SEVENTH FRAMEWORK PROGRAMME

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Abstract:

This document is the second deliverable of the WP27 "Physical Impairments constrain based routing in packet switching networks". This report contains an overview of the WP27 activities during the first year of the project and the activities plan for the second year. During the first year of BONE project, four joint activities were running and one was prepared to start in M25. As result of these joint activities, four conference/workshop papers and four journal papers were published.

Keyword list: monitoring, switching, route, reroute, regenerate, discard, packet, sampling, management level, route level.

Clarification

Nature of the Deliverable

R	Report
P	Prototype
D	Demonstrator
O	Other

Dissemination level of Deliverable

PU	Public
PP	Restricted to other programme participants (including the Commission Services)
RE	Restricted to a group specified by the consortium (including the Commission Services)
CO	Confidential, only for members of the consortium (including the Commission Services)

Disclaimer

The information, documentation and figures available in this deliverable, is written by the BONE ("Building the Future Optical Network in Europe) – project consortium under EC co-financing contract FP7-ICT-216863 and does not necessarily reflect the views of the European Commission.

1. Table of Contents

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3. Executive Summary

This document is the second deliverable of the work package “Physical Impairments constrain based routing in packet switching networks”. It describes the WP27 activities during the first year of this topical project and the activities plan for the second year.

The project has initially gathered five partners and has now expanded for twelve involved partners. There are some partners with little demonstrated activity, however most of the involved partners are clearly showing increasing involvement and activity. The initial activity of the project was to define joint activities based on the partners expertise and project topics (five), they were designed to encompass all the required needs for the good concretization of the project objectives and involve all interested partners and eventually create new momentum for new JA's. Clearly, adjustments were expected and occurred, due both to resources readjustments and topic overlap, e.g. JA.5 was merged to JA.2. Also, structurally of some other finalizing BONE WP's and projects left some related activities without continuation. The ones related to the ambit of the WP27 could still generate results in the scope of this WP and therefore are now continued inside. This is, in the project leader vision a very good result since this project was initially planned as complement to OBS activities which started in the M0 of BONE.

As a general comment, the momentum of the project is increasing and some publications and effective results and mobility are starting to stem out, therefore, we can consider that the project will deliver, probably not all answers to the proposed questions, however a very good vision on the topic.

The topics covered by this work package address the physical impairments based routing in packet switching networks.

4. Introduction

The main objectives of this work package "Physical Impairments constrain based routing in packet switching networks" are to collect monitoring strategies (traffic based ICBR, physical impairments ICBR, possible route parameter monitor, possible packet to packet monitor); collect regenerators (packet by packet regenerators; parameter regenerators) and collect actions (rerouting, signaling, blocking, special fields in the protocols dedicated for the control of the packet passing through the router and controllable at physical layer).

This deliverable describes the work performed within the previously referred objectives and provides updates on the progress of the joint activities.

Firstly, we provide a list of the involved partners in the WP as well as their involvement. Then progress and next steps of each of the described joint activities is presented with some summary sheet and results. Finally some conclusions are drawn.

5. Participants

There are twelve partners collaborating in this work package. Table 1 shows the list of participants and the number of the joint activities, in which they are involved. Two new partners (CTTC, UPCT) joined with a new joint activity proposal (JA.6). A detailed description of the joint activities is provided in the following chapters.

Partner No.	Member	Country	Starting Joint Activities	Present Joint Activities
2	TUW	Austria	JA1, JA2, JA3	JA1, JA2, JA3
9	CTTC	Spain	No involvement	JA6
13	UPC	Spain	JA1, JA2, JA3, JA4, JA5*	JA1, JA2, JA3, JA4, JA6
14	UPCT	Spain	No involvement	JA6
15	UPVLC	Spain	JA1, JA2, JA3, JA5*	JA2
19	AIT	Greece	JA1, JA4	JA1, JA4, JA6
24	BME	Hungary	JA1, JA2, JA3, JA4	JA1, JA2, JA3, JA4
28	ISCOM	Italy	JA1, JA2, JA3, JA4, JA5*	JA1,JA2, JA3, JA4
37	IT	Portugal	JA1, JA2, JA3, JA4, JA5*	JA1, JA2, JA3, JA4
42	BILKENT	Turkey	JA1, JA3, JA4	JA1
48	USWAN	United Kingdom	JA1, JA3, JA4	JA1, JA3, JA4
Collaborating Inst.	NICT	Japan	JA1, JA2	JA1, JA2

*JA.5 was merged to JA.2 due to topic overlap.
JA.6 is a new joint activity proposal.
Dark are the activities that were in the objectives of the partner at project start and are not actually.

Table 1 - Work package participants and their joint activities at the beginning and at the present

6. List of Joint Activities

This chapter describes the joint activities in this workpackage. The following table shows key information about these joint activities:

No	Joint Activity Title	Responsible person	Participants	Mobility Action	Deadline
1	Impairment aware algorithms for optical packet switching (OPS) networks	Gerald Franzl	TUW, UPC, AIT, BME, ISCOM, IT, BILKENT, USWAN, NICT	Started M19	M33
2	Monitoring strategies for OBS and OPS networks JA.5 - Packet monitoring based on nonlinear optical preprocessing and filtering (MERGED)	António Teixeira	TUW, UPC, UPVLC, BME, ISCOM, IT, NICT	Started M13	M33
3	Decision mechanisms for packet transit in OPS networks	António Teixeira	TUW, UPC, BME, ISCOM, IT, USWAN	Started M19	M33
4	Techno-economic study of monitoring techniques in OPS networks	Giorgio Tosi Beleffi	UPC, AIT, BME ISCOM, IT, USWAN	Started M18	M33
6	Impact of physical layer impairments on control plane schemes and proposals for optical circuit and packet switched networks	Salvatore Spadaro	CTTC, UPC, UPCT, AIT, IT	*Planned M25	M33

Table 2 - Summary list of the planned joint activities

6.1 JA-1 - Impairment aware algorithms for optical packet switching (OPS) networks

Participants: G. Franzl, J.A. Lazaro, I. Tomkos, Szilard Zsigmond, G. Tosi-Beleffi, A. Teixeira, Namik Sengezer, K. Ennser, N. Wada

Responsible person: G. Franzl (TUW)

Description:

While attenuation can be assumed to be compensated hop by hop using all optical amplifiers other physical layer impairments (degrading the optical signal quality) accumulate hop by hop. In all-optical networks the routing mechanisms, therefore, shall consider the degradation of the optical signal to avoid paths delivering optical signals not receivable with an acceptable bit error rate (BER).

A distinction needs to be made among two types of impairments: a) the load independent physical layer impairments – these limit the maximum path length, and b) the load dependent, which should be considered in short term routing decisions, e.g., load balancing and hop-by-hop admission control, to assure that the remaining packets on a hop are not unacceptably degraded along their individual paths. Latter causes an NP hard optimization problem and likely heuristics need to be found in order to define viable (fast enough) routing mechanisms.

Most of the studies on packet scheduling in the OPS networks do not consider physical layer impairments. The main objective of scheduling in these studies is contention resolution. However, the utilized scheduling mechanisms used may degrade signal quality. As optical packets traverse fiber delay lines, the signal is attenuated and the amplifiers used to compensate the attenuation contributes ASE noise. Each time the packet is switched through the switching fabric, it may experience additional crosstalk. Moreover, signal quality may be further degraded because of load dependent impairments such as cross phase modulation and four wave mixing, along the output fiber. These types of impairments can be avoided by considering them in the scheduling process.

Objectives:

The aim of this JA is to collect routing algorithms to implement traffic decisions in packet switched networks, based on impairment present in optical systems (PMD, noise, and crosstalk).

Approach:

Firstly the existing ICBR algorithms shall be analyzed on applicability and the most common shortcomings highlighted using the JA1 sub-page in BONE portal. Secondly a scheme/hierarchy shall be outlined that would fit all problems, and finally the possibilities presented in JA2 and JA3 integrated to jointly define a feasible ICBR approach/hierarchy for OPS as one key result of WP27.

Main Outcomes and Results:

- Extended insight in the problems enclosed;
- An idea on where/when which algorithm fits better;
- Some conference papers on specific improvements/proposals;
- A journal paper on findings presenting a joint new/combined proposal;
- Revision Booklet of the state of the art (eventually a revision paper);
- Activity with real mobility or interchange of ideas (mobility actions, conference calls record, JA1 sub-page blog, etc.).

General Contributions (performed):

- Populated the private JA1 sub-page in BONE portal with tools and helpful text to provide a private JA1 internal platform for remote joint work and discussion;
- Asked several authors of BONE related ICTON 2009 papers on IA-RWA and ICBR to add WP27;
- Created list of publications in private JA1 sub-page's wiki-tool including JA internal, BONE internal, as well as external papers of relevance (to be extended by partners);
- Proposed to contribute to chapter 3 in WP15 book (topic related to JA27.1).

Technical Contributions (performed):

- TUW up-loaded description of DWP scheme, which, being circuit oriented, could be implemented as part of an OPS control plane to ensure that optical packets (a bound sequence of light pulses) are individually routed along physically feasible paths only.

Next Steps (foreseen):

- Collect and distribute proposals from JA partners (autonomously via the JA1 sub-page in BONE portal);
- Compare the collected ICBR proposals (compose the booklet utilising the discussion options offered by the JA1 sub-page in BONE portal);
- Outline a scheme respectively a hierarchy of algorithms fitting the OPS specific problems (joint paper potentially resulting from some mobility);
- Contribute to final technical report (compose and write JA1 part);
- BILKENT will investigate the influence of the packet scheduling algorithms in OPS networks on signal quality and BER, and design scheduling algorithms that minimize the BER or guarantee a lower threshold on BER. They will also work on packet scheduling algorithms that consider dynamic fluctuations in EDFA gain occurring in OPS networks.

Mobility actions:

Planed mobility actions:

Currently none is defined. Two spontaneous short mobilities are a rather optimistic guess (based on current commitment, interest and activity of partners).

Requirements:

Expected Duration:

- 17 months

Type of work:

- theoretical (good reasoning)
- simulation (empirical proves)

Skills/facilities required:

- generic network layer view (options)
- control plane basics and principles (restrictions)

Skills /facilities available (to be extended):

- AIT, TUW, and others: experience with multi-constraint routing problems
- BME, KTH, and others: experience with traffic control and management

If interested, contact:

Gerald Franzl (Gerald.Franzl@tuwien.ac.at)

Meetings:

ICTON'09 (30th June 2009)

BONE Second Plenary Meeting Poznan (5th October 2009)

Generated WP Papers:

[1] A. Teixeira (IT), L. Costa (IT), G. Franzl (TUW), S. Azodolmolky (AIT), I. Tomkos (AIT), K. Vlachos (RACTI), S. Zsigmond (BME), T. Cinkler (BME), G. T. Beleffi (ISCOM), P. Gravey (GET), J. A. Lazaro (UPC), C. Vazquez (UC3M), J. Montalvo (UC3M), E. Le Rouzic (FT), T. Loukina (GET), "An Integrated View on Dynamic Monitoring and Compensation for Optical Networks: From Management to Physical Layer", Photonic Network Communications, Vol. 18, No. 2, pp. 191-210, on-line & print, February 2009 (shared with JA2).

[2] N. Sambo (SSSUP), Y. Pointurier (AIT), F. Cugini (SSSUP), P. Castoldi (SSSUP), I. Tomkos (AIT), "Lightpath establishment in PCE-based dynamic transparent optical networks assisted by end-to-end Quality of Transmission estimation", 11th International Conference on Transparent Optical Networks, ICTON 2009, Island of São Miguel, Azores, Portugal, June 2009.

Relevant papers shared from other WPs or previously published on the topic:

[3] I. Tomkos, S. Sygletos, A. Tzanakaki, and G. Markidis, "Impairment Constraint Based Routing in Mesh Optical Networks", in Optical Fiber Communication and the National Fiber Optic Engineers Conference, OFC/NFOEC 2007, Conference on, 2007, pp. 1-3.

[4] M. Gagnaire (GET), "Physical impairments in all-optical networks", Optical Fiber Communications (OFC), San Diego, February 2008.

[5] G. Franzl (TUW), S. Aleksic (TUW), B. Statovci-Halimi (TUW), S. Sarwar (TUW), “Quality of Transmission Management in Dynamically Routed All-Optical Networks”, Proceedings of NOC2008, Krems, Austria, July 2008.

[6] Jirattigalachote (KTH), K. Katrinis (AIT), A. Tzanakaki (AIT), L. Wosinska (KTH), P. Monti (KTH), “Quantifying the Benefit of BER-based Differentiated Path Provisioning in WDM Optical Networks”, ICTON2009, Ponta Delgada, June 2009.

[7] Tzanakaki (AIT), K. Georgakilas (AIT), K. Katrinis (AIT), L. Wosinska (KTH), A. Jirattigalachote (KTH), P. Monti (KTH), “Network Performance Improvement in Survivable WDM Networks considering Physical Layer Constraints”, ICTON 2009, Ponta Delgada, June 2009.

Other information:

Partners: TUW, UPC, AIT, BME, ISCOM, IT, BILKENT, USWAN, NICT

6.2 JA-2 - Monitoring strategies for OBS and OPS networks

Participants: G. Franzl, J.A. Lazaro, Ruth Vilar, R. Llorente, Szilard Zsigmond, G. Tosi-Beleffi, A. Teixeira, Diana Fidalgo, Mário Lima, N. Wada

Responsible person: António Teixeira

Objectives:

The aim of this JA is to collect monitoring techniques to detect physical impairments, and investigate their effectiveness in optical packet switched (OPS) networks.

Moreover, within a sub-WP the recently merged JA5, it is intended to produce a real time fast monitor, to monitor and generate data able to compensate Chromatic Dispersion in packets (based on an eventually available fast tunable compensator).

Description:

Two distinct scenarios are possible:

Monitoring at the router level: The techniques to be implemented must be fast enough to detect physical constraints packet by packet, eventually supported by an all-optical structure.

Monitoring at the management level: For a long-term evaluation of the network impairments, the mitigation techniques used should be route oriented, with a larger time scale.

The individual effectiveness and potential gain from combined consideration could be investigated to outline close-to-optimal strategies given the monitoring options considered available for different scenarios.

Main Outcomes and Results:

– Collection of monitoring techniques from several partners (comparison from e-P/O+), now to be evaluated in context of OPS/OBS;

- Distinguish between routing level (fast signalling) and management level (slow signalling);
- A PMD monitoring technique for AP-RZ multiplexed transmission (UPVLC);
- Acquisition and sharing of any related experimental results;
- 1 Joint experiment IT- UPVLC and 1 Joint paper is expected;
- 1 Booklet.

General Contributions:

- State of the art techniques are being observed, gathered and classified (continuation from e-Photon One + work);
- Two techniques were elected for achieving monitoring of dispersion in packets in this first year;
    - MZI based;
    - SOA pre-processing.
- Implementation of a technique for packet monitoring based on nonlinear optical preprocessing and filtering (simulation and experimental);
- UPC (Josep Prat) implemented a burst monitor in a OBS access optical network which will be, in the second year, assessed in terms of applicability to packet switching environment.

Next Steps:

- Develop low-cost solutions for efficient PMD monitoring as key limitation in high speed OBS/OPS links and different modulation formats (eg. RZ, NRZ, CSRz, RZDPSK and RZDQPSK) (Roberto Llorente and Ruth Vilar- UPVLC);
- Diana Fidalgo (IT) will experimentally implement the packet monitoring based on nonlinear optical preprocessing and filtering technique with Filters provided by Salvador Sales (UPVLC).

Mobility actions:

Predicted 1 (IT-> UPVLC) – Fiber bragg grating fabrication.

Requirements:

Predicted #1

Expected Duration: 2 weeks

Type of work: Practical

Skills/ facilities available: Communication labs (IT/UPVLC)) and FBG fabrication facilities (UPVLC)

If interested, contact:

António Teixeira (teixeira@ua.pt)

Meetings:

ICTON'09 (30th June 2009)

BONE Second Plenary Meeting Poznan (5th October 2009)

Generated WP Papers:

[1] Miroslaw Klinkowski, João Pedro, Davide Careglio, Michal Pióro, João Pires, Paulo Monteiro, Josep Solé-Pareta "An Overview of Routing Methods in Optical Burst Switching Networks", Optical Switching and Networking, 2009.

[2] A. Teixeira, L. Costa, G. Franzl, S. Azodolmolky, I. Tomkos, K. Vlachos, S. Zsigmond, T. Cinkler, G. Tosi-Beleffi, P. Gravey, T. Loukina, J. A. Lazaro, C. Vazquez, J. Montalvo, E. Le Rouzic, "An integrated view on monitoring and compensation for dynamic optical networks: from management to physical layer", Photon Netw Commun, Springer vol.18, pp. 191–210, February 2009.

[3] R. Vilar, J. García, Y. Kim, S. LaRochelle, R. Llorente and F. Ramos, "Path Monitoring for Restoration Functions in Optical Packet-Switched Networks", paper We.B2.6, ICTON, Azores, June 2009. (This paper has been done in collaboration with EURO-FOS).

[4] Roberto Llorente, "PMD Monitoring in Polarization-Multiplexed Transmission Systems by Spectral Polarimetric Analysis", Journal of Lightwave Technology, Vol. 27, No. 16, August 15, 2009.

Relevant papers shared from other WPs or previously published on the topic:

[5] Luis, R., Teixeira, A., Andre, P., Monteiro, P. "Novel distortion resilient OSNR monitoring technique based on evaluation of asynchronous histograms", Microwave and Optical Technology Letters, vol. 48, pp. 1369-1372, 2006.

[6] S. Pachnicke and P. M. Krummrich, "Constraint-Based Routing in Path-Protected Translucent Optical Networks Considering Fiber Nonlinearities and Polarization Mode Dispersion", in APOC2008, 2008.

[7] M. V. Drummond, R. N. Nogueira, P. Monteiro, M. Violas, C. Sterner, and P.-Y. Fonjallaz. "Novel Opto-Electrical Tunable Dispersion Compensator for IM Signals", ECOC, September, 21-23, 2009.

Other information:

Partners: TUW, UPC, UPVLC, BME , ISCOM, IT, NICT

Summary activity results

6.2.1. Packet monitoring based on nonlinear optical preprocessing and filtering

(Former JA5 – Diana Fidalgo; António Teixeira / IT; Salvador Sales / UPVLC)

Main Goals

The intention of this work is to determine the applicability and the related parameters, such as, the packet length, filter bandwidths and detuning of a preprocessing technique which enables the prediction of the packet accumulated dispersion.

The final goal is to conceive a technique which enables real time fast monitor, to monitor and generate inputs to feed an eventual fast tunable compensator.

Setup

The methodology used is firstly perform simulations to optimize the parameters of the system and afterwards try to implement and validate the predicted results.

The configuration used to simulate the methodology is presented bellow. As shown in Fig. 6.2.1.1, the data signal enters the SOA input after propagating through a single-mode fiber (SMF) to induce accumulated dispersion within the range of 60 ps/nm. The semiconductor optical amplifier (SOA) causes a phase modulation of the output signal (self phase modulation), shown in its spectral broadening, designated by red shift. At the output of the SOA, the signal is band-pass filtered to obtain a specific portion of the spectrum. An optimal filter (OBF1) at the output of the SOA is required to choose on the optimum low-frequency and bandwidth for chromatic dispersion monitoring.

A set of simulations were performed in order to optimize the optical filter aiming to improve the quality of the monitoring signal. It was evaluated the impact of the data and pump powers, along with the optimization of optical filters. The required optimal optical filter should be -60 GHz detuned from the data central frequency and have a 20 GHz bandwidth.

The results are obtained for four different data packet length, 0.8, 1.6, 3.2 and 6.4 ns.

After filtering and packing the transmitted data, is combined with a sampling pulse on the MZI-SOA to generate data samples. The data signal frequency is 193 THz and the data and sampling pulses are 150 GHz spaced.

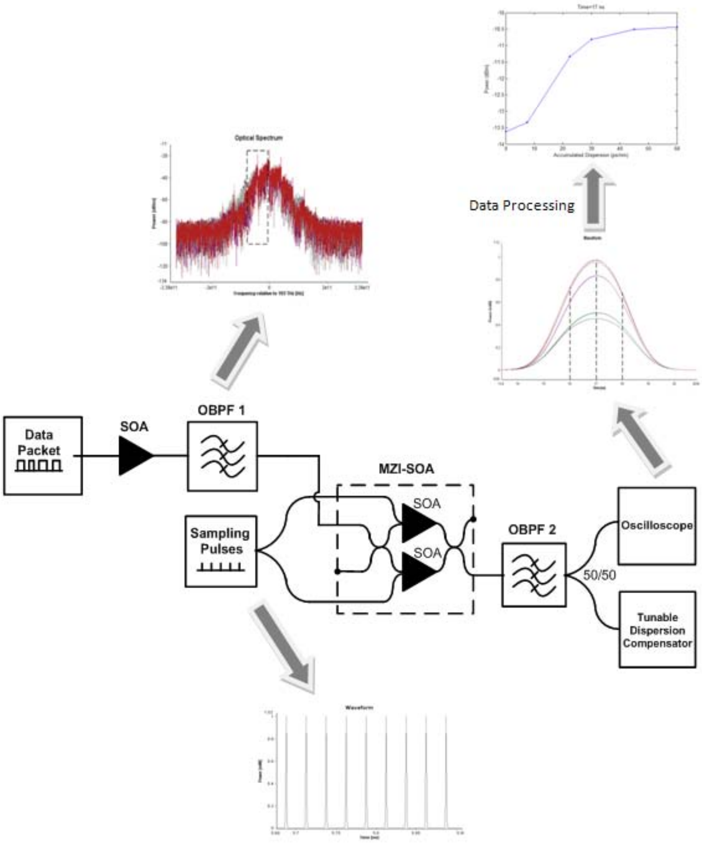

Fig. 6.2.1.1 – Configuration for packet monitoring

The output signal of the MZI-SOA is filtered by an optical filter (OBF2) after being sampled by pulses with central frequency, 194.5 THz. A study was performed to get the optimum bandwidth of this filter (0.3, 2, 5 and 10 GHz). The data samples were analyzed, so that the relation between the output power and the accumulated dispersion on the system is determined.

After the accumulated dispersion is estimated this can be compensated by a tunable dispersion compensator.

The simulation results are obtained by VPI simulator.

Results

– **First Step**

The behavior of system for different OBPF1 bandwidths and detuning was studied and characterized. For this, it was necessary to collect information about the time shapes of the sampled data for different values of accumulated dispersion. For reference some inner samples were used at 15, 16, 17, 18 and 19 ns for six different values of accumulated dispersion (0, 7.5, 22.5, 30, 45 and 60 ps/nm).

Some results obtained are shown bellow.

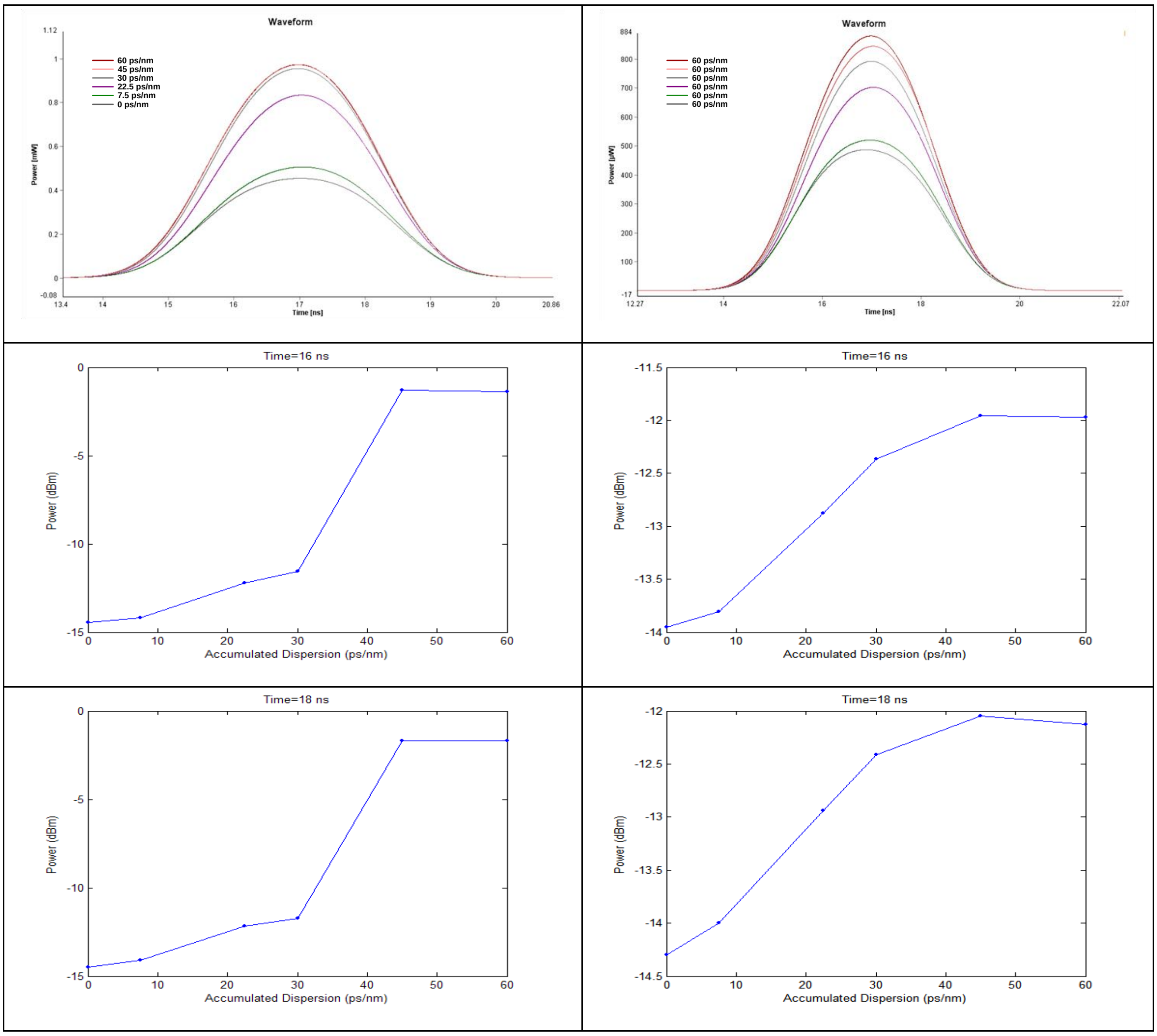

Fig. 6.2.1.2 –Simulation results for 4 packets with 32 bits each, an OBPF1 with 20 GHz bandwidth and -60 GHz detuned (left side) and with 10 GHz bandwidth and -50 GHz detuned (right side) and for an OBPF2 with 0.3 GHz bandwidth

For the two previous examples shown, it can be concluded that the left case (OBPF1 bandwidth =20 GHz, detuning= -60 GHz) presents betters results. For the instants 16 and 18 ns, monitoring is achieved between 0 and 45 ps/nm accumulated dispersion with power range of about 12 dB. For the second case (OBPF1 bandwidth =10 GHz, detuning= -50 GHz), monitoring is achieved for the same range of dispersion (0 and 45 ps/nm) however with smaller power range, about 2 dB. The choice of OBPF1 optimal parameters had a base point, the compromise between the accumulated dispersion and output power ranges.

This methodology was not exhaustively tested since the amount of possible combinations is quite high. For the obtained results, it was concluded that an OBPF1 with ~20 GHz bandwidth and ~ -60 GHz detuning presents better results. Thus, for all different lengths packets and different OBPF2 bandwidths combinations, it was applied an OBPF1 with 20 GHz bandwidth and -60 GHz detuning.

– **Second Step**

Time evolution of the data between 4 and 5.4 ns was gathered, for six different values of accumulated dispersion (0, 7.5, 22.5, 30, 45 and 60 ps/nm), four OBPF2 bandwidths (0.3, 2, 5, 10 GHz) and for four different packets length (0.8, 1.6, 3.2 and 6.4 ns). We took LP as the packet length and LB is the OBPF2 bandwidth of each of the combinations. The results were normalized and try to get any eventual correlation between the curves. Some of the obtained curves are shown in figures below.

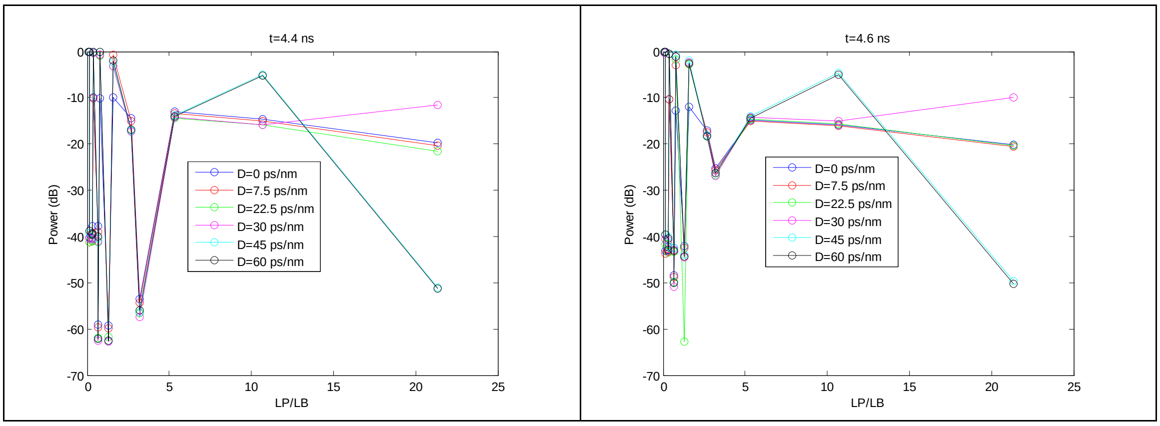

Fig. 6.2.1.3 – Relation between normalized power and LP/LB for different accumulated dispersion values

The obtained results show that, changing the length packets (LP) and changing the OBPF2 bandwidth (LB), the behavior of the curves changes. It is understandable that both for small packets (LP->0) or high bandwidths (LB->high) the variance on the obtained results is high since there is low pass effect. On the other hand, if the packet is too long (LP-> high) or the bandwidth is to small (LB->0), the indication of the measured sample is either not too representative nor enough respectively, therefore the sample will not represent correctly the accumulated dispersion. So, LP/LB, can be considered a good figure of merit for this type of system since it can be used to characterize the system with one single parameter. So, for LP/LB>5 and for accumulated dispersions of 0 to 30 ps/nm one can expect to have good monitoring with this system.

The figure 6.2.1.4, is similar to the obtained previous, but in this case, it is shown the average power for the considered time interval.

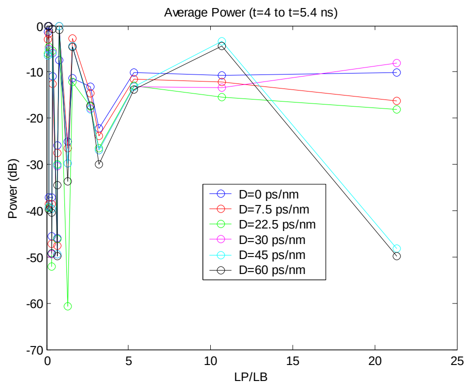

Fig. 6.2.1.4 – Relation between normalized average power and LP/LB for different accumulated dispersion values

The obtained results are similar for average power of the samples in the interval and for instantaneous power certifying the methodology also for the case of monitoring with the average power.

Conclusions

It can be concluded, that can be taken the relation between the length packet and the OBPF2 bandwidth (LP/LB) as a merit figure to choose some parameters of the system in study, such as, packet length, OBPF2 bandwidth and the accumulated dispersion range that offer better results to monitoring Chromatic Dispersion.

The next step will be to test the methodology in the lab. For that the filter is being produced at the UPVLC.

6.2.2. Burst monitor in a OBS access optical network

(Josep Prat / UPC)

Introduction

In an optical network dealing with transmission of optical burst, the different packets travelling through and arriving to the receiver end, present different amplitude, noise accumulation, extinction ratio and, also, can be of different time length. Although there is a time guard and a preamble considered before each new burst data packet, conventional receivers are not suitable for burst mode operation because they cannot instantaneously handle the different arriving packets with large difference in optical power and phase alignment [1] [2].

We are studying and developing a new receiver design introducing the necessary elements to allow burst mode traffic in different kinds of optical network, like access and OBS.

Receiver Description

The Receiver design is composed by different parts, showed in Fig. 6.2.2.1. The optical signal is detected with a photodetector that can be a PIN+TIA, this kind of receivers use to be AC coupled, they also can be DC coupled but then they require high impedance at the output. In the first case the DC and the low frequency components can be obtained through the photodiode voltage feed pad. In the second, the output signal can be divided into two paths, one with high impedance and operational amplifiers and the other with a DC block plus RF amplifiers. After these stages of amplification, the signal has to be combined adjusting the cut frequency and amplitude of both contributions. The next step is to apply the mathematical square root function (SQRT) [4] which will allow us to partially compensate the square law characteristic of the photodiode, make the eye diagram more symmetrical and also compress the signal of the packets with high optical power. After the SQRT block, the requirements of amplitude adjustment are relaxed for the following elements. The signal the passes through different circuits: the burst enable (BE) to determine the end of a packet after more than 72 zeros, the threshold detector and a delay line, to adapt the signal plus the threshold level time and introduce both in a limiter amplifier. The receiver has been designed with ADS and the layout implemented with FR4 material.

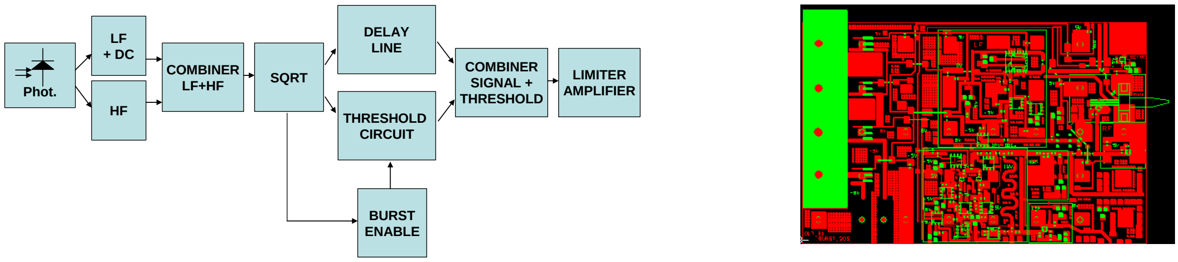

Fig. 6.2.2.1 – a) Receiver functional block diagram, b) Layout

Burst Enable

The circuit shown in Fig. 6.2.2.2 has been designed to implement the burst enable signal. When more than 72 consecutive zeros arrive to the detector, the output is set to zero and it means that the packet has finished. In order to test it, the following signal has been introduced as a pattern data:

"110011001100110011001100110011001100110011001100110011001100110011001100110011001100110011001100
11001100110011001100101010000000000000000000000010010100110000000000000000000000000000000000001110
10101110000101011110000000111001101001001010000000000000000000000000000000000000000000000000000000
01110111010101100001111100110100000000000000000000000000000000000000000000000000000000000000000000
00000000000000110011001100110011001100110011001100110011001100110011001100110011001100110011001100110011
00110011001100110011001100110011001010101011101010111000010101111000000011100110100100101000000000000000000000000
000000000000000000000000000000000001110111010000000000000000000000000000000000000000000000000000001110011010010010101000
00000000000000000000000000000000000000000000000000000000000000000000000000000000000000000000000000
000000000000000000000000000000000000000000000000000000000000000000"

The 66 bits with the pattern “00110011…” constitute a preamble of 20 ns. The packets in the simulation are very short (around 200 ns) for simplicity reasons and for testing the worst cases.

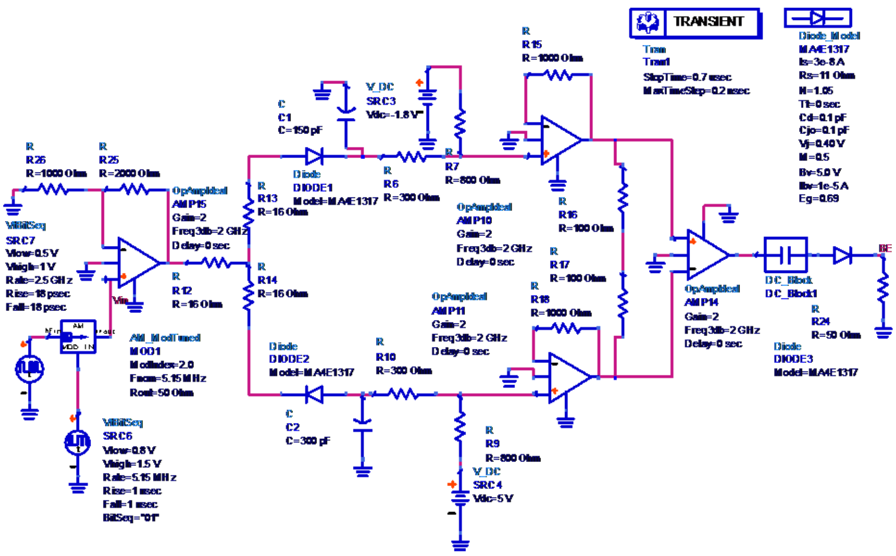

Fig. 6.2.2.2 – BE circuit ADS simulation schematic

To create different packets with variable ER and amplitude with the ADS simulator, an amplitude modulator uses the bit sequence of the pattern data at 2.5 Gbps and modulates it at 5.15 Mhz (according to the size of the packet) with the pattern “01”. Fig. 6.2.2.3 presents the results for different situations. The voltage sources SRC4 and SCR3 of Fig. 6.2.2.2 have to be slightly modified when the zero level is constant for packets of different amplitude. We are currently optimizing this effect.

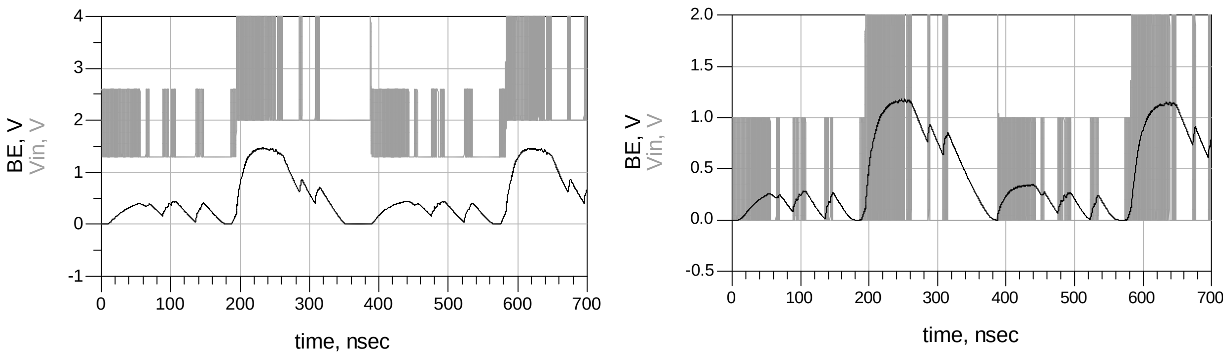

Fig. 6.2.2.3 – Input data and burst enable output for different packets

The current implementation of this subsystem, and its optimization from this analysis, has to demonstrate, in the next period, the practical feasibility of fast burst detection and monitoring in OBS and access PON, in a diversity of network conditions.

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6.3 JA-3 - Decision mechanisms for packet transit in OPS networks

Participants: G. Franzl, J.A. Lazaro, Szilard Zsigmond, G. Tosi-Beleffi, A. Teixeira, K. Ennser

Responsible person: António Teixeira

Objectives:

The aim of this JA is to collect actions to be implemented on the reception of optical packets, prior routing to an out-port, depending on the information supplied by the monitoring system. Operations like re-routing, signaling, blocking and discard of packet are among the objectives of study.

Moreover, special fields of the communication protocol, dedicated for the control of packet routing, potentially controllable at the physical layer (e.g. TTL in the IP protocol), shall be considered and their usage studied.

Main Outcomes and Results:

- 1 Joint experiment;
- 1 Joint paper;
- 1 Booklet.

General Contributions:

- Recently started M18;
- Mobility to NICT on ultrafast switching/wavelength conversion;
  - First steps are already ongoing on assembling all-optical logical functions (within other projects e.g. EURO-FOS).
    [1] Flip Flop / counter / label holder.
- BME (Szilard Zsigmond) investigated the performance of NRZ-OOK, NRZ-DPSK, NRZ-DQPSK, NRZ-8PSK and NRZ-16-QAM modulation and their influence to 400Gbit/s/port optical packet switched systems (OPS) performance;
- UPC (Jose A. Lazaro) investigated a technique based in pre-distorting the packet at the ONU, in order to pre-compensate the gain overshoots that will occur in the EDF based amplification stages of the network;
- UPC (Josep Segarra, Josep Prat) investigated OBS in hybrid metro-access network with fast tuneable lasers with limited tuneability.

Next Steps:

- Continuing the present activity

Mobility actions:

1. Drummond and Jacklyn went in Japan between 20th of April to 22nd of June to experimental test “All-optical tunable wavelength conversion of a 160 Gb/s RZ OTDM signal using a PPLN waveguide at room temperature operation”.

2. Szilard Zsigmond (BME) have been at NICT for one year to study the cascadeability of OPS node for different modulation formats and their impact on an OPS network environment;

Mobility action #1

Duration: 2 Months

Type of work: Practical

Skills/ facilities available: Communication labs (IT/NICT)) and PPLN (NICT)

Mobility action #2

Duration: 1 year

Type of work: Practical

Skills/ facilities available: Communication labs (IT/NICT)

Predicted 1: (BME -> NICT) - All-optical 3R and processing for photonic networks;

Predicted 2 (UNIROMA2/ISCOM->IT) – All optical switching technology.

Requirements:

Predicted #1

Expected Duration: 9 months

Type of work: Practical

Skills/ facilities available: Communication lab (NICT)

Predicted #2

Expected Duration: 4 months

Type of work: Practical

Skills/ facilities available: Communication lab (IT)

If interested, contact:

António Teixeira (teixeira@ua.pt)

Meetings:

ICTON’09 (30th June 2009)

BONE Second Plenary Meeting Poznan (5th October 2009)

Generated WP Papers:

[1] I. Papagiannakis, D. Klonidis, V. Curri, P. Poggiolini, G. Bosco, R.I. Killey, M. Omella, J.Prat, D. Fonseca, A. Teixeira, A. Cartaxo, R. Freund, E. Grivas, A. Bogris, A.N. Birbas, and I. Tomkos., "Electronic Distortion Compensation in the Mitigation of Optical Transmission Impairments: The view of JP-E ePhoton/ONe+ project", IET of Optoelectronics, 2009.

[2] M. V. Drummond, J. D. Reis, R. N. Nogueira, P. P. Monteiro, A. L. Teixeira, S. Shinada, N. Wada and H. Ito, "Wavelength Conversion of a 160 Gb/s RZ OTDM Signal in a PPLN Waveguide at Room Temperature", International Conference on Photonics in Switching, September 15-19, 2009.

[3] Sz. Zsigmond, H. Furukawa, N. Wada,"Investigation of Spectral Efficient Modulation Formats for 400Gbit/s/port Optical Packet Switched System" OFC 2010.

Relevant papers shared from other WPs or previously published on the topic:

[4] A. Teixeira, P. Andre, R. Nogueira, P. Monteiro, J. da Rocha, "All-optical routing limitations due to semiconductor optical amplifiers dynamics", Lecture Notes in Computer Science, 3124:766-771, 2004.

[5] S. Pachnicke, T. Paschenda, and P. M. Krummrich, "Physical impairment based regenerator placement and routing in translucent optical networks", 2008 Conference on Optical Fiber Communication/National Fiber Optic Engineers Conference, Vols 1-8, pp. 2535-2537 3037, 2008.

Other information:

Partners: TUW, UPC, BME, ISCOM, IT, USWAN

Summary activity results

6.3.1. Investigation of Spectral Efficient Modulation Formats for 400Gbit/s/port Optical Packet Switched System

(Szilard Zsigmond / BME)

Introduction

Optical packet switching (OPS) is considered as a near future technology for optical networks [1-3]; however there are several open issues such as the spectral efficiency of these systems.

It was investigated by extensive simulations the performance of NRZ-OOK, NRZ-DPSK, NRZ-DQPSK, NRZ-8PSK and NRZ-16-quadrature amplitude modulation (NRZ-16-QAM) and their influence on the system overall performance. In this simulation, we assumed SOA switches instead of PLZT switches, to improve the system performance. The aim was to demonstrate that OPS systems can be spectrally efficient and handle high level modulation formats.

Experimental Setup

The OPS prototype setup was presented in [6]. The DWDM/OOK optical packets consist of multiple 10 Gbit/s NRZ-OOK optical payloads of different N-wavelength and a PSK optical label. The basic setup can be seen in Fig. 6.3.1.1. Polarization-controllers were set in front of all modulators and switches. In the optical packet transmitter, 64 arrayed distributed feedback lasers with 50 GHz spacing were used as payload light sources. The continuous waves of 32 odd channels and 32 even channels were fed into arrayed waveguide grating, and collectively modulated by LiNbO3 intensity modulator. In case of [7]-[8] where DPSK and DQPSK modulation was published for the payload generation two modulators were used. The first one is an intensity, which makes the packet envelope and generates a 12.96 Mpackets/s packet pattern. The second modulator is a phase modulator, which superimpose 10 Gbit/s NRZ-DPSK or 20/Gbit/s NRZ-DQPSK data of PN: 29-1 and PN:27-1 according to the packet pattern for odd and even channels, respectively. A 10 GHz mode-locked laser diode (MLLD) with a pulse width of 2.0 ps and a center wavelength of 1530.0 nm was used as a label light source. The 10 GHz optical pulse train was modulated according to the packet pattern with LN-IM 3. The pulses were input into a 200 Gchip/s multiple optical encoder with an AWG configuration [12], and different PSK optical codes were generated as labels “A” and “B” from two output ports. The labels “A” and “B” were shifted and combined. By coupling labels and 10 Gbit/s payloads of 32 even and 32 odd channels, 640 Gbit DWDM/NRZ optical packets were generated. A Label was copied and attached before and behind payloads. The duration of one packet is fixed at 77.1 ns. The OPS system consists of optical label processors using multiple optical decoders [12], plomb lanthanum zirconate titanate (PLZT) optical switches, optical fiber-delay-line (FDL) buffers, and an electrical buffer manager. Generated packets were copied and fed into input port 1 and 2 of OPS system. The multiple optical decoder was set to recognize only label “A”. In matched cases of labels “A”, the switch controller output gate signals to open and close 1 x 2 PLZT switch. The buffer manager received packet arrival information and controlled 1 x 8 PLZT switches in buffers to avoid packet collisions. An optical buffer consists of a 1 x 8 PLZT switch, 3 FDLs and one drop line. The 1 x 8 switch was used as a 1 x 4 switch with a gate switch to improve the extinction ratio. The length of 3 FDLs is 0, 16, and 32 m, respectively. The maximum buffer size is 2 packets. In the optical packet receiver, 64 channels were demultiplexed by AWG. Depending from the modulation formats different receivers were used. In [6] a direct detection with burst mode receiver, in [7]-[8] balance receivers were used. The clock and data of a payload was recovered by an optical packet receiver (PR) and its BER was measured by an error-detector (ED).

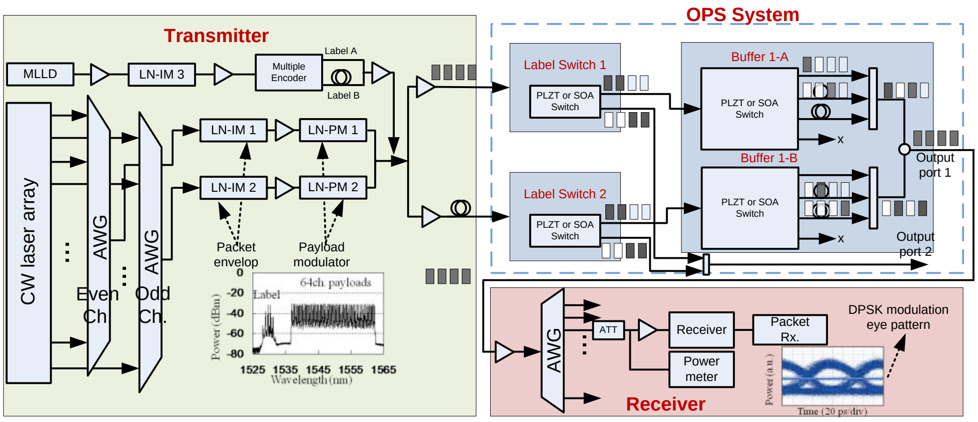

Fig. 6.3.1.1 – Schematic of the OPS node

Simulation Setup

The basic setup is the same as the experiment setup presented in Fig. 6.3.1.1. The aim of the investigation was the payload therefore we do not consider the label distortion. Firstly, we measured the key parameters of the experimental system for use as simulation inputs. These were the wavelength and power dependence of the EDFA gain and noise figure, the wavelength dependency of the crosstalk and insertion loss of the switch and receiver parameters. All the simulations were carried out using VPI Transmission Maker simulation tool [13]. Due to time and memory constraint instead of 25 packets used in the real experiment, the simulations used only 4 packets. For realistic results the same switch ports and buffering scheme were used as in real experiment as shown in Fig. 6.3.1.1. To validate the results we compared the obtained spectra, eye diagrams and BER curves in case of NRZ-OOK, NRZ-DPSK, and NRZ-DQPSK modulation where we had experimental results also, and found a very good match between the simulation and experiment results. Less than 1 dB power penalty difference was obtained between the simulation and experiment in any cases [14].

To further improve the performance of the OPS node we have decided to investigate the performance of the node by replacing the PLZT switches with a new SOA-based switch developed recently by Fujitsu Limited Company [10]. The PLZT switches have an insertion loss of 12-18 dB and crosstalk of 18-60 dB depending from the polarization and wavelength, contrarily the SOA switches has 6 dB insertion losses and 40 dB crosstalk and less than 1 dB wavelength dependency. The switch setup was designed for 40 channel/100 GHz channel spacing, thus we had to modify the OPS node. Also the preliminary data of the switch characteristic, which served as input for the simulations, were given for this scenario. Instead of using 64 channels/50 GHz spacing in the following simulation results, we used 40 channel/100GHz spacing. As to conclude the differences between the simulation and experimental setup were the number of channel and the spacing, the neglected label distortion, the reduced number of packets and the replaced switch. In case of NRZ-8PSK and NRZ-16-QAM modulation, coherent homodyne receivers were used with a local oscillator linewidth of 150GHz. For modulation a pair of single drive modulator was used. The nonlinearity of the Mach-Zender modulator was taken into account and compensated by modifying the driving signal. The channel symbol rate is 10 GHz which leads to different bitrates, depending from the modulation formats. In case of NRZ-OOK the total throughput of the OPS node is 400 ($40\lambda \times 10$) Gbit/s, however in case of NRZ-16-QAM modulation this modifies to 1600 ($40\lambda \times 4\times 10$) Gbit/s.

Results

Fig. 6.3.1.2 (a) shows the obtained BER curves for different modulation formats. Each set of curves contains the obtained results for different channels. As it is to be seen error free (10-9) operation was obtained for each channel for every modulation formats. As it was expected NRZ-DPSK performs the best, than NRZ-OOK, than NRZ-DQPSK, than NRZ-8PSK, and NRZ-16-QAM is the worst. The power penalty between the best and worst performing formats is around 12-18 dBm. As the result indicates there is a significant channel quality difference. This is due to the spectral tilt at the receiver point, see Fig. 6.3.1.2 (c), originated from the burst mode EDFAs and SOA switches. Fig. 6.3.1.2 (b) plots the constellation diagrams for NRZ-8-PSK and NRZ-16-QAM signals. Also, small discrepancies can be found in the results of the BER curves in case of NRZ-8-PSK and NRZ-16-QAM. This is due to the limited memory of the simulation computer, which leads for a limited number of bits at the BER measurements. Despite of this inconsistency the BER curves clearly shows error free operation for all the wavelengths and modulation formats.

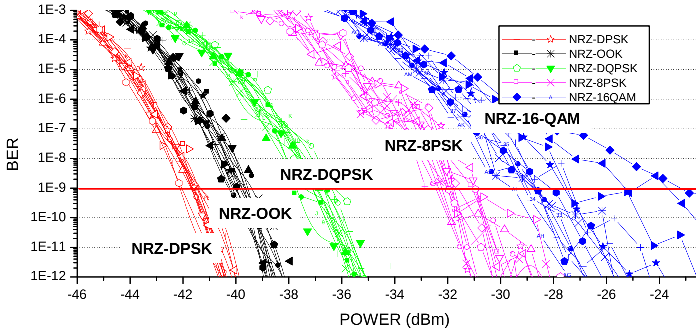

Fig. 6.3.1.2 (a) - Obtained BER curves for different modulation formats

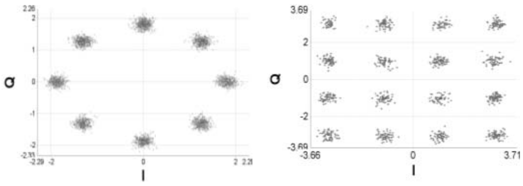

Fig. 6.3.1.2 (b) - Constellation diagram of the received NRZ-8-PSK and NRZ-16-QAM signals

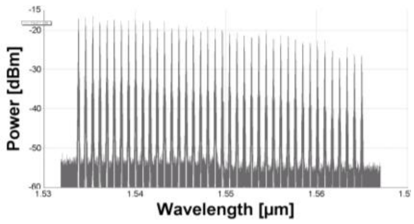

Fig. 6.3.1.2 (c) - Optical spectra before the receiver

Conclusions

In this work we compare different modulation formats and their performance on a 400 Gbit/s/port OPS system. We show by extensive simulations that all the modulation formats: NRZ-OOK, NRZ-DPSK, NRZ-DQPSK, NRZ-8PSK and NRZ-16-QAM achieve error free operation for all wavelengths. As conclusion, it was shown than spectral efficiency can be fulfilled in optical packet switched systems as well.

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6.3.2. Packet Carving

(Jose Lazaro/UPC)

Introduction

When dealing with Erbium Doped Fibre Amplifiers in burst mode, packet overshoot and transients must be considered since they can degrade in a significant way the overall performance of the network.

Gain variations of the EDFs are due to changes in the population inversion of the EDF, driving to a gain overshoots in the packets. Different techniques have been considered to mitigate this undesired effect, such as Automatic Gain Control [1] and all-Optical Automatic Gain Control [2]. These techniques require and active laser or a stabilizing lasing loop in the Remote Nodes (RN) of the network in order to balance the EDF performance as a function of the network load.

We present a technique based in pre-distorting the packet at the ONU, in order to pre-compensate the gain overshoots that will occur in the EDF based amplification stages of the network [3].

Packet-Carving technique

For carrying out an experimental verification of the proposed technique, and Reflective Semiconductor Optical Amplifier (RSOA) based ONU is used. A first order low pass was used as distorting element at the burst enable signal of the RSOA, for generating the desired slope for the pre-distorted packet. A scheme of the experimental set-up and the packet carving circuitry can be seen in Fig. 6.3.2.1.

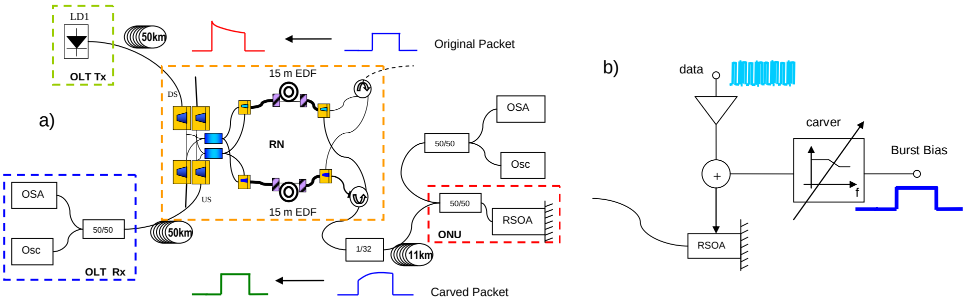

Fig. 6.3.2.1 – a) Experimental set-up, b) Packet carving circuitry.

Since the overshoot amplitude will depend on the input power of the packet at the amplifier stage, means of signalling and monitoring must be considered for and optimal performance of the proposed technique.

By monitoring the packet envelope at the receiver fine adjustment of the pre-distortion can be done, for a better equalization of the received packet. In this case higher layers should provide some signalling to the ONU in order to adapt the pre-distortion value as a function of the received packet envelope. Fig. 6.3.2.2 shows the pre-distorted packet envelope and the received packet envelope at the OLT.

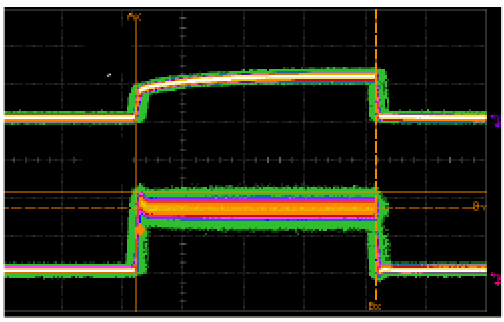

Fig. 6.3.2.2 – a) Carved packet at ONU output, b) Received packet at the OLT

The following figure shows the optimal packet carving pre-distortion for the case of a two stages amplifier, with 8 and 10 m of HE980 EDF, pumped with 28 dBm at 1480nm each one. Signal power varies from -18 dBm to -8 dBm.

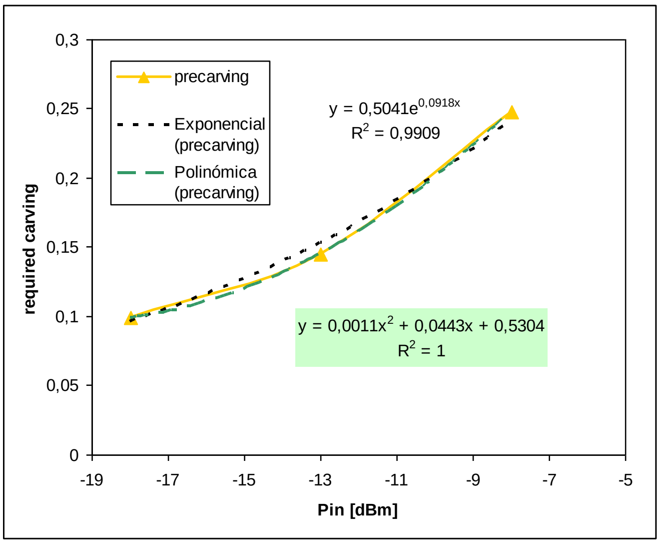

Fig. 6.3.2.3 – Fitted function for 2 stages amplifier with 28 dBm of pump power

As can be seen, a polynomial function fits perfectly with the experimental values, showing the function to be implemented in the carving module. For this specific case, the pre-carving function is $f = 0.001x^2+0.0443x+0.5304$, determined by the experimentally measured overshoot for the dual stage amplifier.

The network should include this equalization module in order to pre-distort or not the data as a function of the number and the load of the amplifiers until the Rx Node.

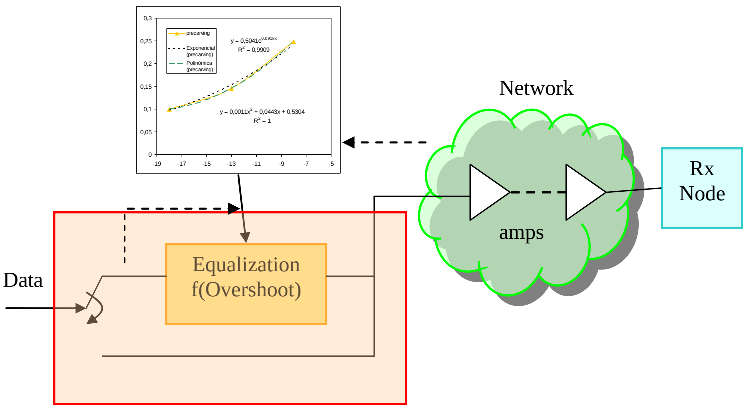

Fig. 6.3.2.4 – Network scheme. Including this Equalization module that can be bypassed if no packed carving is required

By using the proposed technique and by monitoring the received packet envelope, and adaptative packet pre-distortion can be carried out, as a function of the number of amplification stages (0, 1, 2…) and the load of this stages that the packet crosses (determined by the input power and the pump power), with the aim to enhance the performance of the network using erbium doped fibre amplifiers in burst mode operation.

More experimental results, in terms of packet overshoot reduction and OSNR measurement

s of the proposed technique can also be seen in a more detailed way in WP15.

References

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6.3.3. OBS in hybrid metro-access network with fast tuneable lasers with limited tuneability

(Josep Segarra; Josep Prat / UPC)

Introduction

The OBS Dynamic Bandwidth Allocation can be applied to a metro-access ring-trees network, and TLDs can be shared by several dedicated tree PONs (tPONs) [1]. The same design applies for upstream, substituting tunable laser diodes TLDs by tunable photodetectors (PDs). Dividing the whole optical band of L wavelengths/tPONs in R optical band regions, TLDs just need tuneability in the assigned band region, which is a more relaxed technological condition, since TLD have practical difficulties in reaching the optical full band. With S the number of wavelengths/tPONs in a region, the number of bands is R = L / S. An OS selects the side of the ring to which the TLD will transmit. The number of TLDs T to be used in a band depends on the traffic conditions. The TLDs are gathered in a single output band and the bands are multiplexed in a unique output with a Coarse Multiplexer (CMUX), as shown in Fig. 6.3.3.1.

SARDANA OLT design approaches

The tPON layout is based on a tree topology using a 1 x K splitter, with a dedicated wavelength for each tPON. Each RN can manage two tPONs. Thus, the total number of reached users with N RNs and a split ratio in the tree of K is U = N x 2K (e.g. 320 = 5 x 2 x 32). The SARDANA network can attain up to 16 RNs and its maximum split ratio is K = 32, therefore a maximum of 1024 users can be achieved with M = 2N = 32 tPONs. Hence, a maximum of 32 wavelengths are to be managed by the OLT. We will consider the double-fiber ring SARDANA architecture in order to ease RB impairments. If a single-fiber ring is utilized, just a circulator is needed at the OLT to separate the transmission part from the reception part, one for east side and another for west side of the ring.

The simplest OLT architecture for transmission is to have a Fixed LD (FLD), e.g. a Distributed Feedback (DFB) LD, dedicated to each wavelength/tPON, a total of M FLDs [1]. The M FLDs are connected to the east side or to the west side of the ring by employing Optical Switches (OSs). The FLDs signals after the OSs are all multiplexed in a unique output with an M x 1 AWG, one for each side of the ring. The RNs are bidirectional and then the same up wavelengths are up transmitted for both east and west sides.

The same transmission structure can be used in the reception part. The receiver east and west sides of the ring are demultiplexed in each one of the up-wavelengths by the AWG, and afterwards an OS selects which of the two sides is chosen to attain the best signal at the receiver PD.

In this simple OLT transmission structure we need as many LDs as tPONs and wavelengths, then the LDs are only shared by the users of a tPON. To protect the network from LD failure, we require duplicating the LDs.

In the reception scenario we require as many PDs as wavelengths, but the PD is a cheap component and this structure avoiding tunable filters is resourceful even if the PDs are duplicated to protect from fail PD device.

In order to share optical transmission resources achieving a better traffic efficiency, we can use tunable LDs (TLDs) shared by several tPONs [1]; the TLDs also protect the network from LD failure (Fig. 6.3.3.1). We divide the optical band in R optical regions; in that way the TLDs do not need to have full tuneability in the whole band, but only tuneability in the assigned sub-band region, which is a relaxed technological condition. Being L the number of wavelengths and tPONs in a region, the number of regions is R = M / L. An OS selects the side of the ring to which the TLD will transmit, one OS for each TLD. The number of TLDs T to be used in a region depends on the traffic conditions. The TLDs are gathered in a single output by a combiner, one for each region; finally the combiners are multiplexed in a unique output with a Coarse Multiplexer (CMUX), which multiplexes the R sub-bands, as shown in Fig. 6.3.3.2.

A typical number of wavelengths/tPONs per region may be L = 8 and, with a total of M = 32 tPONs and wavelengths, the number of optical regions is 4. The number of TLDs per region T may be from 1 to 8, depending on the traffic needs. With a channel separation of 0.8 nm, the tunable range of the TLD for 8 wavelengths is only 5.6 nm, which is a very relaxed technological condition and a commercially available option. Two channels can be wasted as a guard band in the CMUX; therefore, the total used band is 29.6 nm, which can be allocated in the C or L optical bands as illustrated in Fig. 6.3.3.2.

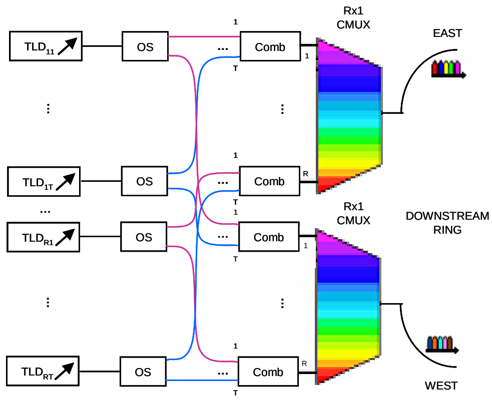


Fig.6.3.3.1 – SARDANA OLT transmission part design with TLDs shared by several tPONs and laser tuneability distributed in optical sub-band regions

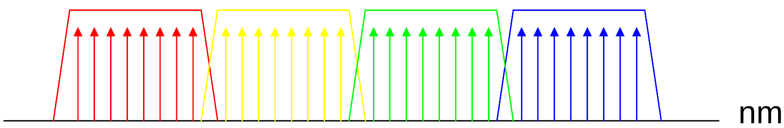


Fig.6.3.3.2 – Proposed SARDANA wavelength plan and CMUX wavelength allocation in 4 optical regions with TLDs shared by 8 wavelengths/tPONs per optical region

In all of the OLT designs OSs are required to choose the working side of the ring. The OSs select the side of the ring which provides the best transmitted and received signal; therefore, in the simple OLT structure, the OSs only operate to protect in case of fiber cut. In this case a switching speed lower than 10 ms is enough; this can be achieved with the use of low-priced Micro-electromechanical System (MEMS) switches, which are based on small mirrors coated with electrical material such that applying an external electrical field the mirror is shifted aside [2], [3].

In the OLT design with optical sub-band regions scenario, using low speed OSs requires a complete optical sub-band to be transmitted in the same side of the ring. But, different wavelengths/tPONs positioned in the same optical sub-band may have different optimal transmission side of the ring; hence, they are to be transmitted in different sides of the ring. Then, to share the same TLD for working in both sides of the ring, the OSs must be able to switch at optical burst level.

For high speed there are 1 x 2 and 1 x S electro-optical switches; the oldest solution is based on Lithium Niobate (LiNbO3) (LN) [4], a ferro-electric crystal having nonlinear and piezoelectric properties operating at a switching time less than 10 ns; however its major limitations are driving voltage versus device length, polarization dependence and DC drift. A more recent version of OS is based on a new waveguide material, Lead Lanthanum Zirconium Titanate (Pb,La)(Zr,Ti)O3 (PLZT) [5], providing dense integration, miniaturization, low power dissipation and higher electro-optical coefficient than LN. The PLZT switches show low voltage drive and less than 10 ns response characteristics.

Summary of the Hybrid WDM/TDM PON architectures

Several Hybrid WDM/TDM PON architectures described and proposed in this chapter have full accessibility to the optical resources at the OLT and full-duplex (FD) operation, namely: 1) Hybrid WDM/TDM PON with tunable filters at CO and R-ONUs, 2) Hybrid WDM/TDM PON with tunable filters at CO and Light Source at ONUs, 3) OXC architecture, which provides scalability. They are based on thermal AWGs in outside plant, furnishing a secure transmission.

The architectures with WDM ring and RNs may have or have not full accessibility to the optical resources at the CO, depending on how its LDs/PDs are connected to the ring. The ring architecture provides resilient protection and easy scalability by adding new RNs in the ring, but when the final access is based on splitters, they are not secure and need encryption. Similar number of users is achieved with the OXC architecture and ring architectures although much longer distances are achieved in the SARDANA network for the sake of the remote pumped optical amplification. Nevertheless, all these full optical access architectures based on RNs and rings, with FD operation, may apply the DBA protocol.

Applying the OBS DBA protocol to a ring-tree metro-access network

The proposed OBS DBA protocol can also be applied to the metro-access network architecture. The LDs at the OLT serve both downstream and upstream transmission in an Intensity modulation (IM) format and a Half–Duplex (HD) operation. Nevertheless, a Full-Duplex (FD) manner in the same wavelength can also be accomplished combining ASK-ASK, FSK-ASK and SCM-SCM formats for downstream-upstream transmission, respectively [6].

Simulations for equal distance OLT-ONUs, one LD server and SP rule have been executed, neglecting the control polling signaling. This case matches the simple OLT structure or the structure with only one TLD per optical region (Fig. 6.3.3.1 and Fig. 6.3.3.2). Again the aggregation time edge is set to 20 ms for all CoS and the bit rate gain ratio is A = 100, providing a mean time of service tWHT = 0.2 ms, equal for each CoS. In this network, the optical rate for downstream is 10 Gb/s and for upstream is 2.5 Gb/s. A rate gain A = 100 guarantees a mean data source VBR bin of 100 Mb/s and 25 Mb/s for down and up transmission, respectively.

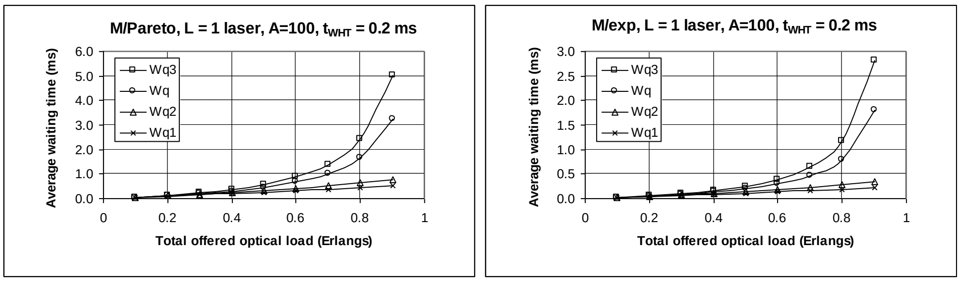
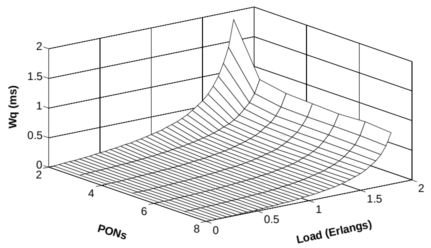


Fig. 6.3.3.3 – Total average waiting time Wq and Wqi for each CoS, with only one LD server and SP queuing with 3 CoS. On the left under SRD traffic, on the right under LRD traffic

These results are the same that the ones obtained in the former simulations. The results under LRD traffic (Fig. 6.3.3.3) show that the average waiting times for the first and second CoS to be served are very low; for a high load of Ad = 0.8 erlangs, which corresponds to 80 active users, they are inferior to 0.6 ms, while for the best-effort CoS the average waiting time reaches up to 2.4 ms and the total Wq is 1.7 ms.

We consider now two TLDs servers in an optical region of several tPONs, equal distance OLT-ONUs and without PQ. The DBA module must take into account in which tPON each ONU is situated, because every tPON has its own wavelength and while an ONU is served in a tPON, no other ONU in the same tPON can be served simultaneously; therefore, a new ONU in queue to be served must wait the wavelength/tPON to be free, even though the second TLD is free. The ONUs are supposed to belong to the tPONs in a uniform distribution. Simulations results without PQ show the dependence of the waiting time with respect to the number of tPONs involved: the lower is the number of tPONs the greater is the waiting time, for the same total number of users. But this effect is only considerable for a very low number of tPONs, especially for two tPONs, and at high traffic load, and even in this case the average delays Wq are acceptable, as depicted in Figs. 6.3.3.4 and 6.3.3.5:



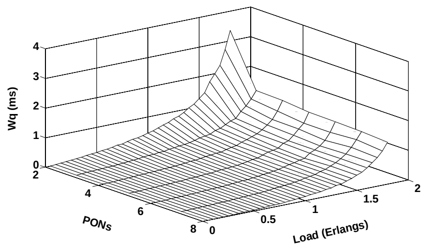
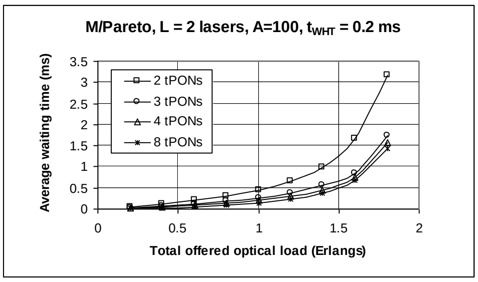


Fig. 6.3.3.4 – Average waiting time Wq with 2 TLDs for downstream and upstream, without PQ and different number of tPONs. On the left under SRD traffic, on the right under LRD traffic



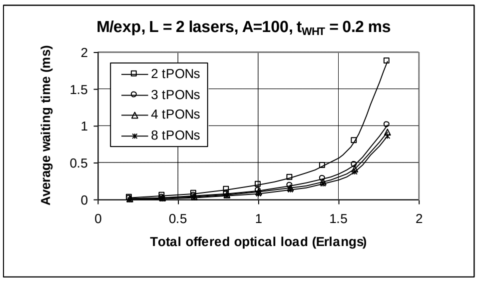


Fig. 6.3.3.5 – Average waiting time Wq with 2 TLDs for different number of tPONs; on the left under SRD traffic, on the right under LRD traffic.

PQ with Strict Priority is also considered in the simulations with two TLDs servers in an optical region of several tPONs. Higher CoS bursts are served before lower CoS bursts, but the wavelength/tPON to be free is in addition taken into account. The performance under LRD traffic for 8 tPONs exhibits for first and second CoS delays inferior to 0.3 ms for 1.8 erlangs (Fig. 6.3.3.6), which correspond to 180 active users. But with only 2 served tPONs these delays increase up to 2 ms because of the blocking tPON effect.

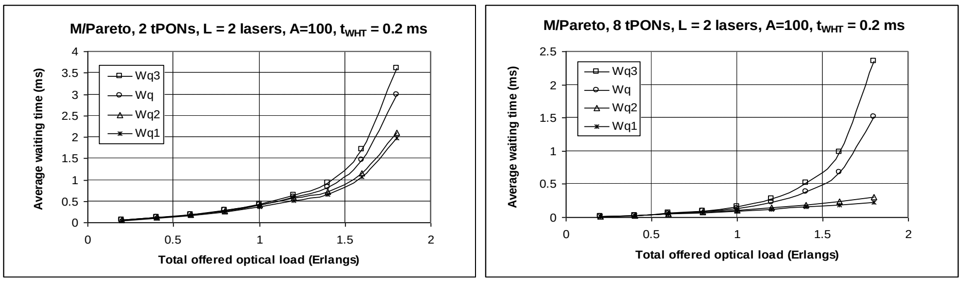


Fig. 6.3.3.6 – Total average waiting time Wq and Wqi for each CoS with 2 TLDs, Strict Priority queuing discipline and under LRD traffic; on the left for 8 tPONs, on the right for 2 tPONs.

Broadband and random services with QoS are supported featuring OBS with a proposed DBA protocol centralized at the OLT, where all the costly equipment is located. In the downstream direction, the OLT knows instantly the traffic needs, handling the aggregation buffers for each ONU, and has the full bandwidth to down transmit data bursts to the ONUs whenever it wants. To manage the upstream traffic, the ONUs are cyclically polled to know their traffic needs, and the OLT gets a global knowledge of the up traffic requirements at the ONUs every cycle. The OBS DBA module has been adapted to the limited tuneability of wavelength routing devices.

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6.4 JA-4 - Techno-economic study of monitoring techniques in OPS networks

Participants: J.A. Lazaro, I. Tomkos, Szilard Zsigmond, G. Tosi-Beleffi, A. Teixeira, K. Ennser

Responsible person: Giorgio MariaTosi-Beleffi

Objectives:

The aim of this JA is carrying out OPS network studies in different scenarios, depending on the monitoring level (flow, packet combined) and ICBR techniques to be integrated in the short/long term.

Where monitoring on flow level is assumed to be performed at optical signal destinations determining the end-to-end signal degradation along an entire route (path), and monitoring on packet level at every node, realizing the common hop-by-hop scheme of today's digital networks.

Monitoring flows end-to-end is assumed least costly as at destinations optical signals are assumed to be converted to electrical domain anyhow and therefore techniques requiring O/E conversion do not require additional O/E converters. Monitoring packets individually at every node (per hop) is assumed the most equipment intensive approach. The decision complexity opposes that; i.e., end-to-end information on signal degradation first needs to be correlated in order to identify the responsible source and thereby the actions required to solve a problem.

The economic impact of monitoring devices shall be compared to the economic impact of imperfectly delivered optical signals using extreme examples, a private customer (IP-TV) and a security/health relevant application (remote control of a power distribution network).

Main Outcomes and Results:

- Industry interest in monitoring for OPS;
- 1 Booklet.

General Contributions:

- Outcomes from the "MARS" session in ICTON 09 were collected, and interests from the industry were attracted;
- Planning of the next ICTON MARS session focused on techno economic studies;
- Contact established with NICT - National Institute of Communications and Information Technologies (Tokyo, Japan) in order to set up a joint cooperation on the themes of this JA.

Next Steps:

- Mobility plans depending on the interested partners (end of 2009 – beginning of 2010);
- Worksop organization;
- Data collection in order to set a general draft on the related subject.

Mobility actions:

Planed mobility actions: to be estimated (depending on interested partners).

Requirements:

Expected Duration: 2 hours.

Type of work: workshop or special session integrated on a conference, where a panel of experts could gather around the subject.

If interested, contact:

Giorgio Tosi-Belleffi (giorgio.tosibeleffi@sviluppoeconomico.gov.it)

Meetings:

ICTON'09 (30th June 2009)

BONE Second Plenary Meeting Poznan (5th October 2009)

Generated WP Papers:

[1] None to the moment

Other information:
Partners: UPC, AIT, BME, ISCOM, IT, USWAN

6.5 JA-5 - Packet monitoring based on nonlinear optical preprocessing and filtering

This joint activity was incorporated in JA2

6.6 JA-6 - Impact of physical layer impairments on control plane schemes and proposals for optical circuit and packet switched networks

Participants: CTTC (R. Muñoz, R. Casellas, R. Martinez), UPC (J. Sole-Pareta, S. Spadaro, J. Perello, D. Careglio), UPCT (P. Pavon Marin, M.B. García Manrubia), AIT (I. Tomkos, D. Klonidis, S. Azodolmolky)

JA leader: Salvatore Spadaro

Objectives:

The main objective of this joint activity is to investigate the impact of physical layer impairments on control plane schemes for transparent/translucent infrastructures that are suggested or can be considered for both circuit switched and packet switched optical networks.

Approach:

Taking advantage of current experiences and advances in both circuit switched (OCS) and packed/burst switched optical (OPS/OBS) networks, we plan to perform several studies. First, we will focus on OCS with the following aims: 1) an experimental analysis of the impact of different network designs (e.g., transparent, translucent, etc.) on the control plane behavior and the network performance, 2) a benchmarking study to assess and compare different control plane approaches with techno-economic considerations. Then, we will address the problem of verifying and adapting the selected control plane architectures/proposals for the effective management in the OPS/OBS networks. Based on the outcome of this second step, a comparative study among the collected proposals will be performed.

Main Outcomes and Results:

- Comprehensive study for benchmarking of current control planes;
- Analysis of the impact on control and management planes when considering physical layer impairments;
- Collecting the proposals/schemes for control and management plane in both OCS and OPS;
- Publishing the outcome(s) of the investigation in journals (e.g. IEEE Networks or Comm. Mag.) and related conferences.

Mobility actions:
Based on the expertise of the involved partners in this joint activity, at least one short mobility action is planned for February 2010 (with duration of one week).

Requirements:
Expected Duration:
- 1week

Type of work:
- Theoretical, simulation and experimental

Skills/facilities required:

Impact of physical layer impairments and related tools/models control plane basics and principles.

If interested, contact:

Davide Careglio (careglio@ac.upc.edu)

Meetings:
1 meeting predicted

Generated WP Papers:

[1] Not started

Other information:

Partners: CTTC, UPC, UPCT, AIT

7. Conclusions

This document has reported the progress that has been achieved during the first year of this topical project and the activities plan for the second year.

The following, summarizes the 5 JAs in the framework WP27, as well as their current status and planned activities for the following year.

JA1. Impairment aware algorithms for optical packet switching (OPS) networks

- Some research related with the implementation of DWP scheme as part of an OPS control plane to ensure the optical packets are individually routed along physical feasible paths;
- Four papers were submitted, from which, 1 is a journal and 3 conferences;
- No mobility action was performed.

JA2. Monitoring strategies for OBS and OPS networks

- A methodology for packet monitoring was proposed and studied. Joint efforts for demonstrating the methodology in a laboratory experiment.
- In the following year low-cost solutions for efficient PMD monitoring, as key limitation in high speed OBS/OPS links will be studied;
- Six papers were submitted, from which, 3 for journals and 3 for conferences;
- One mobility action planned for the beginning of the year.

JA3. Decision mechanisms for packet transit in OPS networks

- Activities related to OBS/OPS systems were performed (eg. Performance of switching devices in presence of different modulation formats at high data rate per port 400 Gbit/s/port; Carving for mitigation of transients in optical amplifiers; OBS in presence of lasers with limited tunability).
- Only one paper was submitted for a conference;
- Two mobility actions were performed and 2 planned for the beginning of the year.

JA4. Techno-economic study of monitoring techniques in OPS networks

- This JA has started by using one of special techno-economic session in ICTON 09. The contributions and authors interested in the topic of OPS were collected/contacted with the objective of attracting attention to the topic.

JA6. Impact of physical layer impairments on control plane schemes and proposals for optical circuit and packet switched networks

- This JA has not started yet. It is expected that will be started in the beginning of the year.

The joint activities proposals have followed the work planned. However, the increase in the number of partners and mobility actions can also increase the interaction among the research groups. Greater and more solid interaction between institutions and partners is an objective for the following year.