FlexPON: a Hybrid TDM/WDM Network enabling Dynamic Bandwidth Reconfiguration using Wavelength Routing

M.M. de Laat(1), R.L. Duijn(1), E.G.C. Pluk(1), G.N. van den Hoven(1), P.J. Urban(2), H. de Waardt(2)

(1) Genexis B.V., Lodewijkstraat 1a, NL-5652AC Eindhoven, the Netherlands, m.delaat@genexis.nl
(2) COBRA Research Institute of the Eindhoven University of Technology, p.j.urban@tue.nl

Abstract *A new cost-effective FTTH network with high bandwidth efficiency and extreme flexibility is demonstrated. FlexPON uses a stack of coloured PONs combined with remote wavelength routing allowing capacity redistribution.*

Introduction

In access networks, the bandwidth demands of various end-users is unpredictable and shows high variation over time. Within the Freeband project “BroadBand Photonics” [1] and the Smartmix-Memphis project [2] a dynamically reconfigurable broadband photonic access network is developed. By enabling the network operator to easily and remotely reconfigure his access network, the capacity distribution across the end-users can be adapted in time to the demand for bandwidth.

A well-known access network infrastructure is the passive optical network (PON). A PON is a broadcast system in the downstream direction. The upstream transmission is a many-to-one connection and hence some kind of transmission arbitration is required to remove contention. Time division multiplexing (TDM) is the most common way to avoid this contention. The major drawback of PON is the fact that it offers only limited flexibility, because all users share only one communication channel.

Here we propose a new network concept, the flexible PON (FlexPON), which solves this problem. On a high level, FlexPON can be seen as a stack of PONs, each operating on a different wavelength pair. Each end-user can be dynamically assigned to any one of the PONs. Based on the bandwidth demands of the end-users, the end-users are distributed over the PONs, providing the required bandwidth where needed, when needed. To our knowledge, this is the first demonstration of a network concept in which the bandwidth of multiple PONs can be distributed over end-users in an optical way.

Network Architecture

The FlexPON network architecture is shown in Fig.1. A Central Office (CO) connects to a number of Remote Nodes (RNs) in the field using SSMF. Each RN serves several Optical Network Units (ONUs) [3].

The CO transmits multiple downstream (DS) data signals and multiple continuous wave (CW) signals. One DS-signal and one CW-signal form a wavelength channel pair. The CW-signal will be remotely modulated at the ONU. The FlexPON wavelength plan is based on the ITU-T wavelength grid for the C-band to enable the utilization of commercially available elements. In addition, the CO transmits out-of-band control information to the RNs.

The RN consists of a Wavelength Router (WR) and a controller to realize remote reconfiguration of the WR. The WR is an integrated structure of thermally tuned micro-ring resonators [4]. By applying heat, a change of refractive index in the material is created. This results in a change of the resonant wavelength of the micro-ring. The Free Spectral Range (FSR) is defined to fit the ITU-T wavelength grid, enabling the partial drop of a DS-signal and a CW-signal on a single drop port. With this concept, a wavelength channel pair can be dropped to multiple users. Chaining of RNs can be realized using the through port of the WR.

Because the wavelength channels can be re-configured over time, a colourless transceiver is required at the ONU. Upstream (US) and DS signals are separated using a Band Pass Filter (BPF). The DS-signal is received with a regular wideband photodetector, while for the US communication a Reflective Semiconductor Optical Amplifier (RSOA) is

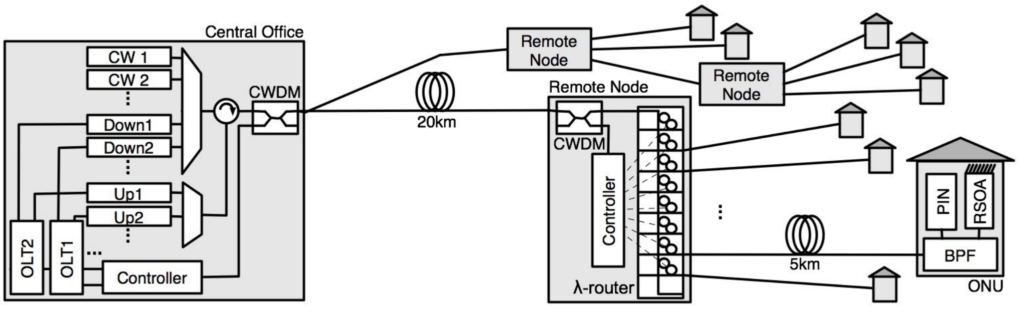

Figure 1: FlexPON network architecture

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chosen. This element reflects the received CW-signal, modulates it with the data and provides gain to it [5].

Experimental Results

An experimental set-up has been realised to show the feasibility of the network, see Fig.2. The major difference compared to the set-up in Fig.1 is the existence of the circulators in the RN. In this first demonstration, the WR has a higher insertion loss than usual. Hence, an optical amplifier was needed to compensate this loss. The circulators prevent that the optical path for upstream communication experience the insertion loss of the WR twice. For combining the upstream channels a 3dB-coupler is used.

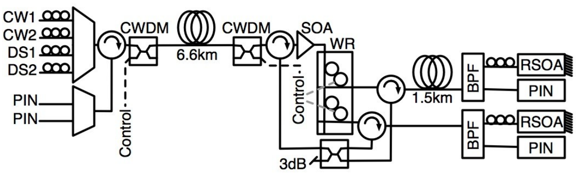

Figure 2: Experimental FlexPON set-up

Two CW-signals and two DS-signals are used in the CO. The wavelengths are chosen according to the ITU-T wavelength grid. The output spectrum of the CO is shown in Fig.3. The dotted line indicates the ideal filter characteristic of the BPF in the ONU.

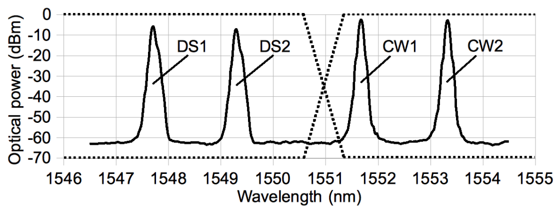

Figure 3: Wavelength spectrum Central Office

The WR device is based on TriPleX™ waveguide technology [6,7], a technology very similar to low cost silica based PLC technology. The WR is composed out of 2 second-order laterally coupled micro-rings. This higher order filter response provides an extinction ratio of ~20dB. The WR is thermally tuned to the correct wavelength. The FSR of the WR corresponds exactly to the designed value of 500GHz. This realizes simultaneous transmission of both DS- and CW-signals.

The CW-signal entering the ONU is directed towards the RSOA by the BPF. The signal is amplified and modulated by the RSOA. A data rate of 1.25Gbit/s and a PRBS of 2^{23}-1 are used. Measurements are performed for the optimized polarization state.

Two different fiber scenarios were used for the measurements: back-to-back (B2B), and 6.6km fiber between CO and RN and 1.5km fiber between RN and ONU. These are realistic values to be used in an access network. The bit-error rate (BER) results can be found in Fig.4. Only upstream transmission is shown, because this is the most critical.

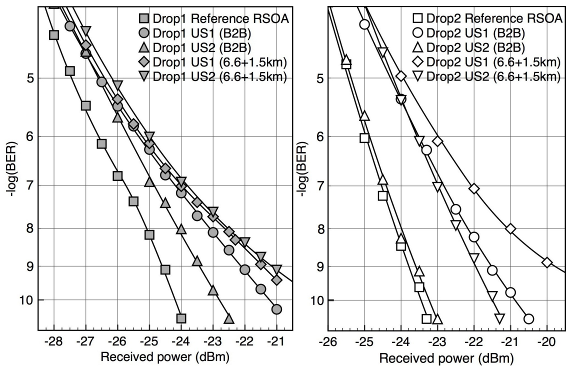

Figure 4: BER as function of received power

The BER results show that error free transmission is realized with fibers included in the network using two fully functional ONUs. For Drop2 a power penalty of 2dB occurs on US1 compared to US2 wavelength. This is due to the fact that the static resonance wavelength of Drop1 is more close to US1 as it is to US2 due to the thermal tuning of the micro-rings. This causes optical power for Drop2 to be lost in Drop1.

Note these results are obtained using a prototype WR. This technology can be improved and optimized, promising a low insertion loss for the device. When 20km fibers is used between CO and RN an error floor is reached for US transmission. The error floor is caused by accumulation of ASE of the amplifiers and by backscattering [8]. This can be resolved by improving technology. Ways to reduce backscattering are mentioned in [9].

Conclusions

In this paper we have proposed and experimentally demonstrated a new flexible PON network (FlexPON) enabling dynamic bandwidth reconfiguration using wavelength routing. The wavelength routing of data channels at 1.25 Gbit/s was demonstrated using a wavelength router based on micro-ring resonators and a reflective semiconductor optical amplifier.

Acknowledgement

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