SEVENTH FRAMEWORK PROGRAMME

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Abstract:

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

There are **eighteen** partners involved in this workpackage and **nine** joint activities are proposed

Keyword list:

Disclaimer

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1. Executive Summary

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

There are 18 partners involved in this workpackage participating in 9 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 has worked on the QoS provisioning in these hybrid technologies.

2. Introduction

The collaboration in the work package "Edge-to-core adaptation for hybrid networks" is focused on the edge-to-node adaptation in hybrid networks. This deliverable summarizes the work done in this WP.

This document is structured as follows: firstly, it shows a list of the partners involved in the work package and of the joint activities. Then, the joint activities results are described. Finally, this report is concluded in the last chapter.

3. Participants

There are eighteen partners involved 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	1,3,8	Spain
11	UAM	9, 10	Spain
12	UC3M	10	Spain
13	UPC	1,7,10	Spain
14	UPCT	6	Spain
15	UPVLC	2	Spain
19	AIT	1,6	Greece
21	RACTI	2,3,7	Greece
27	FUB	5	Italy
29	POLIMI	10	Italy
32	DEISUNIBO	3	Italy
33	UNIMORE	3	Italy
34	UNIROMA1	5	Italy
42	BILKENT	3,7	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		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	Techniques to design optimized transport over optical network	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, there are nine joint activities in this work package. The JAs 3 “Dynamic Multi-Queue Burst Assembly schemes for TCP performance enhancement” and 4 “New assembly schemes taking into account the number of flows and their flow window size.” reported in the previous deliverable have been merged into the new JA 3 “Techniques to design optimized transport over optical network”, because the research topic and partners were very similar. In order to keep the same numbering of the JAs, there is no JA4 and the rest of the JAs keep the same numbering than in the deliverable 24.2.

4.1 JA1 “OBS routing algorithms for resilient and dynamic network scenarios”

Participants: AIT, TID, UPC

Responsible person (please include email): Mirosław Klinkowski (mklinkow@ac.upc.edu)

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

1. Objectives

The main goal of this joint activity was to develop mechanisms, mainly routing algorithms but also control mechanisms at the edge node, for efficient transport of data traffic in optical burst switching (OBS) networks under dynamic traffic conditions. Different research problems have been addressed:

- Comparison of performance of routing algorithms in two alternative OBS network architectures,

- Comparative performance evaluation of several deflection routing based techniques,

- Adaptive burst admission and forwarding in OBS networks,

- A quasi-synchronous OBS network operation,

- Backhauling Wireless Broadband traffic over OBS.

2. Summary of achieved results

AIT

Emerging wired broadband access technologies such as VDSL (Very High Speed Digital Subscriber Line) and Passive Optical Networks (PONs) are able to provisionally or in the long term sustain the growth in traffic requirements in the access segment. However, there are specific deployment scenarios that render wireless broadband access solutions more competitive in terms of capitalization and operational expenses compared to wired counterparts. This is for example the case where deploying a wired access network infrastructure maybe too costly or for various reasons undesirable. In addition there may be cases requiring provisioning of high-rate access to sparsely populated areas or in regions with relatively under-developed networking infrastructure. It is also straightforward that specific network access patterns, namely nomadicity and mobility, and at high data rates can be only achieved through wireless broadband. Obviously, this emerging increase in capacity in the access segment has to occur in accordance with a growth of the capacity in the metro/core segment.

Motivated by the above, our work [1] focused on the seamless integration of two technologies that exhibit the potential of constituting integral parts of the architecture of the Future Internet supporting convergence of wired and wireless network segments at the service level. These are a wireless broadband access technology and more specifically WiMAX integrated with an aggregation metro network solution based on Optical Burst Switching (OBS). In this context, we proposed a sample architecture employing this composite network solution and elaborated in various issues that need to be addressed for such an integrated approach to meet service-level requirements, namely support for end-to-end QoS, service continuity under mobility, nomadicity and load-balancing. Beyond the architectural specification, we implemented a proof-of-concept simulation model realizing the proposed scheme. Using this simulation framework, we produced evaluation results on the benefit of matching standard WiMAX service class specifications with service differentiation in OBS burst assembly.

UPC

In the first year of the project the research group of UPC 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 frequently referenced OBS

network architectures, namely, in conventional OBS (C-OBS), 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. 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. The detailed results are presented in a JLT 2009 journal paper [2].

In 2009 the research group of UPC was continuing the study on routing algorithms, in particular, performing a comparative evaluation of different deflection routing based techniques applied to OBS networks. In this study, the E-OBS architecture was considered and, under this environment, several effective routing strategies proposed in the literature were applied, namely deflection routing, reflection routing, reflection-deflection routing and multi-topology routing. The aim of this study was to analyse all these techniques considering both asynchronous and synchronous burst arrivals and compare their benefits. The comparison has been performed using 10 different 20-node network topologies. The obtained results highlight that the relative gain of the synchronous case over the asynchronous one is dependent of the nodal degree of the network. Between the algorithms, the reflection-deflection routing is the one with the lower burst loss probability. The results are presented in the ICTON 2009 conference paper [3].

The next research topic which was addressed in 2009 concerned the problem of controlling the performance of an OBS network in presence of non-stationary traffic demands. As a result, a joint burst admission control and forwarding mechanism that operates in core nodes was proposed. This mechanism dynamically adapts its behaviour according to the feedback messages received from network nodes. By not forwarding certain bursts not complying with given requirements, an admission control is implicitly made. Moreover, by forwarding bursts to appropriately selected nodes, traffic balancing is achieved. The advantageous effects of the proposed mechanism can additionally be amplified by granting extra offset time to the burst. The benefits provided by this mechanism were supported by numerical results. The detailed results are presented in the ICTON 2009 conference paper [4].

Finally, the last part of research concerned a quasi-synchronous OBS network operation. OBS, in principle, can operate under both asynchronous and synchronous burst departures. Although the asynchronous approach is generally assumed in OBS owing to its simplicity and low technical requirements, it has been shown that performance improvements, in terms of the overall burst loss probability, can be achieved under synchronous operation. Indeed, when effective contention resolution policies (e.g., deflection routing) are applied such improvements are significant. Since perfect synchronisation is not a viable solution, we proposed a novel operation mode with relaxed technical requirements, the quasi-synchronous (QS) operation. Assuming that the process of burst arrivals is Poisson, an exact analytical expression of the burst loss probability under QS operation has been derived for a single-wavelength scenario. The analysis was completed with numerical results that validated the accuracy of the developed model. Furthermore, the issue of not having well aligned clock information between network nodes was considered by proposing a novel re-synchronisation mechanism for OBS networks. Eventually, an evaluation study of the QS operation under different deflection routing techniques was performed. The obtained results show that the novel QS approach can achieve significant performance benefits with respect to the asynchronous operation. Preliminary results of this study were presented during the ICTON

2009 conference, whilst an extended version of the paper will be submitted to the OSN journal [5].

TID has no specific results to report for this JA1 activity.

Mobility actions: -

Meetings: Email and phone conference with the partners are used for the JA coordination.

Papers:

[1] K. Katrinis, A. Tzanakaki, S. Dweikat, S. Vassilaras, R. Nejabati, D. Simeonidou and G. Zervas, "Backhauling Wireless Broadband Traffic over an Optical Aggregation Network: WiMAX over OBS", in Proceedings of the International Workshop on Optical Burst/Packet Switching (WOBS), Madrid, Spain, September 2009.

[2] M. Klinkowski (UPC), D. Careglio (UPC), J. Solé-Pareta (UPC), and M. Marciniak (NIT), "Performance Overview of the Offset Time Emulated OBS Network Architecture", *OSA/IEEE Journal of Lightwave Technology*, vol. 27, no. 14, pp. 2751-2764, July 2009, ISSN: 0733-8724.

[3] O. Pedrola (UPC), S. Rumley (EPFL), D. Careglio (UPC), M. Klinkowski (UPC), P. Pedroso (UPC), J. Solé-Pareta (UPC), and C. Gaumier (EPFL), *A performance survey on deflection routing techniques for OBS networks*, ICTON 09 Proceedings, Island of São Miguel, Azores, Portugal, June 2009.

[4] S. Rumley (EPFL), O. Pedrola (UPC), M. Klinkowski (UPC), P. Pedroso (UPC), C. Gaumier (EPFL), D. Careglio (UPC), and J. Solé-Pareta (UPC), *Adaptive Burst Admission and Forwarding in OBS Networks*, ICTON 09 Proceedings, Island of São Miguel, Azores, Portugal, June 2009.

[5] O. Pedrola (UPC), S. Rumley (EPFL), D. Careglio (UPC), M. Klinkowski (UPC), C. Gaumier (EPFL), and J. Solé-Pareta (UPC), *Performance overview of the Quasi-Synchronous operation in OBS networks*, to be submitted to the OSN Journal.

[6] Oscar González, Anna Maria Guidotti, Carla Raffaelli, Kostas Ramantas, Kyriakos Vlachos, "On transmission control protocol synchronization in optical burst switching", Springer, J. of Photonic Network Communication, Volume 18 Number 3, is pp. 323 - 333, March 2009

Other information:

Overall progress and future work:

AIT is going to work on burst scheduling algorithms at OBS edge routers.

All the tasks planned by UPC in scope of this activity have been completed and no future work is expected apart from the publication of selected results in the OSN journal paper (the paper is already prepared and will be submitted soon).

4.2 JA2 "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 during the Mobility Actions (MA) and active collaborative work between the partners.

During the **first mobility action**, 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. 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.

During the **second mobility** (made by two MAs) action the research activities focused on the design and implementation of a realistic test scenario for video transmissions over OBS, as well as a simulation scenario to compare results. The work carried out, during the second MA, focused on the extension of the OBS testbed of UoEssex to include losses at the core, which will lead to measurable distortions of transmitted video traffic. This can be achieved by emulating background traffic at the core, which competes with video traffic.

A new FPGA module was implemented for the OBS testbed, which generates the background traffic at the core. The background traffic consists of exponentially distributed ON and OFF periods, and competes with video bursts. This module was implemented in VHDL hardware description language, and uses floating point arithmetic operations to generate exponentially distributed random variables. Additionally, a study about the test-bed design, capabilities and physical parameters was made in order to gain required knowledge to design and implement a comparable simulation scenario.

After the three mobility action were carried out, a new multi-class preemptive scheduling scheme was proposed. It was demonstrated that proposed scheduling scheme can actually provide QoS differentiation in different service classes, in a very flexible and efficient way, parameterized by a simple parameter, which expresses guaranteed preemption probability. Proposed scheduling scheme clearly performs better than LAUC-VF with a slightly increased complexity

The performance evaluation of the proposed scheme is performed on an OBS network modeled in the Network Simulator (ns-2) environment. It was study the effectiveness of the proposed scheme in the presence of two traffic types, namely best effort data traffic and real time video traffic, separated in two distinct classes of service. The best effort traffic is generated with fractal traffic generators, and specifically supFRP [1] self-similar process, to mimic the dynamics of real-world internet traffic. Video traffic on the other hand is generated by trace-driven video sources, which are part of the Evalvid framework [2]. Video traffic consists of video streams encoded with MPEG4 coded, the most commonly used at the internet. Through Evalvid framework, we were able to obtain perceptual metrics of video traffic, such as MOS score and PSNR, which can give us a realistic estimation of the video quality which is streamed over a lossy channel.

The proposed preemptive scheduling scheme employs a variation of the Preemption Drop Policy (PDP, described in [3]) which is a probabilistic strategy for provisioning flexible priorities. In an OBS node employing PDP, a free wavelength can be reserved by a burst belonging to any service class (no access restriction techniques are employed) but if all wavelengths are occupied, preemptions can be performed, according to a predefined policy. The preemption policy is parameterized by the definition of *P*, which expresses the probability of a successful preemption. That is, whenever a reservation request for a new burst arrives, this new burst has a probability P to preempt an already scheduled overlapping burst. The preemption policy has to consider the sizes of the two overlapping bursts, as well as their priority classes. In a strict priority system, a higher priority burst always preempts an already scheduled one of a lower priority. However, this policy has a very limited flexibility, and can lead to a significant throughput loss of the low priority class. In this work, we propose a flexible preemption scheme, based on the PDP, where the relative burst sizes are considered in the preemption decision too. Our goal is to capture the tradeoff between throughput maximization and quality degradation.

Preemption probability (P) as defined in the proposed preemption policy depends on the relative significance of two bursts competing for the same resources. The significance of a burst depends on its length (a large burst has a more significant impact on throughput than a smaller one when dropped) and the priority of the service class it belongs to. So, the probability of a class-1 burst preempting a class-0 burst depends partly on their relative burst size, and partly on a constant preemption probability, P_0. P_0 parameter leads to class separation, and provides performance guarantees to high priority bursts, regardless of their size. It must be added here that, a class-0 burst never preempts a class 1 burst, whereas between two bursts of the same service class the smaller one is always preempted. The definition of *P*, given that B_{new}, $CoS_{B_{new}}$ is the size and class identifier of the incoming burst respectively and B_{old}, $CoS_{B_{old}}$ is the size and class identifier of an already scheduled overlapping burst, preemption probability P is defined as follows:

$$P = \begin{cases} P_0 + (1 - P_0) \cdot \dfrac{B_{new}}{B_{old}}, & CoS_{B_{new}} > CoS_{B_{old}} \\ & B_{new} > B_{old} \\ 1, & B_{new} < B_{old} \\ 0, & \end{cases}$$

[1] M. Yuksel, B. Sikdar, K.S. Vastola, and B. Szymanski, 'Workload generation for ns Simulations of Wide Area Networks and the Internet', in proceedings of CNDS Conference, 2000

[2] J. Klaue, B. Rathke, and A. Wolisz, "EvalVid - A Framework for Video Transmission and Quality Evaluation", In Proc. of the 13th International Conference on Modelling Techniques and Tools for Computer Performance Evaluation, Urbana, Illinois, USA, September 2003.

[3] H. Øverby, N. Stol, Providing quality-of-service in optical packet/ burst switched networks with the preemptive drop policy, In: Proceedings of the Third International Conference in Networking, (ICN), vol. 1, pp. 312–319, 2004

Mobility actions: (3)

Tito Raúl Vargas (UPVLC) visit RACTI. Patras, Greece. 4 weeks. 24 May to 22 June 08.
Tito Raúl Vargas (UPVLC) visit UEssex. Colchester, UK. 5 weeks. 16 Nov - 20 Dec. 08.
Kostas Ramantas (RACTI) visit UEssex. Colchester, UK. 5 weeks. 16 Nov - 20 Dec. 08.

Meetings:

3 meeting during Broadnets 2009. Madrid.

4 skype meetings, September - October 2009.

1 meeting during the BONE Plenary meeting, Poznan, 2009.

Constant communication via e-mail during 2009.

Papers:

1 Joint paper BroadNets 2009.
3 papers: ICTON-08, WOBS/BroadNets 08, URSI-08 (Spain).

Kostas Ramantas, Tito Raúl Vargas, Juan Carlos Guerri and Kyriakos Vlachos. **A preemtive scheduling scheme for flexible QoS provisioning in OBS networks.** Sixth International Conference on Broadband Communications, Networks, and Systems - Broadnets 2009, September 14 – 17, 2009. Madrid, Spain.

T.R. Vargas, J.C. Guerri, S. Sales. ***Efectos del algoritmo de ensamblado basado en tamaño sobre el tráfico de vídeo en redes OBS***. XXIII Simposium Nacional de la Unión Científica Internacional de Radio - URSI 2008. 22 – 24 de Septiembre. Madrid. España.

T.R. Vargas, J.C. Guerri, S. Sales. ***Effect and Optimization of Burst Assembly Algorithms for Video Traffic Transmissions over OBS Networks***. Fifth International Conference on Broadband Communications, Networks, and Systems - Broadnets 2008. International Workshop on Optical Burst/Packet Switching – WOBS 2008. September 8 – 11, 2008. London, UK.

T.R. Vargas, J.C. Guerri, S. Sales. ***Optimal configuration for size-based burst assembly algorithms at the edge node for video traffic transmissions over OBS networks.*** 10th Anniversary International Conference on Transparent Optical Networks - ICTON 2008. June 22-26, 2008. Athens, Greece.

Overall progress and future work:

The first mobility action of the JA was carried out with the following results:

- It was made an improvement of the OBS - ns2, Combining our simulators and adding new modules that make possible video evaluation.

- Evaluation of video transmission over OBS networks was carried out. Using as a traffic source traces from typical video samples and using a complete OBS network scenario. It was implemented background traffic generators for the OBS – ns2.

- A Preemptive Scheduling Scheme for flexible QoS provisioning in OBS networks was proposed as a QoS mechanism for video traffic.

- As a final result one joint paper.

Tow other mobility actions were carried out, the research activities were held at University of Essex in the photonic network laboratory. The collaboration was between RACTI, UPVLC and UoEssex.

- The work carried out, during the MA, focused on the extension of the OBS test-bed to include losses at the core, which will lead to measurable distortions of transmitted video traffic.

- A new FPGA module was implemented for the OBS test-bed, which generates the background traffic at the core.

- A study about the test-bed design, capabilities and physical parameters, was made to design and implement a comparable simulation scenario.

Future work:

Publish a join journal paper based in the preemptive scheduling scheme for flexible QoS in OBS networks. More video quality evaluation metrics will be presented and the impact using such new scheduling algorithm.

One mobility action will be held. To evaluate the FPGA module that generates background traffic at the core and asses video quality transmissions. Extend the aggregation mechanism of the test-bed for Video application. And one joint paper will be published as final result.

4.3 JA3 "Techniques to design optimized transport over optical networks"

Participants: RACTI, UNIBO, UNIMORE, TID, BILKENT

Responsible person (please include email): kvlachos@ceid.upatras.gr

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

The efficient transmission of TCP traffic over OBS networks is a challenging problem, due to the high sensitivity of TCP congestion control mechanism to losses. In this work, we propose solutions to this problem, through the burst assembly and scheduling mechanism of OBS. Another issue investigated is the synchronization phenomenon for TCP flows which happen when legacy access networks are interconnected to a Optical Burst Switched (OBS) network. In addition, different architectures for edge nodes in OBS networks have been investigated focusing, in particular, on the assembly function.

RACTI investigated ways to achieve performance enhancements for TCP traffic, in terms of throughput maximization and fairness, taking into account intrinsic details of TCP protocol in the burst assembly and scheduling process. RACTI designed TCP-friendly burst assembly and scheduling protocols and test, whether these can achieve a significant performance advantage. In particular, RACTI proposed a new multi-class TCP-aware preemptive scheduling scheme that supports strict priorities and performed an in-depth study through mathematical modelling and simulation. For their evaluation, we have performed some real-world experiments using Network Simulator (ns-2) environment with synthetic traffic representing typical internet use, combining long-lived TCP connections (ftp transfers) and short-lived connections (mostly http traffic or small file transfers). DFL gain, as described in [2] increases proportionally to the square root of the number of segments per burst, so large assembly timers will generally lead to increased correlation gains. On the other hand, RTT increases linearly with the assembly timer, as $RTT = RTT_0 + 2T_{MAX}$. Thus, there exists a trade-off between maximizing DFL gain and minimizing delay penalty (denoted by RTT) for

a specific TCP flow, based on its congestion window and there is an optimal assembly timer that maximizes its TCP throughput. On these grounds, multi-class congestion window based assembly scheme was proposed in [4], which dynamically assigns TCP flows to burst assembly classes with different timers, according to their TCP congestion window, as denoted by Eq. (1).

$$T_{assembly\ time} = \begin{cases} 1msec & if\ window < B \\ 5msec & if\ B < window < C \\ 10msec & if\ window > B \end{cases} \quad \textbf{Eq. (1)}$$

In order to satisfy both design goals, i.e. ensuring fairness and maximizing throughput, we propose the use of a TCP-aware scheduling algorithm. RACTI proposed, a preemptive scheduling algorithm PLAUC-VF based on LAUC-VF. PLAUC-VF stores burst length, class of service, as well as a unique burst identifier for all scheduled bursts. This information is typically required for preemptive algorithms to base preemption decisions, and make the reconfiguration of OBS nodes possible.

The PLAUC-VF variation used in this paper has the ability to keep track of and preempt the two most recent scheduled bursts. Thus, the channel selection phase remains identical to the one used in LAUC-VF, ensuring that on average the time complexity remains low. If the channel selection fails, then the more computationally demanding preemption phase follows.

More information can be retried from [1].

To further enhance OBS flexibility, UNIMORE and UNIBO partners investigated the case when hybrid multi-granular core nodes can be employed. Examples of this kind of switching solution are described in literature and test-beds have been set up to prove the feasibility of this concept. The main idea behind multi-granular hybrid switching is to support multi-granular application requirements with different technologies which are characterized by different configuration times. The main target of these design concepts is to achieve short term feasibility while maintaining low switch costs. These switches are said hybrid because they employ different technologies like MEMS and SOAs to implement slow and fast switching paths, respectively. As a consequence of hybrid switch solutions, paths with different set up delays are available in the OBS network. One of the research activities in this field is aimed at optimizing shared usage of these paths. As far as the OBS network design, hybrid solutions impact on the values of the base offset that takes into account the time needed to set up a path through the core switches. Longer offset times are needed in the slow path case than for fast paths. Different offset times differently influence upper layer performance and these effects are worth to be evaluated. The employment of different optical technologies in core nodes implies different set-up times for the corresponding switching matrices. This means that different offset times have also to be considered, depending on the kind of connection datagrams belong to. We assume as fast connections all connections whose datagrams are put in bursts which are switched in core nodes employing the fastest optical technologies, which means shortest set-up times, and as slow connections when the related bursts are switched employing slower optical technologies, which leads to longer set-up times. Therefore, it is necessary that the hybrid time-volume based assembly algorithm behaves differently for fast and slow connections. It is then assumed that for slow connections $T_{max}= T_{max\text{-}slow} > T_{max}= T_{max\text{-}fast}$, used for fast connections. Also, it is assumed that slow connections carry long and medium size bursts whereas fast connections are used for short bursts. To this end, $L_{max}= L_{max\text{-}slow} > L_{max}= L_{max\text{-}fast}$. Numerical investigations [2] show that for low burst losses, fast connections can provide remarkable higher TCP throughputs than

slow connections, whereas for burst losses greater or equal to 0.001 the average throughput is roughly the same, despite of different transmission rates and technologies.

Another issue investigated is the synchronization phenomenon for TCP flows which happen when legacy access networks are interconnected to a Optical Burst Switched (OBS) network. Different architectures for edge nodes in OBS networks have been investigated focusing, in particular, on the assembly function.

Two mixed flow hybrid time-volume based assembly algorithms which operate on multi-queue systems have been proposed and evaluated. The former is based on two queues with the distribution of N TCP flows to one of the two and the latter operates on N/5 queues, limiting to five the maximum number of TCP flows involved in a possible burst loss.

Results show that by using proper multi-queue assembly schemes which reduce the synchronization effect is possible to improve the TCP throughput as much as twice the value obtained with single queue schemes.

BILKENT partner focused on adaptive burst assembly algorithms and the congestion in OBS control plane. These two problems have been separately studied in the literature so far. It has been shown that contending bursts at a core optical switch in an OBS network may experience unfair loss rates based on their residual offset times and burst lengths, that are called path length priority effect (PLPE) and burst length priority effect (BLPE), respectively. BILKENT proposed a new adaptive timer-based burst assembly algorithm (ATBA) which uses loss rate measurements for determining the burst generation rates of traffic flows in order to mitigate the undesired effects of PLPE and BLPE. ATBA uses a constant burst generation rate per ingress node in order to constrain the congestion in the control plane and distributes this burst generation rate among traffic streams so that traffic flows experiencing larger burst loss rates due to PLPE and BLPE can use higher burst generation rates resulting in shorter bursts. Using ATBA, we show that the fairness index of the burst loss rate distribution significantly improves with respect to the case of using equal burst generation rates. In addition to achieving better fairness, it is also shown that the total goodput of the OBS network improves by 5% compared with the case without using ATBA.

Mobility actions: 1

Meetings: Teleconferences were carried for the coordination of the work

Papers:

[1] Kostas Ramantas and Kyriakos Vlachos, “A combined TCP aware scheduling and assembly scheme for OBS networks”, in proceeding of WOBS 2009, Madrid, Spain vol. 1, pp. 1-6.

[2] M. Casoni , C. Raffaelli, “TCP Performance over Optical Burst-Switched Networks with Different Access Technologies”, OSA/IEEE Journal of Optical Communications and Networking (JOCN), No. 1, pp. 103-112, June 2009.

[3] M. Casoni C. Raffaelli, "TCP Performance in Hybrid Multigranular OBS Networks", Proc. of IEEE Workshop on Optical/Burst Switching 2009, Madrid (SP), September 14, 2009.
[4] M. Casoni, "TCP Performance in Hybrid EPON/OBS Networks", Proc. Of 13th International Conference on Optical Networking Design and Modeling - ONDM 2009, February 2009.

Other information:

Overall progress and future work:

Partners will continue the work during Y3 of the project and will further investigate issues for optimizing performance of TCP over OBS networks.

4.4 JA5: "The OTDM Add-Drop technique to overcome granularity problems in optical networks"

Participants: V. Eramo, A. Cianfrani (Uniroma1), F. Matera, L. Rea, A. Valenti (FUB), A. Germoni (Coritel)

Responsible person: Vincenzo Eramo (UNIROMA1), Vincenzo.Eramo@uniroma1.it

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

Granularity Problem in Optical Networks

The Optical Cross Connect (OXC) cost is little dependent on the bit rate carried out on each wavelength but it is strongly dependent on and increases with the number of lighpaths to be switched. The number of switched lighpaths and hence the realization cost of an OXC is reduced by increasing the bit rate carried out on each lighpath. If each logical link of an IP network were mapped on a lighpath, the increase in bit rate carried out on each lighpath would decrease the connectivity degree of the logical topology. Consequently the switching bandwidth required to each IP router may be too high and electronic technology may not be able to support this switching bandwidth. According to these considerations, it is strongly desirable to maintain different the logical and lighpath bit-rates and to implement solutions able to groom lower bit rate logical connections on each lighpath.

Super-Lightpath Solution

The solution is based on Optical Time Division Multiplexing (OTDM). Its operation mode is the following:

i) the big bandwidth of each Lighpath is split in D sub-channels by using OTDM; D is referred to as multiplexing degree.

ii) each Lighpath can carry out up to *D* logical connections originating from the same IP router; because a lighpath can carry out more than one logical connection, it is referred to as Super-Lighpath.
iii) each destination IP router extracts the information carried out on its sub-channel.

Notice that the introduced solution is very simple and does not increase the OXC realization cost because the OXC is designed so that only wavelength switching and not Time-Slot switching is performed.

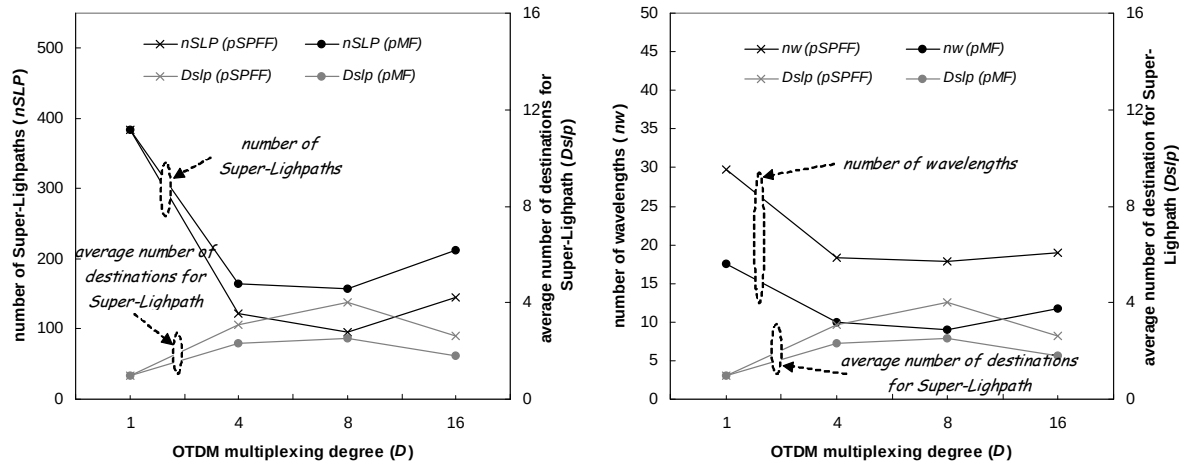
I° Year's Activities and Results

To increase the Super-Lighpath solution efficiency we proposed a new network architecture in which the edge nodes are able to perform OTDM Add-Drop function. 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. With this solution it is possible the sub-channels reuse and to save in terms of used resources. Two heuristics have been proposed to solve the Super-RWA (Routing and Wavelength Assignment) problem. Numerical results show a gain up to 27% in the number of wavelengths required to solve the Super-RWA problem when Add-Drop Super-Lightpath solution is adopted.

II° Year's Activities and Results

We proposed two modified heuristics to solve Super-RWA (Routing and Wavelength Assignment) problem so that physical impairments are considered during Super-Lightpath routing. Physical impairments have been evaluated through a physical model implemented in Fondazione Ugo Bordoni and Super-RWA problem has been solved by fixing the Super-Lightpath length as a function of channel bit rate. Both the introduced heuristics allow the routing of Super-Lighpaths with guaranteed Bit Error Rate (BER). The first heuristic, referred to as physical Shortest Path First First (*pSFF*), minimizes the Super-Lighpath length in terms of number of hops and uses the first available wavelength. In the Maximum Fill (*MF*) heuristic, a wavelength is selected and the maximum number of Super-Lighpaths is routed by using this wavelength. The effectiveness of the heuristics has been evaluated on some physical topologies and when random logical topologies with several connectivity degrees *p* are considered. The RTWA problem under physical impairments has been solved versus the OTDM multiplexing degree *D*. The resource consumption is characterized by both the number of Super-Lightpaths routed and the number of used wavelengths. As a matter of example we report some results in Fig. 1. We consider a random logical topology with connectivity degree *p* equal to 16. The bit-rate carried on each logical link is 2,5 Gbit/s. We consider the COST 266 physical topology with 26 nodes using G.655 fiber in which the Optical Amplifiers are located every 100 m. Chromatic dispersion compensators are used in each segment. We compare the cases in which *D*=1,4,8,16 logical connections are carried out on each Super-Lighpath. That leads to have the bit-rates carried out on each Super-Lighpath equal to 2.5, 10, 20 and 40 Gb/s for *D*=1,4,8,16 respectively. We report in Fig. 1 the number of Super-Lighptahs (*nSLP*), the number of used wavelengths (*nw*) and the average number of destinations for Super-Lighpath (*Dslp*) when *pSPFF* and *pMF* heuristics are taken into account. From the results reported in Fig. 1 we notice that when physical impairment is taken into account, we have an optimum value of *D* in which both the number of routed Super-Lighpaths and the number of wavelengths is minimized. The optimum value *D* equals 8 for *pSPFF* that requires the routing of 96 Super-Lighpaths and the use of 18 wavelengths. As we can see this optimum value for *D* is reached when the maximum number of destinations for each Super-Lighpath is carried out. The maximization of the number of destinations carried out on each Super-Lighpath for an intermediate value of *D* is due to the fact that when *D* is small the number of destinations is limited by *D* itself; on the contrary when *D* is high, the

number of destinations is limited by the physical impairment that makes Super-Lighpaths shorter. Consequently a number of destinations smaller than *D* may be reached.



(a) (b)

Figure 1 Number of Super-Lighpaths (*nSLP*) (a) and number of wavelengths (*nw*) (b) as a function of the multiplexing degree *D*. The 266 COST network with 26 nodes and random logical topology with connectivity degree *p*=16 are taken into account. The bit-rate carried on each logical link is 2,5 Gbit/s.

Mobility actions:
Antonio Cianfrani CIANFRANI (UNIROMA1) (3 weeks) from UNIROMA1 to FUB (July 2008)
Valenti Alessandro (FUB) (3 weeks) from FUB to UNIROMA1 (July 2008)
Germoni Angelo (Co.Ri.Tel.) (1 week) from Co.Ri.Tel. to UNIROMA1 (November 2009)

Meetings:
2 at UNIROMA1: June 15th 2008, September 20th 2008
1 at FUB: July 18th 2008

Papers:

[1] V. Eramo, M. Listanti, A. Cianfrani, F. Matera, L. Rea: **Performance Evaluation for Optical Networks with OTDM Add-Drop functionality**, ICTON 2008, Athens (Greece), June 2008.

[2] V. Eramo, M. Listanti, A. Cianfrani, A. Germoni, F. Matera, A. Germoni: **Routing and Wavelength Assignment Problem in OTDM/WDM Networks with Physical Impairments**, NOC 2009, Valladolid (Spain), June 2009.

Overall progress and future work:

The OTDM/WDM network performance will be evaluated in dynamic traffic conditions.

4.5 JA6 "Traffic conditioning and congestion control in OBS/OPS networks"

Participants: UPCT

Responsible person (please include email): Pablo Pavon Mariño, pablo.pavon@upct.es

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

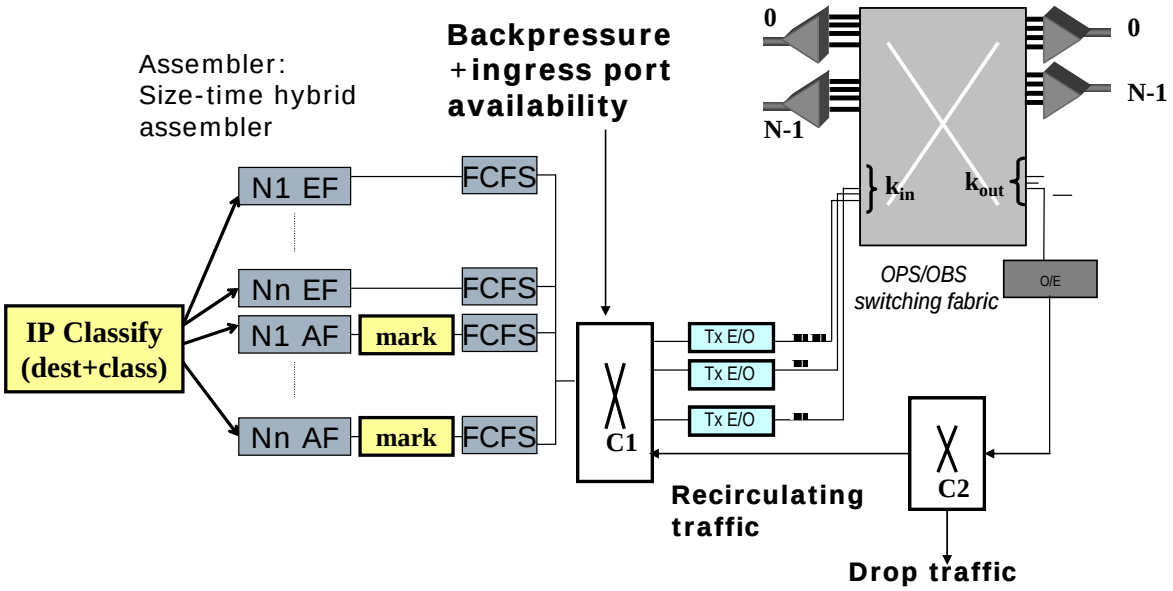
The objective of this JA is the study of possible techniques for traffic conditioning and congestion control which could be suitable for OPS/OBS networks, focusing on the edge node.

In the first stage of the JA, the expertise of the interested partners was collected. Past and ongoing work in the topic was surveyed. UPCT focused on OPS networks with the following properties.

In a first step a simulation tool was developed, as a modification of the oPASS switching tool [Bue05]. 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, thanks to the hash-table-based management of the event list given by the OMNeT++ kernel.

The work continued with a survey of the traffic shaping proposals in Optical Packet/Burst Switching networks. This work has been disseminated in the publication [Can08].

The work has led to the proposal of a node architecture, for a potential network based on the DiffServ architecture, according to RFC 3270 (for DiffServ-MPLS networks). Next figure described the node scheme proposed:



Input traffic is assumed to be composed of IP packets. They are classified at the input following a conventional destination-class scheme, present in MPLS LER nodes. An optical packet/burst assembler is dedicated for each of the possible LSPs. After assembled, the packets are directed to a FCFS electronic queue. In the figure, two classes are defined EF (Expedited Forwarding) and AF (Assured Forwarding). They correspond to two conventional PSCs (PHB scheduling classes). AF traffic is marked following an IN/OUT policy. That means that bursts of traffic which exceed the bandwidth contract for a given LSP produce optical packets/bursts marked as OUT. These packets are supposed to receive a worse priority in the nodes.

The C1 electronic switch with its corresponding scheduling algorithm, are in charge of selecting the queues which are going to be served. The candidate packets are those at the head of the queues from the "add" traffic, and from the recirculating traffic, coming from the electronic switch C2. The number of injection ports kin and of egress ports kout in the switch, are to be dimensioned.

Some simulations studies have been carried out, following the previous scheme. The benchmark has been the reference NSFNET topology. Interesting results have been obtained for the case in which the packets are of fixed size, and are optically aligned at the switch inputs. The scenario defined, injected a 10% of EF traffic and a 90% of AF traffic. Results showed that a low amount of optical buffering was required (2-3 FDLs) to obtain a target packet loss of 10^{-4} for the AF IN packets (that is, the traffic inside the contract).

The definition of the node architecture, together with the simulation tool developed for the evaluation of the shaping schemes, are the main outcomes of this JA.

[Bue05] M.V. Bueno-Delgado, J. A. Veiga-Gontán, P. Pavón-Mariño, J. Garcia-Haro, "oPASS: A simulation tool for the performance evaluation of Optical Packet Switching architectures", Proc. of the European Symposium on Simulation Tools for Research and Education in Optical Network (STREON 2005), Brest (France), October 2005.

[Can08] M.D. Cano, P. Pavon-Mariño, A. Ortuño-Manzanera, J. Garcia-Haro, " Traffic shaping trends in optical packet/burst switching networks" , Proceedings of the 1 0th International Conference on Transparent Optical Networks (ICTON 2008), vol. 3, pp. 134-137, Athens (Greece), June 2008.

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, several conference calls have been scheduled, mostly during the first year.

Papers:

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.

Other information:

Overall progress and future work:

4.6 JA7 "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 (Bilkent, UPC, RACTI) of this project carried out a survey on Quality of Service (QoS) differentiation mechanisms that are proposed for Optical Burst Switching (OBS) networks. For this purpose, existing QoS differentiation mechanisms are first classified based on whether one-way or two-way signaling is used. Moreover, one-way QoS differentiation mechanisms are further 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.

Two basic mechanisms are identified for edge-based QoS differentiation, namely offset time-based and burst length-based differentiation. On the other hand, preemptive dropping, threshold-based dropping, and intentional dropping are identified as main core-based OBS mechanisms. Under a common topology and scenario, these QoS mechanisms are thoroughly studied

i) for UDP traffic

ii) TCP traffic

for which the performance metric was burst loss probability for the former case and TCP level throughput for the latter case. The impact of two-way signaling for QoS in OBS networks is also studied for a recently proposed two-way QoS differentiation mechanism proposed by one of the partners. This joint work was not only meant to be a survey but also a means of disseminating new research results for QoS differentiation in OBS networks.

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 low priority traffic especially for high loads stemming from phantom bursts. The results obtained for TCP traffic suggest that increased offset differences between the high priority and low priority 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 (which was not the case for the offset-based differentiation with UDP offered traffic). These results lead us to believe that provisioning of offset-based QoS is crucial especially when the traffic is TCP-based. Burst length based differentiation proves to be very effective for TCP traffic since goodput of high priority flows significantly increase as a result of both decreasing delay and decreasing loss rate. Therefore, we conclude that the burst-length based differentiation is more suitable for TCP offered traffic compared to offset-based differentiation. 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: None

Meetings: None

Papers: Nail Akar, Ezhan Karasan, Kyriakos G. Vlachos, Emmanouel A. Varvarigos, Davide Careglio, Miroslaw Klinkowski, Josep Sole-Pareta, "A survey of quality of service differentiation mechanisms for optical burst switching networks," *Optical Switching and Networking*, Volume 7, Issue 1, Pages 1-11, January 2010.

Other information:

Overall progress and future work:

4.7 JA8 "Design and evaluation of a periodic OBS burst reordering model for TCP throughput estimation"

Participants: Sebastian Gunreben (UST-IKR), Oscar Gonzalez de Dios (TID)

Responsible person (please include email):
Sebastian Gunreben (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 patterns in a general OBS network delay environment and second we derive the periodic reordering model for the TCP performance.

In the first reporting period, we focused on the classification of reordering pattern in packet and burst switched networks. We identified three different metrics, which suited to describe packet reordering: (1) Reordering ratio to indicate the amount of reordering in a network, (2) Reordering extent to indicate the relative shift of packet in a stream. This measure is necessary to quantify the buffer size at the receiver. (3) N-reordering metric to quantify the number of duplicate acknowledgements violations of TCP. In [1], we introduced our reordering model to evaluate these three metrics for deterministic traffic (voice traffic). Besides this, the model is also valid for Poisson traffic arrivals. [1] shows in detail the extensive mathematical description of this model.

In the last reporting period, we further detailed our reordering model with respect to limiting cases with respect to other traffic characteristics. Our reordering model bases on the assumption on deterministic traffic of a given load level. If this requirement is fulfilled, we are able to calculate precisely the value of the above metrics to quantify the reordering pattern.

We changed the assumptions on the traffic characteristic with respect to the traffic load and traffic model. Our study included traffic loads, which were larger and smaller than the original considered traffic load. Additionally, we changed the traffic model from a deterministic traffic model towards a general traffic model. We published our findings in detail in [2]. Inhere, we gave a short summary:

We applied our reordering traffic model on a general traffic model. We found that if the general traffic model and the deterministic traffic model have the same mean value, the deterministic traffic model always creates more reordering than any generic traffic model. Consequently, our reordering model in combination with a deterministic traffic enables a worst-case estimation on the amount of reordering in a given reordering scenario. We included the detailed mathematical proof in [2].

The second major result considers this worst-case property with respect to changing traffic means. We found that if the model remains unchanged, a larger traffic mean rate always enables worst-case estimations for deterministic traffic with respect to a general traffic model. If the traffic mean rate is smaller than the original traffic mean rate of the reordering model, deterministic traffic does not serve for worst-case estimations anymore. In this scenario, the reordering model degrades due to the larger inter-arrival times with respect to the configuration of the model.

Mobility actions:

Meetings:

BONE Plenary Meeting - Oct 2008
Rome, 20/10/2008 - 21/10/2008

Joint Plenary meeting - June 2009
Bologna, Italy, 08/06/2009 - 09/06/2009

Papers:

[1] S. Gunreben (UST-IKR), *An Optical Burst Reordering Model for a Time-based Burst Assembly Scheme*, WOBS 2009, London

[2] S. Gunreben (UST-IKR), O. G. de Dios (TID), *Why deterministic traffic shows the highest reordering ratio*, Workshop on Optical Burst/Packet Switching, Madrid, September 2009.

Other information:

Overall progress and future work:

The Joint Activity ends with 12/2009. Open questions are the combination of the TCP model with respect to the reordering pattern characterized by the reordering metrics of above. With the reordering model, the effect on TCP may be estimated.

4.8 JA9 "Synchronous traffic and OBS"

Participants: UC3M, UAM

Responsible person (please include email): David Larrabeiti, UC3M (dlarra@it.uc3m.es)

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

This work presents a novel performance analysis of Polymorphous OBS networks, a new flavour of OBS which permits the reservation of periodic time-slots at OBS core nodes. This allows POBS to provide a flexible, yet transparent, approach for supporting the idiosyncrasies of today's most popular services over the same underlying network architecture of OBS. In POBS, the spare gaps in between synchronous TDM reservations can be used for the allocation of best-effort data bursts, leading to a more efficient utilisation of the optical capacity.

This work further shows how to extend the well-known Erlang Fixed Point algorithm to evaluate the performance behaviour of POBS networks, whereby asynchronous data bursts coexist with high-priority periodic TDM reservations. The performance evaluation algorithm is applied to a number of case scenarios, showing the benefits arisen due to the flexibility of POBS.

Mobility actions: -

Meetings: 9 coordination meetings at UC3M and UAM premises

Papers: One paper already published:

J. A. Hernández, P. Reviriego, J. L. García-Dorado, V. López, D. Larrabeiti, J. Aracil: *Performance evaluation and design of Polymorphous OBS networks with guaranteed TDM services.* IEEE/OSA J. Lightwave Technology, vol. 27, no. 13, pp. 2495-2505. (July, 2009).

Other information:

Overall progress and future work:

4.9 JA 10 "Advanced optical amplifier for OBS/OPS transmission"

Participants:

Davide Careglio and Josep Sole-Pareta – UPC

Javier Aracil – UAM

Stefano Taccheo – POLIMI (now USWAN)

Marcelo Zannin and Karin Ennser – USWAN

Responsible person (please include email): Karin Ennser (k.ennser@swansea.ac.uk)

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

The recent activities carried out are an attempt to assess the performance of burst amplification in critical chaotic cases. After laboratory investigation of these phenomena, the ongoing research aims at providing evidence for a more complete understanding. Computational simulations are the tool chosen to achieve the goal.

The simulation tool is being optimized and applied to special cases with the purpose of comparing the performance of different patterns of burst transmission.

Mobility actions:

Meetings: The coordination with the partners has been done via email and phone conferences.

Papers:

Journal Paper Accepted for Publication:

M. Zannin, K. Ennser, S. Taccheo, D. Careglio, J. Sole-Pareta, J. Aracil. *On The Benefits of Optical Gain Clamped Amplification in Optical Burst Switching Networks*. Accepted for publication in Journal of Lightwave Technology.

Conference Papers Published:

K. Ennser, M. Zannin, S. Taccheo, *Extending Reach of Passive Optical Networks through Optical Amplification*. 11th International Conference on Transparent Optical Networks, Azores, Portugal, June 2009.

M. Zannin, K. Ennser, S. Taccheo, D. Careglio, J. Sole-Pareta, J. Aracil. *Effective Amplification of Real WDM Burst Traffic Using Optical Gain Clamping*. Conference on Quantum Electronics and Laser Science, San Diego, USA, May 2008.

K. Ennser, M. Zannin, S. Taccheo, D. Careglio, J. Sole-Pareta, J. Aracil. *Optical Amplifier for Optical Burst Switching Networks*. 10th International Conference on Transparent Optical Networks, Athens, Greece, June 2008.

M. Zannin, S. Taccheo, D. Careglio, J. Sole-Pareta, J. Aracil. *BER Improvement Using Optical Gain Clamped Amplifier for Burst Transmission and Critical Cases Studies*. Optical Communication Conference, San Diego, USA, March 2009.

Other information:

Overall progress and future work: The results of the investigation will be submitted to the Journal of Lightwave Technology, as the follow up of the recent papers that were accepted for publication on this issue.

5. Conclusions

The joint activities have followed their work plan so the work package has fulfilled the objectives defined in the project technical annex.

This document shows an assessment of the work package results based on the number of meetings, papers, mobility actions and joint project proposals. There are four checkpoints were this stats has been collected: 1) Rome meeting (plenary BONE meeting, October 2008), 2) Bologna meeting (joint WP11-WP12-WP21-WP22-WP24-WP26 meeting June 2009), 3) Poznan meeting (plenary BONE meeting, October 2009) and 4) Final Report for the compilation of information for this document.

Figure 1 illustrates the number of meetings for the different JAs (let us remark that JA4 has been merged with JA3). The total number of meetings in all joint activities is 30. All joint activities have shown interaction (email, phone), but we can highlight the collaboration in JA 2 and JA 9.

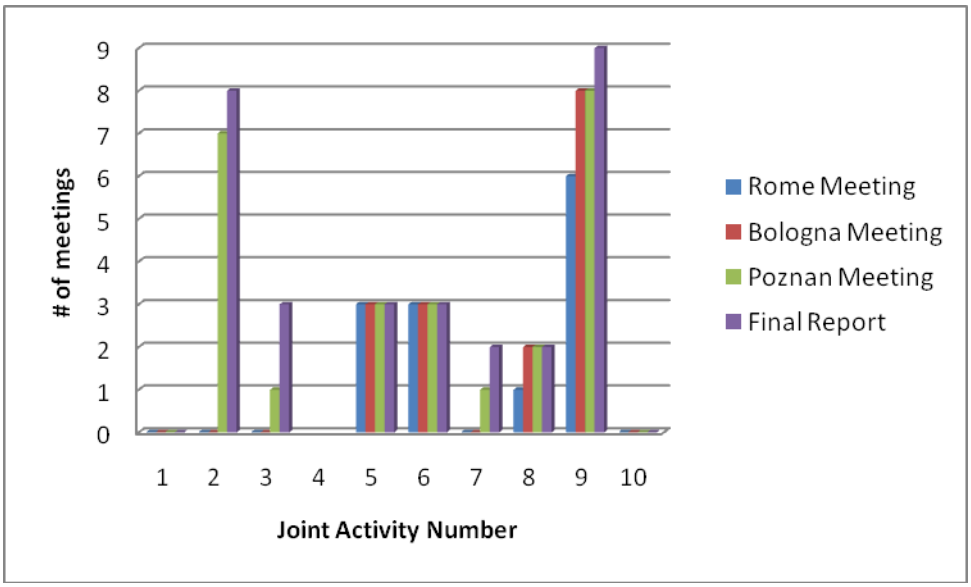


Figure 1: Number of meetings during the project

Figure 2 depicts the number of papers (conference and journals) published in each Joint activity. The number of publications is 25, 19 conference articles and 7 journal publications.

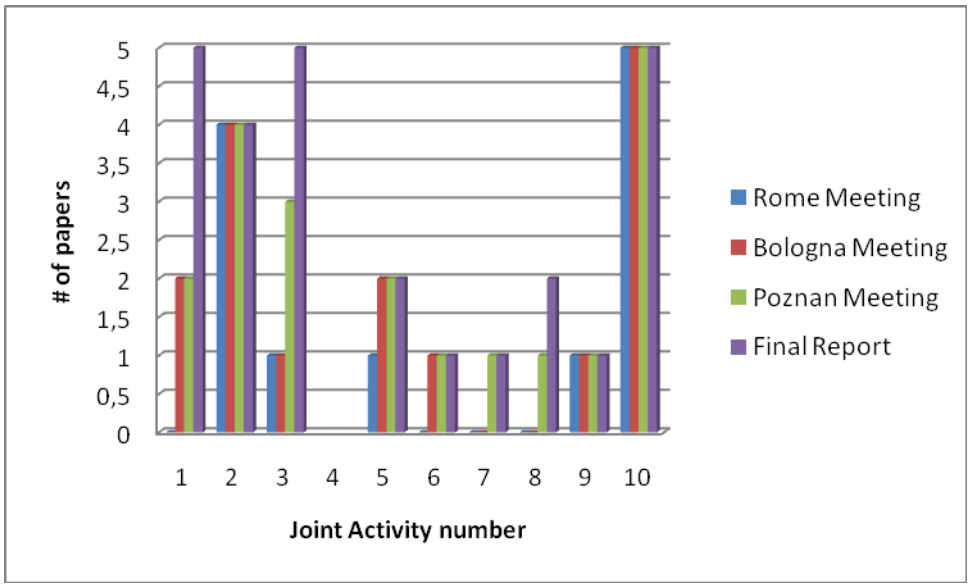


Figure 2: Number of papers during the project

The number of mobility actions is shown in Figure 3. Eight mobility actions are done in this work package in 4 different joint activities.

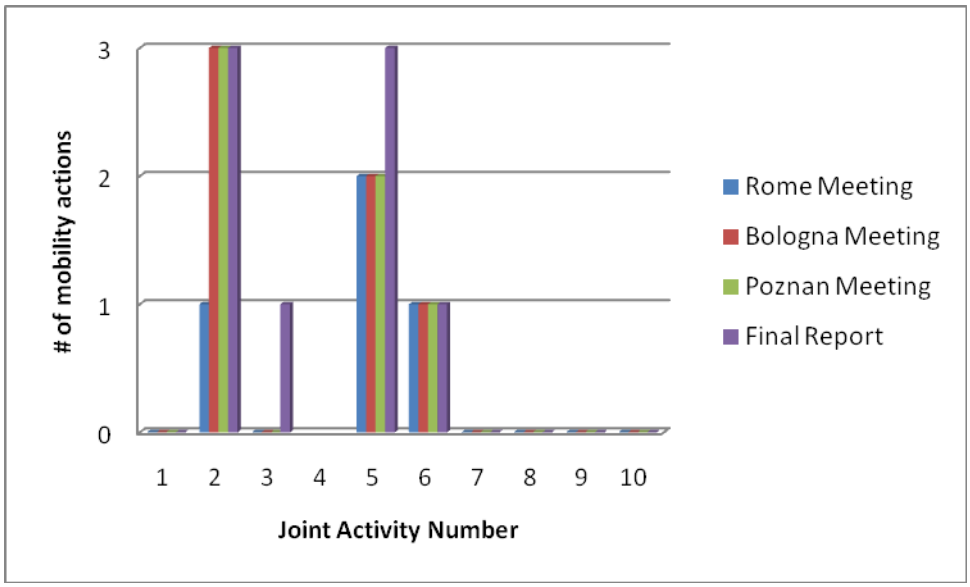


Figure 3: Number of mobility actions during the project

Figure 4 summarizes the contribution of each joint activity. There is a joint project proposal from the JA1. The number of publications is 26: 12 joint conference article, 7 joint journal publications and 7 single partner conference articles. Let us remark that all JAs have at least one joint article, although there are some results published by single partners.

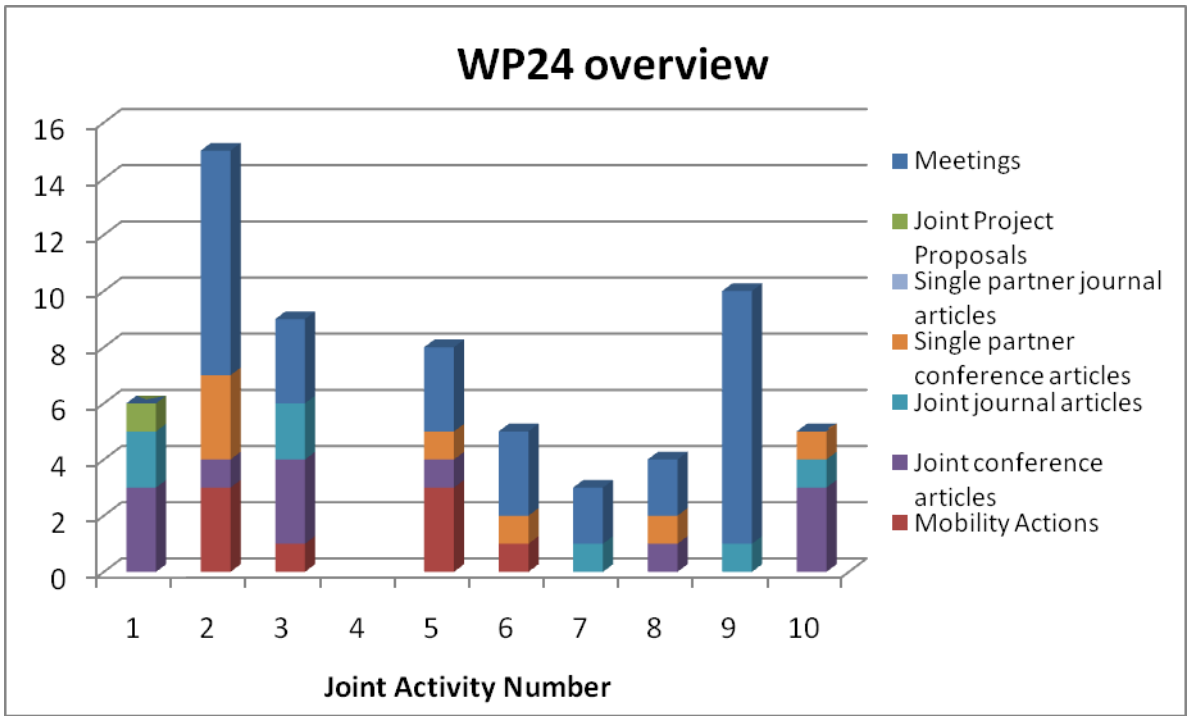


Figure 4: Work package performance in terms of publications, exchange visits and project proposals

In light of the results of the previous graph, we can say that the workpackage performance in terms of publications, exchange visits and project proposals, shows that the workpackage work has been fruitful and the collaboration between the partners has been achieved.