SEVENTH FRAMEWORK PROGRAMME

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Abstract:

This document is the second deliverable of the WP24 "Topical Project on Edge-to-core adaptation for hybrid networks". This report contains the work carried out during the first year within the planned joint activities.

There are **nineteen** partners involved in this workpackage and **ten** joint activities are proposed

Keyword list:

Disclaimer

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1. Executive Summary

This document is the second deliverable of the work package "Edge-to-core adaptation for hybrid networks". It contains reports on the work carried during first year of the project within proposed joint activities

There are 19 partners involved in this workpackage participating in 10 joint activities. The topics covered by this work package address the hybrid technologies in optical networks with focus on edge-to-node adaptation in hybrid networks. Particular topics addressed in this work package include: Hybrid OBS/OPS architectures, synchronous traffic over hybrid optical technologies as well as the provisioning of IP services over WDM technologies. Moreover, this work package will pay attention to the QoS provided by these hybrid technologies.

2. Introduction

The main objective of the work package "Edge-to-core adaptation for hybrid networks" is to address the issues that concern edge-to-node adaptation in hybrid networks. This deliverable describes the work done in this WP and provide an updates on progress of the planned joint activities.

First, we provide a list of the partners involves in the work package as well as the joint activities in which they are involved. Then we focus on the development and next steps of the joint activities. Finally, we conclude this report in the last chapter.

3. Participants

There are twenty three 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. A detailed description of the joint activities is provided in the following chapter.

Partner No	Member	Joint Activities	Country
5	TUB	6	Germany
7	USTIKR	8	Germany
10	TID	1,3,4,8	Spain
11	UAM	9, 10	Spain
12	UC3M	10	Spain
13	UPC	1,7,10	Spain
14	UPCT	6	Spain
15	UPVLC	1, 2	Spain
19	AIT	1,6	Greece
21	RACTI	2,3,4,7	Greece
27	FUB	5	Italy
29	POLIMI	10	Italy
32	DEISUNIBO	3,4	Italy
33	UNIMORE	3,4	Italy
34	UNIROMA1	5	Italy
42	BILKENT	3,4,7	Turkey
47	UEssex	2	United Kingdom
48	USWAN	14	United Kingdom

Table 1: Work package participants and their joint activities

4. List of Joint Activities

This chapter describes the joint activities that will be carried out in this work package. Following, Table 2 shows key information about these joint activities:

No	Joint Activity Title	Responsible person	Participants	Mobility Action	Deadline
1	OBS routing algorithms for resilient and dynamic network scenarios	Miroslaw Klinkowski (mklinkow@ac.upc.edu)	UPC, TID, AIT, UPV		M24
2	Evaluation of video transmission over OBS networks for different assembly schemes	Tito Raúl Vargas (tivarher@iteam.upv.es)	UPVLC, RACTI, UEssex	Yes (3)	M24
3	Dynamic Multi-Queue Burst Assembly schemes for TCP performance enhancement	Kostas Ramantas (ramantas@ceid.upatras.gr)	UNIBO, RACTI, TID, UNIMORE, BILKENT	Yes	
4	New assembly schemes taking into account the number of flows and their flow window size.	Kostas Ramantas (ramantas@ceid.upatras.gr)	UNIBO, RACTI, TID, UNIMORE, BILKENT	Yes	
5	The OTDM Add-Drop technique to overcome granularity problems in optical networks	Vincenzo Eramo (vincenzo.eramo@uniroma1.it)	UNIROMA1, FUB		M24
6	Traffic conditioning and congestion control in OBS/OPS networks	Pablo Pavón (pablo.pavon@upct.es)	UPCT, TUB, AIT		M24
7	Survey on QoS differentiation Mechanisms for OBS	Nail Akar (akar@ee.bilkent.edu.tr)	BILKENT, UPC, RACTI		M12
8	Design and evaluation of a periodic OBS burst reordering model for TCP throughput estimation	Sebastian Gunreben (sebastian.gunreben@ikr.uni-stuttgart.de)	UST-IKR, TID		M13
9	Synchronous traffic and OBS	David Larrabeiti (dlarra@it.uc3m.es)	UC3M		M13
10	Advanced optical amplifier for OBS/OPS transmission	Marcelo Zannin (m.da-rosa-zannin.397006@swansea.ac.uk)	USWAN, UAM, UPC, POLIMI		M24

Table 2: Summary list of the planned joint activities

As it is depicted in previous table, ten joint activities are planned for this work package. Some of the JAs reported in the previous deliverable are moved to other WPs since they fit better in the objectives of the other WPs. These JAs are:

New WP	Joint Activity Title	Responsible person	Participants	Comment
WP26	End-to-end multi-layer switching algorithm for IP over WDM networks	Víctor López (victor.lopez@uam.es)	UAM, TID	This JA is merged into the JA "Multi-layer algorithm using Bayesian decision theory"
WP11	Optical buffering technologies survey	Hisao Nakajima (hisao.nakajima@orange-ftgroup.com)	FT, TUW, DEIS-UNIBO, UPC,	
WP11	Analisys of the effects of erbium amplification in burst/packet networks	Giorgio Maria Tosi Beleffi (giorgio.tosibeleffi@comunicazioni.it)	ISCOM, IT	
WP11	Benchmarking of network architectures for guaranteed service provisioning	Alexandros Stavdas (astavdas@uop.gr)	UoP, UEssex, UAM	

4.1 OBS routing algorithms for resilient and dynamic network scenarios

Participants: AIT, TID, UPC, UPV

Responsible person: Miroslaw Klinkowski (mklinkow@ac.upc.edu)

Description of the work carried out so far (1 page):

UPC

In 2008 the research group of UPC has studied the problem of dynamic isolated deflection/alternative routing in OBS networks. A particular focus was on the comparison of performance of selected routing algorithms in two different OBS network architectures, namely, in conventional OBS (C-OBS) [1], where offset times are introduced in edge nodes by a delayed transmission of data burst, and in so-called offset time-emulated OBS (E-OBS), where offset times are introduced in core nodes by means of a fibre delay coil [2]. A motivation for this work was the intention to show that the application of the E-OBS architecture may facilitate the routing management. In fact, in E-OBS there is no constraint on the length of the routing path due to the so-called insufficient offset time effect. On the contrary, such effect is observed in C-OBS. Below a brief summary of this work and achieved results are presented.

In analyzed scenario, two alternative routing algorithms, namely, a Path Excluding Routing (PER) algorithm and a Bypass Path Routing (BPR) algorithm were implemented in an E-OBS network. Both BPR and PER, which were originally proposed for optical packet switching networks [3], perform a deflection of transmitted burst from a primary to an alternative routing path if there are no transmission resources available on the primary path (due to congestion or failure). The routing decision is taken per burst on the base of only local (isolated) output link state information. This implies that neither the algorithms require any knowledge about the network state nor any signalling state advertisement is necessary. The algorithms were compared with both shortest path (SP) routing and deflection routing (DR) applied to a (connection-less) C-OBS network. Just to recall, DR allows selecting an alternative output port in case of congestion in the output port of the shortest path; if the deflection succeeds, the following nodes are in charge of redirecting the burst towards its destination. In this analysis it was considered that the DR algorithm was limited to two deflections. At edge nodes, the offset time of every burst was introduced accordingly. If more deflections were required inside the network, a burst was dropped due to insufficient offset time.

Figure 1 shows the burst loss probability as a function of the normalized offered load achieved for NSFNet, an American backbone network topology. It can be observed that DR, PER, and BPR algorithms experience almost the same burst losses under light load condition and all of them outperform SP routing. When increasing the load, DR tends to approach (and even surpass) the performance of SP. This behaviour was already known and consistent with previous works as e.g. [4]. Both PER and BPR are well separated from SP at any traffic load condition.

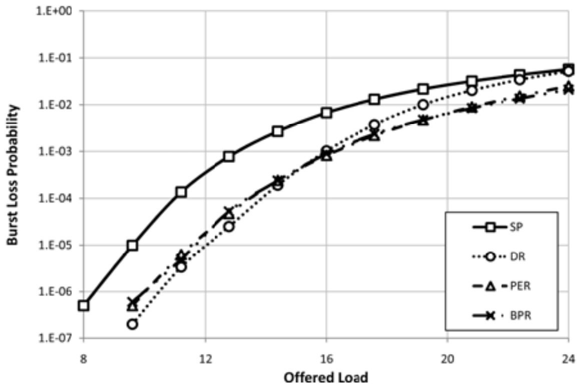


Figure 1 Burst blocking probability as a function of the normalized load comparing SP and DR algorithms applied to C-OBS and PER and BPR algorithms applied to E-OBS.

Figure 2 compares the routing algorithms applied in different network topologies; the x-axis is ordered according to the nodal degree (respectively 2 for a ring network, 2.93 for the NSFNet network, 3 for a meshed-ring network, and 4 for a torus network). In this analysis, a benchmarking reference for the burst loss probability, obtained with SP in C-OBS, is defined at the level of 10^{-2}; this reference implies a load of 10.08, 16.86, 11.97, 17.28 Erlangs for ring, NSFNet, meshed-ring, and torus topology, respectively. Under these load conditions, the overall burst losses for DR, PER and BPR algorithms were evaluated. The results indicate that, in a ring topology, any alternative routing algorithms do not bring any benefits. Increasing the nodal degree from 2 to 4, while DR presents slightly better performance than SP, the gain of PER and BPR becomes significant. Between them, BPR achieves the lowest burst losses. The observed low performance of DR is due to the insufficient offset time effect experienced in C-OBS. On the other hand, both PER and BPR benefit from E-OBS, which does not suffer the problem of insufficient offset times.

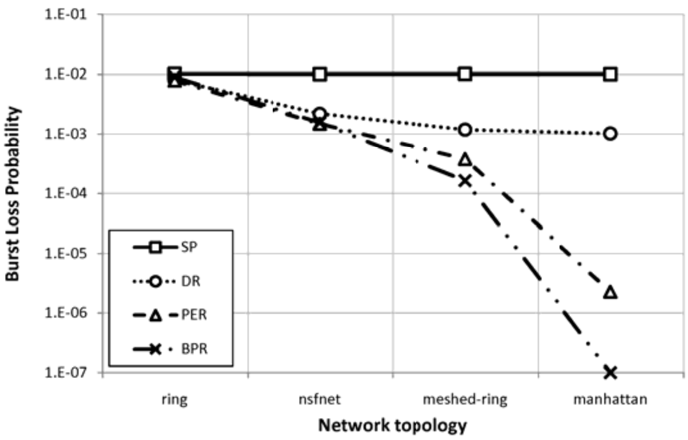


Figure 2 Burst blocking probability as a function of the network nodal degree comparing SP and DR algorithms applied to C-OBS and PER and BPR algorithms applied to E-OBS in different network topologies; the benchmarking reference is the 10^{-2} performance of SP routing.

UPV

The research group of UPV has joined the JA1 very recently and is just initiating its research activity. The details of research interest and future plans are presented in the "Overall progress and future work" section.

AIT and **TID** have no specific results to report for the last year period.

References

[1] C. Qiao and M. Yoo, "Optical burst switching (OBS) - a new paradigm for an optical Internet", J. High Speed Networks, vol. 8, no. 1, pp. 69-84, Mar. 1999.

[2] M. Klinkowski, D. Careglio, and J. Solé-Pareta, "Offset-time emulated OBS control architecture", in Proc. of ECOC 2006, Cannes, France, Oct. 2006.

[3] M. Klinkowski, F. Herrero, D. Careglio, and J. Solé-Pareta, "Adaptive routing algorithms for optical packet switching networks", in Proc. ONDM2005, Milan, Italy, Feb. 2005.

[4] A. Zalesky, H.L. Vu, Z. Rosberg, E.W.M. Wong, and M. Zukerman, "Modelling and performance evaluation of optical burst switched networks with deection routing and wavelength reservation", in Proc. INFOCOM 2004, Hong Kong, China, March 2004.

Mobility actions: no

Meetings: no

Papers: no

Other information:

Overall progress and future work:

So far, the interest of the UPC research group was on the problem of dynamic alternative routing in OBS networks without any quality of service (QoS) guarantees. Some of the results achieved during this study have been presented in a paper submitted to the JLT journal. Next year it is planned to focus on the routing methods with QoS support. In order to approach the problem, the application of optimization methods, including (integer) linear programming methods, is considered.

The research group of UPV, which has joined the JA1 recently, is going to address the problem of QoS routing and QoS based burst assembly and scheduling in OBS networks. A particular focus will be on the effect of burst assembly schemes on the quality of video transmission considering the variation of the number of video flows. The main objective of this study is to propose a QoS mechanism and a QoS routing scheme that would support dynamic video streaming traffic in an OBS network.

A joint collaboration, including a mobility action, is planned between UPC and UPV. The addressed topic will be the QoS routing.

4.2 Evaluation of video transmission over OBS networks for different assembly schemes

Participants: UPVLC, RACTI, UEssex

Responsible person Tito Raúl Vargas (tivarher@iteam.upv.es)

Description of the work carried out so far

The work carried out so far within the scope of this Joint Activity (JA) has been done in the first Mobility Action (MA) planned. The main work consisted in initiate integration and collaboration between the partners involved in the JA and trying to meet two objectives: a) improvement of the OBS- ns2 simulator, with new modules for video evaluation using different burst aggregation schemes and b)design and implement of a video evaluation process to get results of video quality using the OBS-ns2 simulator and software tools.

During the first Mobility Action (MA) the main work that has been carried out was the evaluation of video transmission over OBS networks through event driven simulation. Tasks realized during the MA could be summarized as follow:

a) First, each partner involved in the MA presented the event driven simulator used in the evaluation and modeling of OBS networks to choose one suitable to MA target. The simulator used was the ns-2 simulator with an OBS module. b) Then, the configuration of one simulator with modules that were provided for the partners. c) Once, the ns2-OBS simulator was set up UPVLC explained the framework of evaluation of video transmission that they used to obtain results about the quality of video after transmission and codification at the end of the simulation process. d) The next step was the improvement of the ns2-OBS simulator configured in the task b with a framework of video quality evaluation. e) After setting up the simulator the next step was prove the simulation environment, video traces from video samples was prepared, also we discussed and decided an OBS network topology and traffic characteristic, a background fractal traffic sources was programmed.

The simulation scenario include an NSF OBS network topology, with different video sources in one ingress node to the same egress node, background fractal traffic in each ingress node, a time-based burst assembly algorithm, and a LAUC scheduling algorithm.

f) Different simulations were carried out and video quality evaluation of video transmitted over OBS networks have been made to prove the correct operation of the simulator. g) With the simulator almost completed we started discussions about the implementation of a burst assembly algorithm and a scheduling algorithm in order to guarantee high video quality transmission over OBS networks, the idea is to work towards a QoS mechanism proposal for video transmissions over OBS networks. h) During the MA we have started the redaction of a joint publication; the work carried out in this MA is the base of the actual work of the Joint Activity.

Mobility actions:

1. Tito Raúl Vargas, from UPVLC to RACTI. Patras, Greece. 4 weeks. 24 May to 22 June 2008.

2. Tito Raúl Vargas, from UPVLC to UEssex, Colchester, UK. 5 weeks. 16 November to 20 December 2008.

3. Kostas Ramantas, from RACTI to UEssex, 5 weeks. Colchester, UK 16 November to 20 December 2008.

Meetings:

A part from the mobility actions the partners involved in this JA have been in touch through instant messaging applications.

Papers:

1 joint papers. The paper in its final steps. Paper target: Globecom 2009.

3 papers: ICTON-08, WOBS/Broadnets 08, URSI-08 (Spain).

Other information:

Overall progress and future work:

The activities planned will be carried out in the second mobility actions (mobility action 2 and 3) and the main objectives are:

- Propose QoS mechanism for video transmissions over OBS.

- Design and implement a simulation scenario to match the OBS video capable testbed (UEssex) and compare the results.

- Design/implement a realistic test scenario for video over OBS (emulating contention, back ground traffics, etc)

- Extending the aggregation mechanism of the Essex test-bet (algorithm + hardware) for Video application.

4.3 Dynamic Multi-Queue Burst Assembly schemes for TCP performance enhancement

Participants: UNIBO, RACTI, TID, UNIMORE, BILKENT

Responsible person: Kyriakos Vlachos/Kostas Ramantas (kvlachos, ramantas)@ceid.upatras.gr

Description of the work carried out so far (1 page):

Work in the joint activity has been focused in evaluating multi-queue burst assembly queues for enhancing TCP performance. One of the key issues studied is the TCP synchronization effect. University of Bologna collaborated with the RACTI/UPATRAS and Telefonica, TID, Spain, to study TCP synchronization when different packet/burst assembly functions are concerned. In OBS networks, burst losses foster such an effect, which can yield an undesirable TCP performance. The different assembly strategies studied included a) per flow queuing (ideal case, where each flow has its own assembly queue) and b) mix flow (typical in OBS networks). The studies (simulations) were carried out by keeping the aggregate access bandwidth generated by the N_F TCP agent constant and varying the number of these agents, so that the greater the number of agents the lower the bandwidth of each agent bandwidth. Both the aggregated throughput and the average throughput and its variance were measured. Based on the analysis, it was clear that employing a single assembly queue is not appropriate for TCP over OBS networks. It yields sub-optimal performance and temporarily overloads the network due to flow synchronization. In order to truly de-synchronize flows, a new scheme was proposed employing a multi-queue burst assembler, where flows are allocated dynamically to different queues. All incoming flows are divided to more than one queue with equal probabilities for the whole assembly period, keeping the flows per queue constant and equal to each other. It was shown that such a dynamic flow allocation to more than one assembly queue may provide a significant gain and reduce synchronization by more than 50%.

BILKENT studied the influence of the number of burstifiers on TCP performance for an OBS network. In particular, the goodput of TCP flows between an ingress and an egress nodes travelling through an optical network was studied as the number of assembly buffers per destination varies. First, the burst-length independent losses resulting from the contention in the core OBS network using a non-void-filling burst scheduling algorithm, e.g., Horizon, are studied. Then, burst length dependent losses arising as a result of void-filling scheduling algorithms, e.g., LAUC-VF, are studied for two different TCP flow models: FTP-type long-lived flows and variable size short-lived flows. Simulation results show that for both types of scheduling algorithms, both types of TCP flow models and different TCP versions (Reno, Newreno and Sack), TCP goodput increases as the number of burst assemblers per egress node is increased for an OBS network employing timer-based assembly algorithm. The improvement from one burstifier to moderate number of burst assemblers is significant (15-50% depending on the burst loss probability, per-hop processing delay and the TCP version), but the goodput difference between moderate number of buffers and per-flow aggregation is relatively small, implying that an OBS edge switch should use moderate number of assembly buffers per destination for enhanced TCP performance without substantially increasing the hardware complexity.

Partners UNIMORE performed similar studies.

An overall comparative study is on progress.

Mobility actions:

Meetings: June 2008 (during ICTON 2008), October 2008 (joint meeting with other WPs during plenary).

Papers:

1. Oscar González de Dios, Anna Maria Guidotti, Carla Raffaelli, Kostas Ramantas, Kyriakos Vlachos, “On TCP Synchronization in Optical Burst Switching”, submitted to Photonic Network Communications.
2. G. Gurel and E. Karasan, “Using Multiple per Egress Burstifiers for Enhanced TCP Performance in OBS Networks,” Photonic Network Communications, accepted for publication

Other information:

Overall progress and future work:

RACTI will study alternative techniques for enhancing TCP performance combining assembly and scheduling mechanism.

4.4 New assembly schemes taking into account the number of flows and their flow window size.

Participants: UNIBO, RACTI, TID, UNIMORE, BILKENT

Responsible person: Kyriakos Vlachos/Kostas Ramantas (kvlachos, ramantas)@ceid.upatras.gr

Description of the work carried out so far (1 page): work in the joint activity was focused on the study of a new assembly scheme based on the instant congestion window size. RACTI/UPATRAS, University of Bologna and Telefonica jointly developed a dedicated TCP-over-OBS simulator using ns-2 tool and conducted full-scale experiment on the NSFnet topology to identify how segments, flows distribution over the assembled bursts varies with aggregation time. Based on the analysis, it was shown that measuring averaging throughputs is not indicative of TCP performance, and conceals true flow behavior in the network. In order to truly enhance TCP performance, the instant window size is a metric to be considered for determining the optimum assembly time. Further, static use of fixed timer is not enough and a dynamic process is preferred that assigns flows to different assembly queues with different assembly timers. In order to evaluate such a scheme, we have implemented a new assembly scheme with three different queues per source–destination pair. Each queue had a different assembly timer, and incoming packets were assigned to these, based on their instant window size. The implementation of this assembly scheme requires the communication of the window size to the burstifier, which is not standard in the current TCP implementations. Based on simulation results, it was found that a 3-queue burstifier with different assembly timers is able to increase TCP performance in a fair way for all the aggregated flows.

Partner Bilkent also performed similar studies. Using simulations, it was again shown that the usage of the congestion window (cwnd) size of TCP flows in the burst assembly algorithm consistently improves the TCP goodput (by up to 38.4%) compared with the fixed-delay timer based assembly even when the timer based assembler uses the optimum assembly period threshold value. A new adaptive burst assembly algorithm for TCP traffic in OBS networks, was then proposed and which is called congestion window (cwnd) based burst assembly algorithm (CWBA). In this algorithm, cwnd size of the TCP flow is taken into account in determining when to form the burst, where the assembled burst sizes are directly proportional to the cwnd size of TCP. In addition, to CWBA, a hybrid version of the CWBA algorithm and the timer based burst assembly algorithm is proposed, which is the mixed cwnd/timer based burst assembly (MCWBA) algorithm. The crucial property of MCWBA algorithm is that it puts an upper bound on the delay introduced by the burst assembly process. The performances of the two burst assembly algorithms are investigated again with the simulations that are performed in two different network topologies.

Mobility actions:

Meetings: June 2008 (during ICTON 2008)

Papers:

1. Kostas Ramantas, Kyriakos Vlachos, Óscar González de Dios, Javier Aracil and Carla Raffaelli, "Timer-based burst assembly algorithms and their effect in TCP Congestion window", OSA J. Optical Networks, vol. 7, Iss. 5, pp. 487-495, May 2008.

Other information:

Overall progress and future work:

RACTI is developing an analytical solution of the proposed assembly scheme to predict congestion window size and extract indicative performance metrics for TCP over OBS transmission.

4.5 The OTDM Add-Drop technique to overcome granularity problems in optical networks

Participants: V. Eramo, M. Listanti, A. Cianfrani (Uniroma1)

F. Matera, L. Rea, A. Valenti (FUB)

A. Germoni (Coritel)

Responsible person: V. Eramo (Vincenzo.Eramo@uniroma1.it)

Description of the work carried out so far (1 page):

In the first year of the JA #5 the effectiveness of an OTDM Add-Drop technique in OTDM/WDM optical networks has been evaluated.

Wavelength Routed (WR) optical networks represent the most interesting solution for the constant increase in bandwidth demand, due to the growth of both real-time services and number of connected users. WR networks allow for the exploitation of the huge fiber bandwidth, which is divided into many non overlapping channels, each one represented by a different wavelength. In WR networks each logical connection between a source node and a destination node is realized through a Lightpath that is a semi-permanent optical channel composed by the union of consecutive optical fibers from the source node to the destination node. To overcome granularity problems an evolution of Lightpath solution is possible thanks to Optical Time Division Multiplexing (OTDM) performed directly in the optical domain. In particular each channel, represented by its wavelength, is partitioned into a fixed number of sub-channels, each one represented by a specific time slot in the OTDM frame. In this way the huge Lightpath bandwidth, which is too much large for a single logical connection, is split and can be used by more logical connections. In particular it is possible to construct a Super-Lightpath which is able to carry all connections from a single source node to *D* different destinations using a single wavelength: each connection uses one or more sub-channels and each destination is able to extract sub-channels directed to itself and to route the Super-Lightpath until the last destination is reached. Notice as the Super-Lighpath solution has the advantage to overcome granularity problems in WDM optical networks maintaining low at the same time the Optical Cross Connect (OXC) complexity. In fact OTDM aggregation are operations only performed at the network edges.

In the first year of the Joint Activity, we proposed and evaluated a Super-Lighpath solution in which the destination nodes are provided with OTDM Add-Drop function. In this case is still used a OTDM scheme and a clustering of the connections from a source node toward *D* destinations, but now each destination node, after the data reception from a sub-channel, can reuse that sub-channel to transmit its own data directed to one of the Super-Lightpath destinations. This is possible thanks to deployment of Add-Drop multiplexers (ADM) in optical domain [1]. With this solution the sub-channels reuse is possible and the inefficiency of simple Super-Lightpath approach is overcame: a sub-channel, after the data receiving in its own destination node, continues with unnecessary data toward the final destination of the Super-Lightpath. In our evaluation we will highlight that using a OTDM scheme with Add-Drop functions, and so Super-Lightpaths with Add-Drop, it is possible to reduce the number of wavelengths needed to solve Routing and Wavelength Assignment (RWA) problem with respect to Lightpath case and also with respect to Super-Lightpath case. To better explain this aspect we show an example in which the logical topology and the physical topology reported in Fig. 1.a e Fig. 1.b are considered respectively. In Fig. 1.a logical topology composed by three IP routers and three directed logical connections is reported; for the sake of simplicity only one-way connections have been considered. The physical topology, proposed in Fig. 1.b, is composed by five optical fibers and five OXCs. The Lighpath (L), Super-Lighpath (SL) and Super-Lighpath with Add-Drop (SLAD) solutions are shown in Fig. 1.c, 1.d and 1.e respectively. We assume that OXCs are not provided with wavelength converters. Each Lighpath must be routed on the same wavelength.

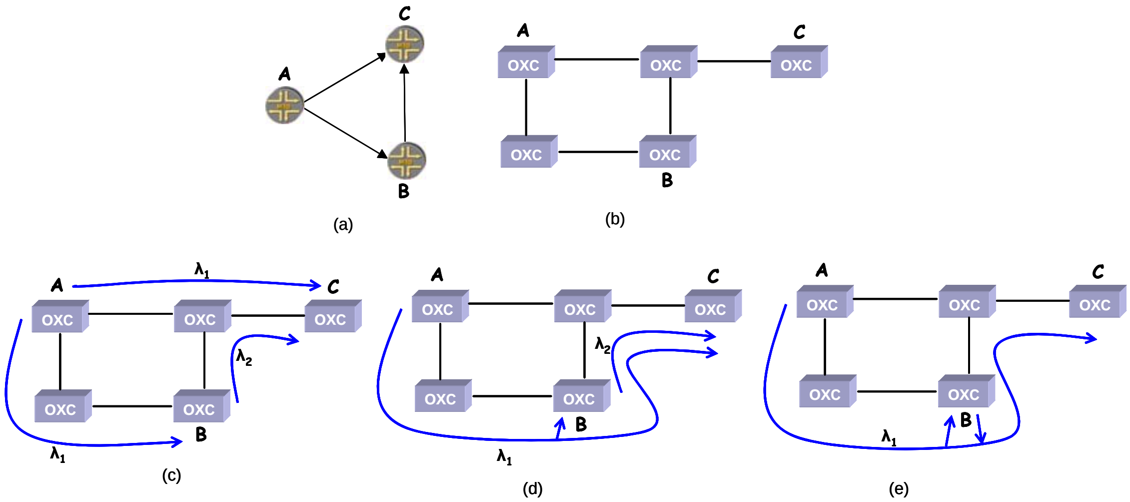


Figure 1. The logical topology (a) is mapped on the physical topology (b) according to three different solutions: Lighpath (c), SuperLighpath (d) and SuperLighpath with Add-Drop.

To evaluate the effectiveness of the proposed solution, RWA problems have been solved for S, SL and SLAD solutions. Because the problems are NP-Hard, Super-Shortest Path First Fit (SSPF) and Super-Maximum Fill (MF) heuristics, proposed in [2], have been modified and used. The details on SPFF and MF heuristics have reported in [3].

Next we present experimental results to evaluate the effectiveness of the proposed SLAD solution when the considered physical topology is the U.S Long-Distance Network comprising 28 nodes and 45 links. Three different connectivity degrees p=8, 12, 16 have been considered and for each connectivity degree we have randomly generated 50 logical topologies. For each of L, SL, SLAD solutions we report the number of wavelengths needed to solve the RWA problem when SPFF and MF heuristics are used. These results, reported in Tables 1.a, 1.b, 1.c for p=8, 12, 16 respectively, are obtained as a function of parameters D and G. D is the number of destinations for each SuperLighpath. G ($1 \leq G \leq D$-1) is the number of sub-channels available for re-use when Add-Drop function is considered. In particular time slots #1, #2,…#G can be re-used by the destinations of the SuperLighpath. Notice that when G=0, the number of wavelengths of SL solution is evaluated. The results of the L solutions are obtained when D=1 and G=0. In Tables 1.a, 1.b and 1.c, we have reported for each heuristic the average number w of wavelength required to solve the problem and the percentage gain in terms of wavelength used of SLAD solution with respect to SL solution, defined as:

$$\eta_{D,G} = 100 \frac{w_{D,0} - w_{D,G}}{w_{D,0}}$$

wherein:
-$w_{D,0}$ is the number of wavelengths needed for SL solution with *D* destinations per SuperLighpath
-$w_{D,G}$ is the number of wavelengths needed for SLAD solution with *D* destinations per SuperLighpath and when *G* time-slots are re-used.

D-G	*w-SPFF*	η	*w-MF*	*w-MF*
1-0	24,35	-	16,55	-
4-0	13,85	-	9,9	-
4-1	12,8	7,58%	9,1	8,08%
4-2	12,65	8,66%	9	9,09%
4-3	12,65	8,66%	9	9,09%

(a)

D-G	*w-SPFF*	η	*w-MF*	*w-MF*
1-0	36,15	-	25,05	-
4-0	17,5	-	12,55	-
4-1	15,95	8,86%	11,95	4,78%
4-2	15,55	11,14%	11,7	6,77%
4-3	15,55	11,14%	11,6	7,57%
6-0	17,65	-	11,95	-
6-1	15,4	12,75%	10,95	8,37%
6-2	15	15,01%	10,75	10,04%
6-3	14,65	17%	10,35	13,39%
6-4	14,55	17,56%	10,3	13,81%
6-5	14,55	17,56%	10,3	13,81%

(b)

D-G	*w-SPFF*	η	*w-MF*	*w-MF*
1-0	46,55	-	32,94	-
4-0	19,93	-	14,88	-
4-1	18,55	6,88%	14,12	5,14%
4-2	18,29	8,18%	13,82	7,11%
4-3	18,22	8,55%	13,82	7,11%
8-0	21,48	-	13,76	-
8-1	17,74	17,41%	12,47	9,4%
8-2	16,89	21,38%	11,94	13,25%
8-3	16,22	24,48%	11,29	17,95%
8-4	15,89	26,03%	11,06	19,66%
8-5	15,67	27,07%	11	20,08%
8-6	15,67	27,07%	11	20,08%
8-7	15,67	27,07%	11	20,08%

(c)

Table 1. Evaluation of Effectiveness of the SuperLighpath solution with Add-Drop for U.S Long Distance Network with p=8 (a), p=12 (b), p=16 (c) and D=1,4,6,8.

Results show that the Add-Drop solution performs better and allows for saving up to 27% of wavalength needed with respect to Super-Lightpath case. Moreover all results confirm that the SPFF algorithm is outperformed by the MF and show that the percentage gains are increasing monotonic functions with saturation thresholds.

[1] P.J. Almeida, P. Petropoulos, F. Parmigiani, M. Ibsen, D.J. Richardson, OTDM Add-Drop Multiplexer Based on Time-Frequency Signal Processing, vol. 24, no. 7, pp 2720-2732, September 2005.
[2] M. Mellia, E. Leonardi, M. Feleting, R. Gaudino, F. Neri, Exploiting OTDM technology in WDM networks, in Proc. IEEE INFOCOM 2002, New York (USA), pp. 1822-1831, June 2002.
[3] V. Eramo, M. Listanti, A. Cianfrani, F. Matera, L. Rea, Performance Evaluation for Optical Networks with OTDM Add-Drop functionality, in Proc. ICTON 2008, Athens, June 22nd-26th 2008.

Mobility actions: No

Meetings: 3

2 meetings at Uniroma1: June 15th 2008, September 20th 2008

1 meeting at FUB: July 18th 2008

Papers: 2 (1 submitted)

V. Eramo, M. Listanti, A. Cianfrani, F. Matera, L. Rea, Performance Evaluation for Optical Networks with OTDM Add-Drop functionality, in Proc. ICTON 2008, Athens, June 22nd-26th 2008.

V. Eramo, M. Listanti, A. Cianfrani, A. Germoni, F. Pisani, F. Matera, Routing and Wavelength Assignment Problem in OTDM/WDM Networks with Physical Impairments, submitted to ONDM 2009.

Other information: none

Overall progress and future work:

We will propose and evaluate the performance of OTDM/WDM networks when physical impairments are taking into account. The most interesting aspect of our work is that we propose an easy and efficient way to take into account physical impairments during the execution of the algorithm relative to L, SL and SLAD solutions. In literature different impairments-aware RWA algorithms have been proposed: the most interesting are ones which consider both linear and nonlinear effects. These algorithms are proposed for the dynamic case, logical connections are on demand established, and they both provide that each time a Super-Lightpath is computed, its Optical Signal Noise Ratio (OSNR) has to be computed and compared with a threshold. In this work we consider two heuristics Shortest Path First Fit (SPFF) and Maximum Fill (MF), and we modify them so that physical impairments are considered. The algorithms take into account the maximum length of a Super-Lightpath according to the physical impairment constraints.
We will evaluate the impact of physical impairments in terms of number of wavelengths and number of Super-Lightpaths needed to solve RWA problem for L, SL and SLAD solutions . In particular different OTDM degree and different connectivity degree of the logical topology will be considered, and for each case physical-aware algorithm results will be compared to classical algorithm ones.

4.6 Traffic conditioning and congestion control in OBS/OPS networks

Participants: Traffic conditioning and congestion control in OBS/OPS networks

Responsible person: Pablo Pavon Mariño (pablo.pavon@upct.es)

Description of the work carried out so far (1 page):

The objective of this JA is the design and evaluation of traffic conditioning and congestion control schemes suitable for OPS/OBS networks, focusing in the edge node.

In the first stage of the JA, the expertise of the interested partners was collected. Past and ongoing work in the topic was surveyed. Each of the partners showed its already developed own simulation tool, tuned to focus on the particular aspects of the network they have been investigating.

The partners agreed in defining a common framework to allow extracting results which could be comparable. This definition process ended with a common documment "Definition of common benchmark". The main aspects inside define a common network topology (NSFNET 14 node), and a common traffic matrix. Shortest-path routing was defined as the default routing for engineering the traffic connections.

Some preliminar results were obtained and shared.

UPCT focused on OPS networks with the following properties. OPS siwtching nodes are able to emulate output buffering, with full wavelength conversion. Packets are aligned by optical synchronization stage before being switched. No offset exists between packet payload and packet header. Packets are of fixed duration of 1 microsecond. Two traffic connections are established for each input-output pair, one for low priority traffic and carries 90% of the load, the other is high priority and carries 10% of the load. Traffic connections are fed by assemblers which generate optical packet with exponential interarrival time.

A first study tried to evaluate the performances of the simulation kernel (OMNeT++ based). In particular, the effect of loading the internal event list with a larger number of events was evaluated. This is relevant to test long-haul networks, where traveling packets in the links, reflected as events in the event list, can grow up to millions, degrading the simulation execution time performance. Results showed a negligible effect in the execution time.

A simple shaping at the edge nodes has been tested, consisting of a backpressure signal from the ingress size, so that optical packets are not injected if they are to be lost in the optical part of the edge node because of traversing traffic. The elctronic memory requirements in the edge and the average queueing delay has been evaluated, and showed to be in an acceptable range.

A suvey of traffic conditioning and shaping trends in OPS/OBS networks has been conducted and published [1]. This will feed the future tests in the topic.

AIT work focused on OBS networks. Its simulation tool is based on OPNET. The study in AIT was based on the common topology and traffic framework. OBS JET technique was assumed. Traffic was produced according to a Poisson process while the burst size was exponentially distributed with a mean value of 1 Mbit. The total amount of bursts produced per node in each run was approximately 10^6. The OBS JET protocol was employed and the initial offset parameter for each BHP was computed as: $offset = N \cdot T_{setup} + T_{OXC}$, where N is the number of hops, T_{setup} is the delay for processing each BHP at every node and T_{OXC} the delay for configuring the cross-connects at each intermediate node. For the simulations, T_{setup} = 1 µs and T_{OXC} = 20 µs.

In their tests they also showed the impact in simulation time of large propagation delays in the links. An important observation during AIT simulations was that setting the propagations delays of all links to zero cuts down the simulation run time to the half without sacrificing much precision in the results. Some average burst loss probability curves where obtained, which serve to validate the mode.

TUB work within this JA was two-fold. First, TUB has been working on developing realistic models for the traffic generated at the ingress edge of OBS networks. This has been done using real traces collected from the Internet. Second, TUB developed a simulation model (using OMNeT++) that supports evaluating OBS networks with any given topology. More specifically, the developed simulation model supports following features:

- Time-based, Volume-based and Hybrid burst assembly
- Offset-based reservation
- FIFO and Non-FIFO (void-filling) scheduling algorithms
- FDL buffers (shared and dedicated)
- Wavelength Conversion (shared per node and dedicated per port)
- Minimum-Delay and Minimum-Converter scheduling algorithms

Mobility actions: 1 mobility action has been carried out from UPCT to AIT. The visiting researcher was Pablo Pavon Mariño (UPCT). The stay lasted from 15 th April to 18 th April. Its objective has been planning the collaboration AIT – UPCT in the WP24 and exchanging knowledge in our respective expertises to design this collaboration. Its outcome has been the definition of a common framework for comparison of traffic edge shaping of traffic in OBS/OPS networks. This required interchanging information about simulation tool design, to tune the simulator parameters and allow results comparison.

Meetings: AIT, TUB and UPCT partners met in AIT facilities during ICTON 08 conference and Joint Plenary meeting WP11 WP12 WP21 WP22 WP24 WP26 (June 2008), and during BONE plenery meeting (Rome, October 2008). Also, about 5 phone talks has been scheduled during the process of definition of a common framework, among AIT, TUB and UPCT partners.

Papers:

UPCT has published a paper in the topic:

[1] M. Cano (UPCT), P. Pavon-Mariño (UPCT), A. Ortuño-Manzanera (UPCT), J. Garcia-Haro (UPCT), *Traffic shaping trends in Optical Packet/Burst Switching Networks*, 10th International Conference on Transparent Optical Networks (ICTON 2008), Vol. 3, pp. 134-137, Proceedings of the 10th International Conference on Transparent Optical Networks (ICTON 2008), June 2008. (*Added by UPCT*)

Other information:

Overall progress and future work:

The partners intend to progress on the research line drawn.

4.7 Survey on QoS differentiation Mechanisms for OBS

Participants: BILKENT, UPC, RACTI

Responsible person: Nail Akar akar@ee.bilkent.edu.tr

Description of the work carried out so far : The three partners of this project carried out a survey on Quality of Service Differentiation mechanisms in Optical Burst Switching (OBS) networks. We first categorized QoS differentiation mechanisms based on whether one-way or two-way signaling is used. Moreover, one-way QoS differentiation mechanisms can further be categorized as: *edge-based:* mechanisms are implemented only at the OBS ingress edge node and the core nodes are not involved, *core-based:* mechanisms are implemented only at the OBS core nodes and the edge nodes are not involved, *edge-core-based:* mechanisms require the involvement of both the OBS ingress edge nodes and OBS core nodes. Basically, two mechanisms have been proposed for edge-based QoS differentiation: offset time-based and burst length-based differentiation. On the other hand, preemptive dropping, threshold-based dropping, and intentional dropping are identified as core-based OBS mechanisms. Under a common topology and scenario, we compared different QoS mechanisms i) for UDP traffic ii) TCP traffic for which the performance metric was the burst loss probability for the former case and the metric was the TCP level throughput for the latter case. We also studied the effect of two-way signaling for QoS in OBS networks. This work was not only meant to be a survey but also a means of disseminating new research results for QoS.

Our findings can be summarized as follows: The results obtained for UDP traffic indicate that the preemptive dropping approach achieves performances which are slightly better than offset time-based differentiation and several orders of magnitude better than the wavelength threshold-based dropping scheme. The gain in the preemptive dropping approach is slightly offset by an increase in burst loss rates for LP traffic especially for high loads stemming from phantom bursts. The results obtained for TCP traffic suggest that increased offset differences between the HP and LP traffic are beneficial for small offset differences in terms of TCP goodput but the overall performance and differentiation between the two classes of traffic deteriorate when offset differences grow. Burst length based differentiation is also very effective for TCP traffic since goodputs of HP flows significantly increase as a result of both decreasing delay and decreasing loss rate. These results lead us to believe that provisioning of the offset-based QoS is crucial especially when the traffic is dominated by elastic traffic. The two-way scheme negotiates the reservation horizon of the burst, relaxing the strict delayed reservation. The performance evaluation results show that the proposed QoS mechanism in two-way OBS networks outperforms other timed/delayed reservation protocols in terms of data loss ratio and resource utilization but for bursts that can tolerate the round trip delay required by the two-way reservation process.

Mobility actions:

Meetings:

Papers: A journal paper is written and submitted to JON.

Nail Akar, Ezhan Karasan, Kyriakos G. Vlachos, Manos Varvarigos, Davide Careglio, Miroslaw Klinkowski, Josep Solé-Pareta, “Quality of Service Differentiation Mechanisms in Optical BurstSwitching Networks”, submitted to Journal of Optical Networking, Nov. 2008.

Other information:

Overall progress and future work: An agenda is not set yet for this JA for future work except for potential changes/modifications to be made on the submitted paper towards publication.

4.8 Design and evaluation of a periodic OBS burst reordering model for TCP throughput estimation

Participants: UST-IKR, TID

Responsible person: Sebastian Gunreben (sebastian.gunreben@ikr.uni-stuttgart.de)

Description of the work carried out so far (1 page):

The goal of this activity is to design an analytic TCP throughput model for periodic burst reordering. Burst reordering in OBS networks shows reordering on several layers: the reordering of bursts and the reordering of the carried packets if they belong to the same flow. This includes multi-layer analysis on optical burst reordering and the TCP over OBS periodic loss model. In this activity, we follow a two-step approach. First, we model and evaluate the burst and packet reordering metrics in a general OBS network delay environment and second we derive the periodic reordering model for the TCP performance. In the reporting period, we started with the first step.

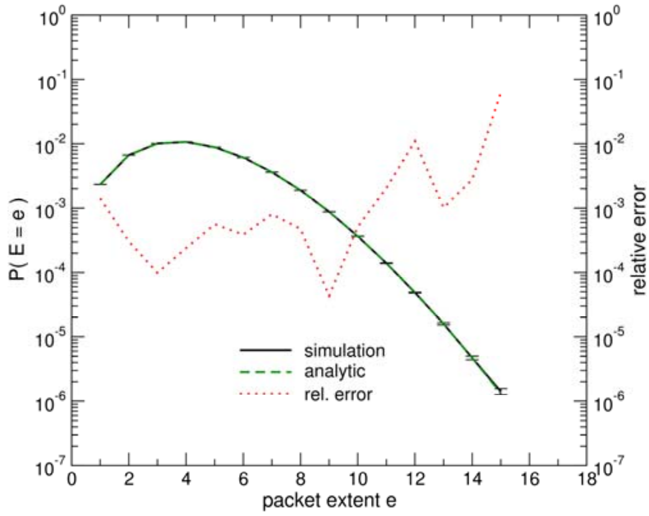
The work focused on the time based assembly scheme at the network edge. This assembly strategy shows a certain traffic characteristic of the departing bursts. Based on this, we focused on the burst reordering and the resulting packet reordering characteristics. We assumed a general network delay distribution between source and destination node. The delay distribution then reflects the contention resolution schemes in OBS networks, e.g. deflection routing and fiber delay lines.

We focused on three different reordering metrics for both burst and packets. The reordering metric comprises the mount of reordered bursts and packets. The reordering extent metric reflects the required buffer size at the destination node for any burst or packet re-sequencing. The n-reordering metric - applied for the packets only - indicates the impact on the TCP protocol. The burst reordering metrics depend on the network delay distribution, while the packet reordering metrics depend on the burst reordering metrics and the packet per burst distribution. The investigation of the burst reordering metrics is consequently the first step.

The inter-departure time of the time-based burst assembly algorithm follows the shifted negative exponential distribution, i.e. the 2-parameter negative exponential distribution. It is hard to obtain the analytic expression of the burst reordering metrics in a general network delay environment. Therefore, we followed a different approach. In parallel, we derived the burst reordering metrics by simulation. The packet reordering metrics, we derived analytically.

For an evaluation of the packet reordering metrics, we compared the simulation results with the analytic expressions. As the simulation results include the burst reordering metrics as well as the packet reordering metrics, we were able to compare both approaches, analytic and simulation. For the analytic expression of the packet reordering metric, the simulation results of the burst reordering serve as an input parameter.

The simulation scenario includes two nodes, the source, and the destination node. The network in between shows a certain network distribution. Our simulation parameters include linear distributed delay probabilities and 10% delay probability.



We compared the packet extent metric both the simulation metrics as well as the analytic expression. We found that our analytic expression fits well to the simulation results. For illustrative purpose, we depict in the figure this outcome together with the relative error of both graphs. The relative error is smaller than one per million for 2/3 of the considered area. In the right part of the figure, the error increases as the number of simulation events is smaller and thus the confidence intervals increase. We described in very detail our approach and the results in our publication [1].

Papers:

[1] Gunreben, S., "An Optical Burst Reordering Model for a Time-based Burst Assembly Scheme", WOBS 2009, London

Overall progress and future work:

We extent the overall duration of this joint activity up to 24 months, i.e. final results may be expected in M24. Besides this, the next steps include the following:

Definition of the simulation setup for a comparison with real TCP implementations

Model of the OBS network delay by discrete abstract links

Time based assembly at the OBS edge nodes

Long-lasting TCP connection

Outcome of the next steps include

Compare experienced burst sequence to analytic results

Compare calculated TCP throughput to measured results

4.9 Synchronous traffic and OBS

Participants: U. Carlos III de Madrid (UC3M), U. Autonoma de Madrid (UAM)

Responsible person: David Larrabeiti (dlarra@it.uc3m.es)

Description of the work carried out so far (1 page):

The joint work has focused on the study of the POBS (Polymorphic OBS) architecture by Qiao. POBS supports hybrid burst-switched pseudo-circuit-switched exploitation of the OBS network. The impact of this approach has been analysed analytically and through simulation with the purpose of estimating the decrease of effective capacity and increase of loss for background non-synchronous traffic caused by synchronous reservations. The work shows how to extend the well-known Erlang Fixed Point procedure to evaluate the performance behaviour of POBS networks. The Erlang Fixed Point iterative procedure is modified so that the blocking probability computed at each link is replaced by a weighted Erlang-B based equation. This equation takes into account the amount of time over which a number of wavelengths are free multiplied by the blocking probability observed when such number of wavelengths is available. The experiments reveal the outstanding performance of POBS, which provides significant throughput gains with respect to the Hybrid OCS-OBS architecture, especially when the number of periodic TDM reservations is large and their active periods are small. Finally, this work concludes with a design rule of thumb which is intended to assist network operators in evaluating the feasibility and viability of migrating to POBS architectures. The selected metric determines the average number of synchronous TDM reservations required which results in a given throughput gain achieved by POBS.

Mobility actions: none

Meetings:

Several coordination meetings

Papers:

Performance evaluation and design of Polymorphous OBS networks with guaranteed TDM services. (submitted to JLT)

Other information:

Overall progress and future work:

Joint research focused on the possibilities of hybrid optical-electronic approaches that includes auxiliary electronics to deal with low class bursts is underway.

4.10 Advanced optical amplifier for OBS/OPS transmission

Participants:

Davide Careglio and Josep Sole-Pareta – UPC

Javier Aracil – UAM

Stefano Taccheo – USWAN (previously POLIMI)

Marcelo Zannin and **Karin Ennser** – USWAN

Responsible person:

Marcelo Zannin (m.da-rosa-zannin.397006@swansea.ac.uk)

Description of the work carried out so far:

This joint activity brings together expertise in OBS/OPS transmission and advanced optical amplification with the objective of investigating and minimizing amplification impairments in OBS/OPS transmission. Theoretical and experimental analyses of amplification under several cases of burst transmission were performed in order to characterize the behaviour of burst transmission under different conditions. The conditions mainly differ from the network power profile, whose variation means input power variation at the amplifier input. Amongst the cases considered are the complete fault and recovery of a multi-channel WDM system, as well as other cases of power variation depending on the number of channels, burst durations and inter-arrival times considered in the analyses. Evaluation of the burst amplification was obtained through analyses of power excursions, eye diagram measurements and BER curves. Besides considering standard optical amplification, an all-optical feedback configuration that stabilizes the amplifier gain was also considered. The scenarios considered are compared in both configurations of the amplifier, with and without gain clamping.

The behavior of the amplification in special cases allowed the identification of some cases where the performance is unsatisfactory. It is of interest to determine whether these cases with unsatisfactory performance are likely to occur or not. For this purpose, the typical behavior of OBS traffic is characterized through statistical analyses. Typical burst data comes from traffic measurements performed by a tailor-made testbed from an OBS network that interconnects the UPC and the Catalan Network.

The results obtained relate the gain fluctuation observed in the power excursion analyses and the performance of the transmission, which was observed in the eye diagrams and quantified through BER measurements. The robustness of the clamping configuration is observed in the BER curves, despite of the power excursion profiles of special cases with high power variation in the network.

During the analyses of the special cases, it was possible to observe some chaotic behavior of the clamped amplifier gain under certain conditions. Special cases of consecutive bursts with similar parameters may interplay with the physical properties of the clamped amplifier, causing its gain to vary chaotically. These cases were analyzed and their occurrence likelihood was also assessed.

The results obtained during these investigations will be published in two journals (JLT). Preliminary results were presented at the International Conference on Transparent Optical Networks (ICTON 2008), as well as submitted the Optical Fiber Communication Conference (OFC 2009).

Mobility actions: -

Meetings: - Members met during organized WPs and Plenary meetings to discuss progress.

Conference papers

CLEO 2008 – "*Effective Amplification of Real WDM Burst Traffic Using Optical Gain Clamping*".

ICTON 2008 – "*Optical Amplifier for Optical Burst Switching Networks*".

OFC 2009 – "*BER Improvement Using Optical Gain Clamped Amplifier for Burst Transmission and Critical Cases Studies*". Submitted

Journal papers

JLT– *"Effective Amplification in Optical Burst Switching Networks"*.

Concluded, to be submitted shortly.

JLT– Critical Cases of Effective Amplification.

Currently being written, to be concluded by end of November.

Other information:

Overall progress and future work:

Special cases of similar consecutive bursts were identified as critical for the performance of the clamped amplifier. Further studies aim to identify, through simulations, whether non similar bursts will generate the same effect, and how different they must be for the effect to be negligible. Statistical analyses will determine how likely the cases identified as critical are to occur.

5. Conclusions

The number of joint activities is adequate with respect to the number of partners involved in this work package. If all the planned activities follows the steps described in their proposal, this work package will fulfill the objectives defined in the project technical annex.

Publications in international conferences and journals are almost assured thanks to the amount of partners and their expertise. Moreover, mobility actions, which will be carried out within this work package, will increase the interaction among the research groups involved in the work package, which is a secondary objective of this Network of Excellence.

The following graph shows the workpackage performance in terms of publications, exchange visits and project proposals, showing that the workpackage is in good standing.