Results from EU Project SARDANA on 10G extended reach WDM PONs

Josep Prat[1], Jose Lazaro[1], Philippe Chanclou[2], Risto Soila[3], Ana M. Gallardo[4], Antonio Teixeira[5], Giorgio M. TosiBeleffi[6], Ioannis Tomkos[7]

[1] Universitat Politècnica de Catalunya (UPC), 08034 Barcelona; jprat@tsc.upc.edu
[2] OrangeLabs, [3] Tellabs, [4]INTRACOM Telecom, [5] IT-Aveiro, [6] Mise Dip. Comm. ISCOM, Rome, [7] AIT, Athens

Abstract: The presented "Scalable Advanced Ring-based passive Dense Access Network Architecture" transparently integrates WDM metro and PON access technologies, implementing ring protection, 100Km reach and up to 1024 users served at 10Gbps, with passive highly-shared infrastructure.

OCIS Codes: (060.4510) Optical Communications, (060.2320) Fiber optics amplifiers.

1. Introduction

Current research on new network architectures and technologies has to enable universal communication with one order of magnitude increase in terms of connected users, capacity increase and distance reach, as well as incorporating enhanced security, scalability, service integration and other key functionalities. These are precisely the goals of the FP7 European research project "Scalable Advanced Ring-based passive Dense Access Network Architecture" (SARDANA), undertaken by seven partners in 2008-2010 [1], towards the construction of a future-proof access-metro optically converged network that also minimizes the infrastructure and maintenance requirements while keeping compatibility and integration with existing standards. Since operators face a high degree of uncertainty at this level (take rates, user demands, extension branches, etc) and the necessity of deferring the investments, incremental scalability has become a major objective.

Sardana aims at serving more than 1000 users spread along distances up to 100 km, at 10Gbit/s, with 100M-10Gbit/s per user in a flexible way. A rationale base for this approach consists in transparently combining Next Generation 10G-GPON OLT/ONU equipment with WDM metropolitan network transmission and protection schemes. To realize this convergence, a number of innovations are being developed as is described below.

2. Sardana Network Architecture

In search of high scalability and trunk protection, Sardana implements an alternative architecture of the conventional tree WDM/TDM-PON, consisting of the organization of the optical distribution network as a WDM bidirectional ring and TDM access trees, interconnected by means of cascadable optical passive Add&Drop remote nodes (RN), depicted in Fig. 1. The ring+tree topology can be considered as a natural evolution, from the conventional situation where Metro and Access networks are connected by heterogeneous O/E/O equipment at the interfaces between the FTTH OLTs and the Metro network nodes, towards an integrated Metro-Access network. In this case, covering similar geographical area, users and services, but concentrating electronic equipment at a unique CO, and implementing an all-optical passive alternative, operating as a resilient TDM over WDM overlay. Depending on the scenario, the ring+tree mixed topology optimizes the usage of the fiber infrastructure in the ODN, and also offers enhanced scalability and flexible distribution, as new RNs can be installed.

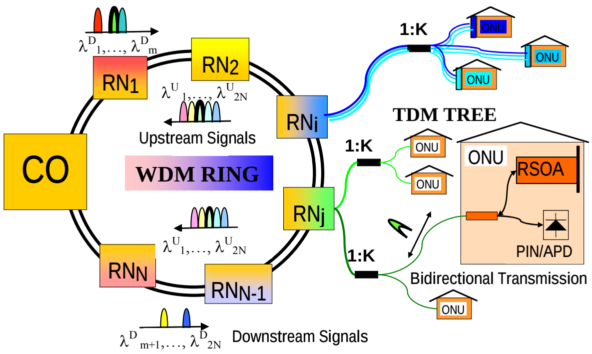

Fig. 1: Sardana network architecture.

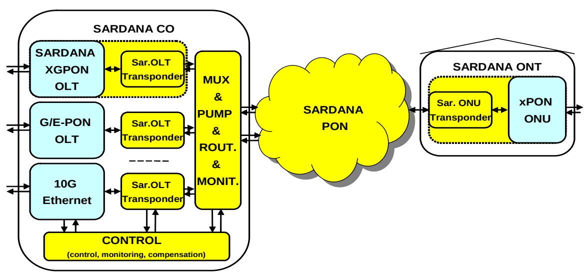

Fig. 2: General network model.

The project mainly focuses on the physical layer, specifically on the optical and electro-optical subsystems, trying to be highly transparent to the protocol, coding and bit rate of existing PON standards. With respect to them, the optical parameters are changed (for example the wavelengths band), but the chipset is kept compatible with ngPON, for a smooth migration and interoperability. The ITU-T GPON standard was taken as the reference point, this being also the most stringent in specifications. By means of optical transponders, the adaptation of standard PON systems to Sardana is performed, incorporating the new functionalities. Therefore, Sardana can be regarded as a new transparent optical layer, with WDM and active E/O devices that can act as traffic collector from existing access systems, and using the existing metro/access optical passive infrastructure (Fig. 2).

For the full network demonstration, a 10G/2.5G MAC, based on FPGA, compatible with xGPON GTC has been developed in the project, and advanced new broadband multimedia services will be exhibited in the field trial.

3. Key subsystems

The implementation of the network subsystems: passive Remote Node (RN), colorless Optical Network Unit (ONU) and the Central Office (CO), encompasses a number of technical challenges. Along the research, although several solutions have been investigated, the decision on the selected one for network demonstration is made on the basis of cost and robustness, leaving more complex advanced solutions for parallel research.

Remote Nodes

The RN is a key element of the Sardana network, and many of the performances and functionalities of the network depend on its design, like protection and routing. They implement cascadable 4-to-1 fiber optical add&drop function, by means of athermal fixed filters, splitters that perform spatial diversity for protection and distribute different wavelengths to each of the access trees, and remote amplification, introduced at the RN by means of Erbium Doped Fibers (EDFs) to compensate add&drop losses; optical pump for the remote amplification is obtained by pump lasers located at the Central Office (CO), also providing extra Raman gain along the ring.

This new network element, passive but with dynamic behavior, incorporated in the new PON, is not present in current standards, but it inherits concepts from the following existing standards: ITU-T G.984.6 on PON Extender Box, ITU-T G.973 on remotely pumped amplifier (ROPA) for submarine systems, ITU-T G.983 PON protection and ITU-T G.808 Generic protection switching.

The RN encompasses some key challenges, like passiveness in the sense of not using electrical supply, efficient 1480 nm pump use, and burst mode amplification generating gain transients. The inset in Figure 3 shows a RN with 2 drop wavelengths (2 trees) and bidirectional remote amplification in the drop. Wavelength extraction is done by means of two athermal thin-film OADMs at alternated 100 GHz or 50 GHz ITU-T grid channels. The natural gain transients due to the amplification of dynamic burst-modes of the PON upstream are cancelled in this RN thanks to the crossed wavelength direction design and co-amplification of higher power continuous downstream, also avoiding Rayleigh backscattering of the ROPA. The implemented RN presents 1 dB insertion loss in by-pass, 6 dB in drop/add, and >30 dB rejection. The loses are largely compensated by about 14 dB gain of the EDF. In [2] this is compared to other types of Extender Boxes for PONs, in terms of reachable trunk & access power budget. We specify up to 16 RNs, thus 32 wavelength channels, with a splitting ratio between 1 and 32 each.

Lately, a reconfigurable RN has been also assembled, operated with optical power by means of special power converting / harvesting modules, controlling latched optical switches or tunable power splitters, that enter into play at network protection and balancing [3].

Optical Network Unit

A key requirement of the ONU is to be colorless and to reuse the down wavelength, in full-duplex operation compatible with xPON electronics. A reflective-ONU optical transceiver based on RSOA has been taken as preferred option because it is the cheapest available choice for the WDM-PON, although it can rise up serious impairments operating in full-duplex with wavelength reuse. To overcome the bandwidth, noise and crosstalk limitations, a complete study of the possible optical modulation formats has been done and several compensating techniques have been developed:

- reduced-ER downstream with feed-forward cancellation at ONU [4]
- wavelength dithering to reduce Rayleigh backscattering and reflections [5]
- up-stream chirped-managed RSOA with offset-filtering, reaching 10G operation [6]
- adaptive electronic equalization, using MLSE and DFE/FFE at 10G [6,7]
- integrated colorless optical FSK demodulation with a SOA/REAM [8].
- wavelength shifting at ONU for reduction of Rayleigh scattering [9]
- other modulation formats tested like SCM, SSB and homodyne PSK are kept as longer term research.

Central Office (CO)

The CO centralizes the light generation for the whole network and its control. The new optics at the CO includes WDM multiplexers, optical pre/post-amplifiers, equalizers, protection switches and monitors.

2. Network tests

First tests of the Sardana network have been performed, in different configurations. Fig. 3 shows the scheme and results in a 105 km ring between Rome and Pomezia cities, at 10G down- and 2.5G up-stream, with 2 RNs and 3 channels; the pump power was below 1.2 watts at 1480nm. Sensitivities are -33 and -36 dBm respectively. Protection against fiber cut was validated, with less than 1 dB penalty at rerouting, in down- and up-stream directions.

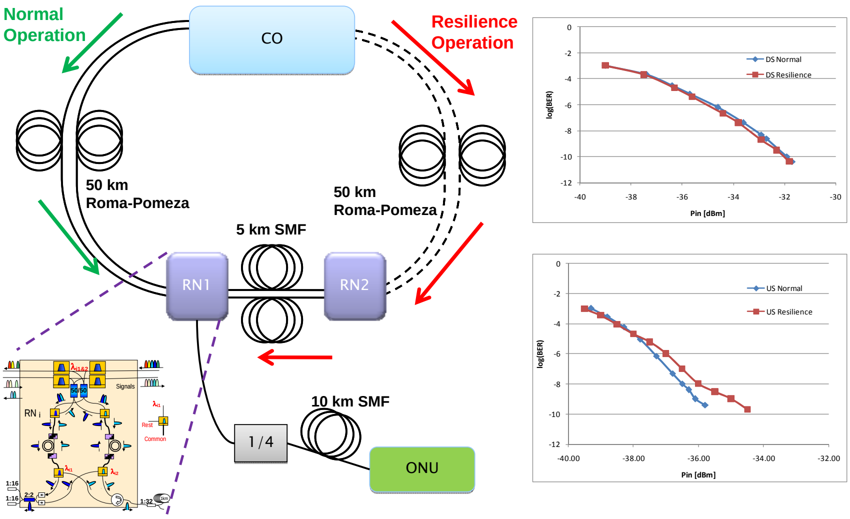

Fig 3: Network test configuration with 105 km ring, RN scheme (inset) and down- (above) / up-stream (below) transmission BER measurements.

With the burst mode upstream operation, any gain transients at CO or RNs EDFAs can be mitigated by means of pre-distortion carving of data packets at the ONU, allowing a strong reduction, to 30%, of the packet overshoot [10]. On the other hand, and because of the highly variant optical traffic at the ring, it is useful to develop an automatic method based on a genetic algorithm to assess and minimize the impact of nonlinear crosstalk in WDM ring channels; by optimizing channel frequencies and powers, the budget is improved in 3-5 dBs [11].

References

[1] European 7th Framework Programme project SARDANA (www.ict-sardana.eu).
[2] F. Saliou, P. Chanclou, F. Laurent, N. Genay, J.A. Lazaro, F. Bonada and J. Prat. “Reach Extension Strategies for Passive Optical Networks", J. Opt. Com. Networks, vol.1, no.4, Sept. 2009.
[3] A. Baptista et al, “Improved remote node configuration for passive ring-tree architectures”, ECOC 2008, Brussels, Sept. 2008, paper Tu1f6.
[4] B. Schrenk, F. Bonada, M. Omella, J.A. Lazaro, J. Prat, “Enhanced Transmission in Long Reach WDM/TDM Passive Optical Networks by Means of Multiple Downstream Cancellation Techniques”, ECOC 2009, paper We.8.5.4, Vienna.
[5] V. Polo, B. Schrenk, F. Bonada, J. Lazaro and J. Prat, “Reduction of Rayleigh Backscattering and Reflection Effects in WDM-PONs by Optical Frequency Dithering”, ECOC 2008, Brussels, Sept. 2008, paper P421.
[6] M. Omella, I. Papagiannakis, B. Schrenk, D. Klonidis, A. N. Birbas J. Kikidis, J. Prat and I. Tomkos, “Full-Duplex Bidirectional Transmission at 10 Gbps in WDM PONs with RSOA-based ONU using Offset Optical Filtering and Electronic Equalization” OFC 2009, San Diego, Paper OThA7.
[7] D. Torrientes, P. Chanclou, F. Laurent, S. Tsyier, Y. Chang, B. Charbonnier and C. Kazmierski, “10Gbit/s for Next Generation PON with Electronic Equalization using Un-cooled 1.55µm Directly Modulated Laser”, ECOC 2009”, Vienna, PDP Th.3.5.
[8] B. Schrenk, J.A. Lazaro, C. Kazmierski, J. Prat, “Colourless FSK/ASK Optical Network Unit Based on a Fabry Pérot Type SOA/REAM for Symmetrical 10 Gb/s WDM-PONs”, ECOC 2009, Vienna, paper We.7.5.6.
[9] M. Omella, J.A. Lázaro, J. Prat, “Driving Requirements for Wavelength Shifting in Colorless ONU with Dual-Arm Modulator”, IEEE/OSA J. Lightwave Technol., vol. 27, no. 17, Sept. 2009.
[10] F. Bonada, B. Schrenk , J. A. Lázaro, V. Polo, P. Chanclou, J. Prat, “Gain Transient Mitigation in Remote Erbium Doped Fibre Amplifiers by Burst Packet Carving at the ONU for Extended Power Budget PONs”, ECOC 2009, paper We.P6.24, Vienna.
[11] J. Reis, B. Neto, P. S. André, A. Teixeira, "WDM Ring Performance Improvement by Means of a Nonlinear Effects Crosstalk Minimization Algorithm", OFC 2009, paper JThA77, San Diego.