED PASSIVE OPTICAL NETWORKS (WDM-PONs) have been discussed for broadband access for more than a decade [1]-[3]. So far, they have not been used on broader scale due to some limitations and lack of standardization. This is now about to change, with the support of ITU-T standardization and the up-ramping availability of key components at reasonably low cost.

II. WDM-PON APPROACHES AND LIMITATIONS

One early, operations-driven requirements on WDM-PON systems is colorlessness of the Optical Network Units (ONUs, the client termination equipment). This requirement says that no wavelength-specific ONU variants are allowed in multi-channel systems in order to reduce operational cost (wavelength planning, spare parts). The requirement led to two implementation approaches for the ONU transmitters, tunable lasers and seeded/reflective transmitters.

Technically, the tunable-laser approach is straightforward. It is taken from high-speed WDM transport where it is used now for several years. For access applications, in particular residential access, these tunable lasers were too costly by at least one order of magnitude. This is the only reason why tunable-laser-based WDM-PON has not been deployed on broad scale so far. This is now, 2014/2015, about to change.

Compared to tunable lasers, seeding approaches have weaker achievable bit-rate × reach product. Today, it is not clear if they can support bit rates beyond 10 Gb/s per channel and distances beyond 20 km at high bit rates.

Comparison of the colorless ONU transmitter approaches can be found, e.g., in [2], [3].

III. ITU-T STANDARDIZATION


Q.2/FSAN provide the G.989.x series of Recommendations which is also referred to as NG-PON2. Recommendation G.989.1 describes requirements that NG-PON2 has to meet with regard to co-existence with legacy PON generations, services, the physical layer, and the system. The decision toward tunable lasers was made in G.989.2 (Physical media dependent layer specification).

The Expanded-Spectrum point-to-point NG-PON2 variant uses WDM channels in a broad wavelength range (1524 to 1625 nm). The Optical Distribution Network (ODN) can be WDM-filtered. This configuration can be regarded as tunable-laser based, wavelength-routed WDM-PON.

ITU-T SG15-Q.6 is considering a new Recommendation on wavelength agnostic interfaces, for now dubbed G.metro. The work of Q.6 is directed toward the channel interface specifications. The intended architecture will be based on a head end, terminating multiple WDM channels, and a number of distributed tail ends, terminating individual WDM channels, similar to the NG-PON2 system. In addition, ring and drop-line architectures need to be covered by G.metro systems, as required by network operators. The reach requirement is 80 km, the per-wavelength data rate between 1 and 10 Gb/s, and the system capacity requirement was given as 40 or 80 channels. To meet these requirements, the network needs to be based on WDM filters, as power splitters would severely limit the system power budget.

IV. WDM-PON WITH TUNABLE LASERS RELOADED

WDM-PON systems require wideband-tunable lasers. Tunability can be achieved by [4]-[5]:

- Electronic Tuning
- Thermal tuning
- Mechanical Tuning

So far, only lasers based on electronic tuning have gained substantial commercial success, mainly multi-section DBR (Distributed Bragg Reflector) lasers. These have been used for high-performance WDM systems. More recently, further types of tunable lasers, e.g., MEM-VCSELs and thermally-tuned Bragg-grating lasers have become available as more cost-effective alternatives for access applications.

Relevant parameters of these lasers are listed in Table I. Launch power refers to unmodulated (continuous wave) output. Modulated launch power can be lower by 7...8 dB.
The SMSR (Side-Mode Suppression Ratio) of VCSELs may become a problem in multi-channel PONs because of coherent (interferometric) crosstalk [6]. This is relevant for the upstream direction of power-split ODN where side modes from interfering channels might coincide with other channel wavelengths and cannot be rejected in the demultiplexing filter in the OLT.

V. FILTERED ARCHITECTURE

Where possible from the viewpoint of legacy installations, WDM-PON access should use filtered ODN:

- *Avoidance of tunable receivers.* In a multi-channel, power-split ODN, ONUs require wavelength-selective receivers (coherent receivers, tunable filters). With filtered ODN, these can be avoided thus reducing cost.
- *Lower accumulated insertion loss.* WDM filters have less insertion loss, compared to power splitters with similar port count. Hence, filters increase maximum reach, or they allow cheaper transceivers with lower power budget.
- *Less interferometric crosstalk.* In power-split ODN, this crosstalk can limit the allowable channel number.

In filtered ODN, it is suppressed in the multiplexer.

Following [6], SMSR requirements of -65 dB can result for 40-channel power-split WDM-PON. This cannot be met with typical semiconductor lasers. Therefore, additional side-mode suppression is necessary. The most effective measure, and the one implemented in any typical WDM transport system, is the implementation of an upstream multiplexer filter. Assuming typical channel isolation of >25 dB, such a filter can reduce the SMSR requirement to the range of -40 dB which can be met with typical DBR lasers, see Table I.

An example network is shown in Fig. 1. Here, the remote node (RN) is resiliently connected to two OLTs. This resilience may become necessary since WDM-PON systems can serve a high number of clients. This way, the optical multiplex section is protected, thus significantly increasing the signal availabilities.

VI. WDM-PON WITH HIGHER BIT RATES

The WDM-PON approaches described support reach up to 80 km, per-channel bit rates of up to 10 Gb/s, and 40 to 80 WDM channels.

Future developments will address these areas. Reach can be increased by means of active reach extenders (i.e., optical amplifiers in the ODN). This is known from typical WDM transport systems and already considered in the standards mentioned.

The increase of the per-channel bit rate beyond 10 Gb/s is straightforward. The WDM channel grid will be 100 GHz, or 50 GHz if channel count is to be as high as 80. This allows all per-channel bit rates as used today, especially since in a WDM-PON, optical path penalties are comparatively low due to distances which are typically clearly shorter than 100 km.

CONCLUSION

WDM-PON is now becoming available as a cost-efficient broadband-access technology. It is currently heavily discussed as solution for, and pushed into, broadband access, backhaul, and fronthaul (the digital variant of radio-over-fiber) applications.

In the NREN context, WDM-PON may be used, depending on the available fiber infrastructure, as the access networking technology between termination sites (points of presence, PoP) of national NREN backbones and geographically dispersed user sites, e.g., at different campuses in a given area.

So far, standardization of WDM-PON has not yet seen significant input from the NREN community. In case any special requirements (e.g., regarding jitter, latency, timing) exist, it would be very interesting to hear these.

REFERENCES

VITAE

Klaus Grobe received the Dipl.-Ing. and Dr.-Ing. degrees in electrical engineering from Leibniz University, Hannover, Germany, in 1990 and 1998, respectively.

He worked over 20 years in the field of WDM. He is one of the authors of Wavelength Division Multiplexing – A Practical Engineering Guide (Hoboken, NJ, Wiley, 2014) and authored and co-authored more than 100 technical publications as well as three further book chapters. He holds 25 (pending) patents.

Dr. Grobe is member of the IEEE Photonic Society, the German VDE/ITG and ITG Study Group 5.3.3 on Photonic Networks. He served OFC Subcommittee 10 in 2009-2012, and works in FSAN and ITU SG15-Q.2.