SEVENTH FRAMEWORK PROGRAMME

Report on Deliverable D02.5

Final report on teaching activities & Presentation of Master in optical networking

FP7-ICT-216863/FER/R/PU/D02.5

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TELECOM-Bretagne / Kevin Heggarty

Abstract:

This deliverable describes organization end execution of BONE teaching activities that comprises creation of curricula for BONE virtual common master study in Optical Communications and Networks, collecting of teaching materials and execution of experimental teaching within 3 BONE Master Schools.

Keyword list:
Education, Master curriculum, Lecturers, Teaching materials, Optical Communications, Optical Networks

Clarification:

Nature of the Deliverable

R Report
P Prototype
D Demonstrator
O Other

Dissemination level of Deliverable:

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

Disclaimer

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Executive Summary:

This document describes the Deliverable D02.5 *Final report on teaching activities & Presentation of Master in optical networking* of WP02 on teaching of the NoE.

Working package WP02 continued teaching activities carried out in e-Photon/ONe and e-Photon/ONe+ where virtual common Master study on Optical Communications and Networks was defined. In these NoEs 8 courses were created which consists of curricula and supported teaching materials. In BONE NoE 2 additional courses were defined and teaching materials collected.

All materials are uploaded on the private part of BONE web site within WP02 section. 36% of materials are prepared for open access according to the Creative Commons Public License and they are ready to be published on the public part of project web. In this way a big portion of NoE expert knowledge is available for dissemination outside the NoE.

In the BONE collection there are 6.343 slides, compared to 4.962 slides collected within e-Photon/ONe+, distributed within 85 teaching modules. 77 contributors from 19 partners were involved in preparing, editing, reviewing and integrating of materials.

The collected set of slides is estimated to be equivalent to 42.29 ECTS credits (average 4.23 ECTS credits per course) dominantly for tutorial part of the study.

Master courses were experimentally executed within BONE Master Schools, each year one school, all together 3 schools (Mons, Krakow and Budapest). Collocated with the Master schools each year were organised 3 Summer schools with topics from optical communications and with the participation of PhD students with their papers. All materials from Master and Summer schools, together with students' papers are stored on BONE web site. Master tutorials and some of Summer school tutorial are available as video streaming for permanent learning.

Special WP02 Task group analysed different aspects of Master studies within NoE partners on order to find out the obstacles to setting up a "real" multi-institution Masters course in Optical Telecommunications and Networks based on the "virtual" Master courses set up in the e-Photon/ONe and BONE NoEs. The report of this analysis is included in the Deliverable D02.2. (WP02 section - Deliverables and Milestones).

Table of Contents

1. Introduction

The large number of academic institutions involved in BONE was a good basis for a common action of improving educational level in photonics within NoE partners and outside. Working together in creating and collecting knowledge, contributors produced a synergic effect. Teaching experience is being shared among teachers and students of NoE partners. Open access enables the offer of materials to public domain. One of goals of WP02 in the period of BONE was to enlarge, update, innovate, experimentally execute and review inheritance from e-Photon/ONe+ NoE.

Application of the results of this activity can be used in the first place by BONE partners in order to improve their Master and PhD education according to local regulations.

2. Partners involved

The following partners contributed to the preparation of **D.02.5**:

1. AGH - Akademia Gorniczo-Hutnicza - Poland
2. DEIS-UNIBO - Alma Mater Studiorum - Università degli Studi di Bologna - Italy
3. UoM / FPMs - Faculté Polytechnique de Mons – Belgium
4. FUB/ Fondazione Ugo Bordoni - Italy
5. ISCOM – Italy
6. GET - Groupe des Ecoles des Télécommunications – France
7. IBBT - Interdisciplinair instituut voor BreedBand Technologie vzw – Belgium
8. IT - Instituto de Telecomunicações - Portugal
9. KTH - Kungliga Tekniska Högskolan – Sweden
10. PoliMI - Politecnico di Milano – Italy
11. PoliTO - Politecnico di Torino – Italy
12. SSSUP - Scuola Superiore Sant'Anna di Studi Universitarie Perfezionamento – Italy
13. FER - Sveuciliste u Zagrebu, Fakultet elektrotehnike i racunarstva – Croatia
14. UPC - Universitat Politècnica de Catalunya – Spain
15. UC3M - Universidad Carlos III de Madrid – Spain
16. PUT - Poznan University of Technology (PUT) - Poland
17. UCAM-DENG - University of Cambridge (UCAM) – United Kingdom
18. Universita Sapienza di Roma – Italy
19. Technical University of Cartagena (UPCT) - Spain

3. Common Master Courses

Working package on teaching WP02 continued teaching activities started in FP6 NoE e-Photon/ONe where virtual common Master study on Optical Communications and Networks was defined. In these NoEs 8 courses with curricula and supported teaching materials were created. In the BONE NoE 2 additional courses were defined and teaching materials collected.

Description of each course consists of Curriculum short description, List of contributors and their affiliations, List of course modules (files) with no. of slides collected and equivalence of ECTS credits based on calculation: 1 ECTS = 150 lesson slides. All modules ready for open access are marked by CC (Creative Common Public License).

3.1 Introduction to optical networks – Light propagation

1st coordinator: Michel Morvan, GET/ENST Bretagne
2nd coordinator: Marc Wuilpart, UMONS/FPMs

Curriculum short description:

Introduction. Optics refresher. Waveguide propagation in optical fibres. Optical fibre fabrication techniques. Attenuation of optical fibres. Dispersion in optical fibres. Polarization in optical fibres. Non-linear effects in fibres. Metrology of optical fibres.

List of contributors:

- Laurent Dupont, Kevin Heggarty, Michel Morvan, Bruno Vinouze, Michel Gadonna, GET/ENST Bretagne, Brest, France
- Patrice Mégret, Veronique Moeyaert, Marc Wuilpart, FPMs, Mons, Belgium

List of course modules (files)

Course content

1. Introduction, Why optical fibres and optical networks? (39 slides)
2. Optics Refresher (45 slides)
3. Waveguide propagation in optical fibres (83 slides)
4. Optical Fibre Fabrication Techniques (27 slides)
5. Attenuation in Optical Fibres (12 slides)
6. Dispersion in Optical Fibres (27 slides)
7. Polarisation in Optical Fibres (28 slides)
8. Non-linear effects in Optical Fibres(34 slides)
9. Metrology of Optical Fibers (56 slides)
10. Polymer Optical Fibres (54 slides)

No. of slides: 405

No. of ECTS: 2.7

3.2. Optical Technologies and Components

1st coordinator: Antonio Teixeira, IT
2nd coordinator: Kevin Heggarty, GET/ENST Betagne

Curriculum short description:

Basic Photonic Measurements. Material growth and processing. Semiconductor materials. Transmission systems performance assessment tools. Optical Amplifiers. Emitters. Receivers. Modulators. Filters. Isolators. Couplers. Switches

List of contributors:

- António Teixeira, Paulo André, Rogério Nogueira, Tiago Silveira, Ana Ferreira, Mário Lima, Ferreira da Rocha, Instituto de Telecomunicações (IT), Aveiro, Portugal
- Giorgio Tosi Beleffi, ISCOM, Roma, Italy

List of course modules (files)

1. Basic Photonic Measurements (44 slides)
2. Material Growth and Processing (54 slides)
3. Semiconductor Materials (49 slides)
4. Transmission Systems Performance Assessment Tools (79 slides)
5. Optical Amplifiers (251 slides)
6. Emitters (95 slides)
7. Receivers (60 slides)
8. Modulators (72 slides)
9. Filters (79 slides)
10. Isolators and Couplers (44 slides)
11. Switches (25 slides)

No. of slides: 849

No. of ECTS: 5.66

3.3 Optical Core Networks

1st coordinator: Piero Castoldi, SSSUP
2nd coordinator: Josep Solé Pareta, UPC

Curriculum short description:

Optical transport technologies. Wavelength routed networks. Optical networking concepts and protocols. Internetworking issues.

List of contributors:

- Achille Pattavina, Guido Maier, Massimo Tornatore, Politecnico di Milano (PoliMI), Italy
- Xavi Masip, Sergi Sánchez, Eva Marín and Josep Solé, Universidad Politecnica de Catalunya (UPC), Barcelona, Spain
- Piero Castoldi, Fabio Baroncelli, Barbara Martini, Luca Valcarenghi, Francesco Paolucci, Valerio Martini, Scuola Superiore Sant'Anna (SSSUP), Italy
- Alesssandro Valenti, Fondazione Ugo Bordoni, Rome, Italy
- Marina Settembre, Ericsson, Italy
- Angelo Coiro, Universita Sapienza, Rome, Italy

List of course modules (files)

1. Optical Transport Network (71 slides) CC
2. WDM Network Design (81 slides) CC
3. Routing and Wavelength Assignment in Optical Networks (82 slides) CC
4. MPLS basics (47 slides) CC
5. MPLS advanced (65 slides) CC
6. ASON, ASTN and GMPLS basics (53 slides) CC
7. GMPLS advanced (58 slides) CC
8. Management protocols (63 slides) CC
9. Service Oriented Network Architectures (73 slides) CC
10. Towards Carrier Ethernet (57 slides) CC
11. Carrier Ethernet (101 slides)

No. of slides: 751

No. of ECTS: 5,01

3.4 Optical Access and Metro Networks

1st coordinator: Achille Pattavina, PoliMI
2nd coordinator: Guido Maier, PoliMI

Curriculum short description:

Introduction to metro and access networks. Access and metro infrastructure. Switched metro optical networks. xPONs access networks. Fiber competitors in broadband access.

List of contributors:

- Guido Maier, Achille Pattavina, Politecnico di Milano (PoliMI), Milano, Italy

List of course modules (files)

1. Introduction to metro and access networks (60 slides)
2. Access and metro infrastructure (130 slides)
3. Switched metro optical networks – Part 1 (191 slides)
4. Switched metro optical networks – Part 2 (103 slides)
5. Switched metro optical networks – Part 3 (173 slides)
6. xPONs access networks (189 slides)
7. Optical switchless network modeling and design (62 slides)

No. of slides: 908

No. ECTS: 6.05

3.5 Photonics in Switching

1st coordinator: Lena Wosinska, KTH
2nd coordinator: Carla Raffaelli, DEIS-UNIBO

Curriculum short description:

Terminology and introduction. Switched networks. Photonics circuit switching. Optical packet switching. Optical burst switching techniques and architectures. Contention resolution. Traffic performance.

List of contributors:

- Lena Wosinska, Bo Willen, Royal Institute of Technology (KTH), Stockholm, Sweden

- Franco Callegati, Carla Raffaelli, Michele Savi, University of Bologna (DEIS–UNIBO), Bologna, Italy
- Wojciech Kabacinski, Poznan University of Technology (PUT), Poznan, Poland
- Guido Maier, Achille Pattavina, Politecnico di Milano, Milano, Italy

List of course modules (files)

1. Basics: optical circuit, packet and burst switching (OCS, OPS, OBS) (90 slides)
2. Optical buffer architectures and performance (84 slides) CC
3. Bufferless switch architectures (93 slides) CC
4. Traffic performance, simulations lecture and lab-work (40 slides) CC
5. Log_2(N, m, p) Switching Fabrics (65 slides)
6. Optical cross-connects (62 slides) CC
7. Optical Burst Switching (29 slides) CC
8. Optical components (49 slides)
9. Scheduling Algorithms (76 slides) CC
10. Single Path and Standard Path Switching Fabrics (36 slides)
11. Switching Fabrics – Classification and Taxonomy (58 slides)
12. Switching Element Technologies (36 slides) CC
13. Three-Stage Switching Fabrics (47 slides)

No. of slides: 765

No. of ECTS: 5.1

3.6 Optical Network Resilience

1st coordinator: Luca Valcarenghi, SSSUP
2nd coordinator: Branko Mikac, FER

Curriculum short description:

Terminology. Introduction to the different concepts related to resilience. Resilient technique basics. Protection and restoration schemes. Network Survivability Resilient network static design. Resilient network statistical analysis. Survivability and availability. Multi-layer resilience. Resilient Network Design. Ethernet Resilience and Resilient Network Time Domain Analysis

List of contributors:

- Luca Valcarenghi, Filippo Cugini, Scuola Superiore Sant'Anna (SSSUP), Pisa, Italy

- Branko Mikac, Robert Inkret, University of Zagreb, (FER), Zagreb, Croatia
- Lena Wosinska, The Royal Institute of Technology (KTH), Stockholm, Sweden
- Mario Pickavet, University of Ghent (IBBT), Ghent, Belgium
- Achille Pattavina, Guido Maier, Massimo Tornatore, Politecnico di Milano (PoliMI), Milano, Italy
- Piotr Chołda, Andrzej Jajszczyk, Krzysztof Wajda AGH-UST, Krakow, Poland
- Ricardo Romeral Ortega, David Larrabeiti, David Garcia Roger, Universidad Carlos III de Madrid (UC3M), Madrid, Spain

List of course modules (files)

1. Terminology (32 slides) CC
2. Network Survivability (89 slides) CC
3. Resilient Network Design (40 slides) CC
4. Resilient Network Statistical Analysis (89 slides) CC
5. Ethernet Resilience and Resilient Network Time Domain Analysis (29 slides) CC
6. Multi-Layer Resilience (77 slides) CC
7. Quality of Resilience (22 slides) CC

No. of slides: 373

No. of ECTS: 2.49

3.7 Optical Transmission

1st coordinator: Véronique Moeyaert, FPMs
2nd coordinator: Michel Morvan, GET/ENST-Bretagne

Curriculum short description:

Basics of optical transmission; Optically amplified transmission links; WDM transmission; Advanced concepts of optical transmission; Description of some optical transmission systems; Photonic simulation tools; Practical works for students.

List of contributors:

Editors:

- Veronique Moeyaert, Víctor García-Muñoz, University of Mons, Mons, Belgium
- Michel Morvan, GET, ENST-Bretagne, Brest, France

Authors:

- Roberto Gaudino, Marco Mellia, Pierluigi Poggiolini, Politecnico di Torino (PoliTo), Torino, Italy
- João Andrade, Paulo André, Ana Ferreira, Mário Lima, Rogério Nogueira, Tiago Silveira, AntónioTeixeira, University of Aveiro (IT), Aveiro, Portugal
- Carlos Bock, Jose Lazaro, Josep Prat, Universidad Politecnica de Catalunya (UPC), Barcelona, Spain
- Laurent Dupont, Bruno Fracasso, Kevin Heggarty, Frédéric Lecoche, Michel Morvan, Bruno Vinouze, Cédric Ware, GET/ENST Bretagne, France
- Marco Forzati, ACREO/KTH, Stockholm, Sweden
- Sébastien Bette, Victor Garcia Munoz, Michel Lamquin, Patrice Mégret, Veronique Moeyaert, Priscille Nankoua, Marc Wuilpart, Kivilcim Yüksel, Faculté Polytechnique de Mons, Mons, Belgium
- Carmen Vázquez, Ricardo Vergaz, D. S. Montero, Universidad Carlos III de Madrid (UC3M), Madrid, Spain
- Filippo Cugini, Scuola Superiore Sant'Anna (SSSUP), Pisa, Italy

List of course modules (files)

No. of slides: 1.147

No. of ECTS: 7,65

3.8 Optical spin-off applications of optical telecommunications technology

1st coordinator: Kevin Heggarty, GET/ENST Bretagne
2nd coordinator: Carmen Vazquez, UC3M

Curriculum short description:

Overview. Fibre sensors. optical datacommunications with transport applications, LEDs and their applications, optical data storage, plastic optical fibres, fibre lasers, displays, MEMs, CCD and CMOS detectors, optical computing, photonic crystals.

List of contributors:

- Kevin Heggarty, Daniel Stoenescu, GET/ENST Bretagne, Brest, France
- Patrice MÉGRET, Marc Wuilpart, Faculté Polytechnique de Mons (FPMs), Mons, Belgium
- Carmen Vazquez, D. Sanchez, Universidad Carlos III de Madrid (UC3M), Madrid, Spain
- Richard Penty, University of Cambridge (UCAM-DENG), Cambridge, United Kingdom

List of course modules (files)

1. Introduction (Available as distance teaching)
2. Optical Data Communication (170 pages)
3. Part I Polymer Optical Fibres (27 slides)
4. Part II Polymer Optical Fibres (27 slides)
5. Optical Fibre Sensors (112 slides)
6. Fiber Lasers and their Applications (122 slides)
7. Display Technologies (in French) (22 slides)
8. 3D Display Technologies Television (in French) (30 slides)

1. Practical Class - Simulation of Data Communications Transmission Systems (5 pages)
2. Practical Class - Fiber-Optic Control Level Sensor and Multiplexing (9 pages)
3. Practical Class - POF Coupler: Manufacturing and Characterization (14 pages)
4. Practical Class - Comparison of Datacom Transmission Technologies (in Franch) (18 pages)
5. Problems Class - Advantages Optics (in Franch) .odt
6. Practical Class - DLP Picoprojector (3 pages)

No. of slides: 340

No. of pages: 49

No. of ECTS: 2,59

3.9 Optimisation and planning in optical networks

1st coordinator: Pablo Pavon Mariño, Technical University of Cartagena (UPCT)
2nd coordinator: Nina Skorin-Kapov, University of Zagreb (FER)

Curriculum short description:

Optical network planning problems are presented. Relevant optimization techniques involved in optical network optimization are reviewed and categorized. A comprehensive set of examples is provided. Lab work is proposed for exemplifying the optimization and planning of multilayer transparent optical networks with an educational version of the MatPlanWDM tool.

List of contributors:

- Pablo Pavon Mariño, Ramon Aparicio Pardo, Technical University of Cartagena (UPCT)
- Nina Skorin-Kapov, University of Zagreb

List of course modules (files)

1. Optical networks planning problems (131 slides) CC
2. Optimization techniques (508 slides) CC
3. Examples (77 slides) CC
4. Laboratory work (10 slides) CC

No. of slides: 726

No. of ECTS: 4.84

3.10 Free space optical technologies for broadband applications

1st coordinator: Giorgio M. Tosi Beleffi, ISCOM, Rome, Italy
2nd coordinator: Antonio Teixeira, Instituto de Telecomunicações (IT), Aveiro, Portugal

Curriculum short description:

History and perspectives of FSO in the TLC scenario, Physics of the FSO Transmission, FSO standard transmission bandwidths, Limiting factors and counteractions, Attenuation, Scattering, Scintillation, Background radiation influence, Thermal and mechanical misalignments, Propagation in presence of atmospheric turbulence, Hazardous levels exposure, Applications and fields of interests of FSO, Evolution and new scenarios of FSO, Inter-satellites/earth to satellites links, Deep space/interplanetary communications.

List of contributors:

- S. Tavares, Paulo André, Antonio Teixeira Instituto de Telecomunicações (IT)
- Giorgio M. Tosi Beleffi, Davide Forin, Gabriele Incerti, (ISCOM)

List of course modules (files)

1. History and perspectives of FSO in the TLC scenario (14 slides)
2. Physics of the FSO Transmission (41 slides)
3. Applications and fields of interests of FSO (24 slides)

No. of slides: 79

No. of ECTS: 0.53

Note:

Common curriculum and teaching materials are released and loaded on the private part of the project web site:

Groups » Group WP02 Teaching

4. Other teaching materials

Additional teaching materials were collected at BONE Master and Summer schools and loaded on the BONE web site:

Group WP02 Teaching >> Main page

Master/Summer Schools 2008, Mons

http://www.ict-bone.eu/portal/faces/public/BONE/ecatwiki?portal:componentId=ewiki&portal:type=render&portal:isSecure=false&groupid=13d3a9561ae8958c011b113d71d20b7d&pmRender=EWikiViewDocument&wikiId=13d3a9561ed46713011ed56d815f006b&document=Master_School_2008

Master/Summer Schools 2009, Krakow

http://www.ict-bone.eu/portal/faces/public/BONE/ecatwiki?portal:componentId=ewiki&portal:type=render&portal:isSecure=false&groupid=13d3a9561ae8958c011b113d71d20b7d&pmRender=EWikiViewDocument&wikiId=13d3a9561ed46713011ed56d815f006b&document=Master_School_2009

Master/Summer Schools 2010, Budapest

http://www.ict-bone.eu/portal/faces/public/BONE/ecatwiki?portal:componentId=ewiki&portal:type=render&portal:isSecure=false&groupid=13d3a9561ae8958c011b113d71d20b7d&pmRender=EWikiViewDocument&wikiId=13d3a9561ed46713011ed56d815f006b&document=Master_School_2010

5. Conclusions

This document describes the results of activities carried out in creating of teaching materials for virtual common master study in Optical Communications and Networks during the period of duration of BONE project. Common Master study has been defined in FP6 NoE e-Photon/ONe comprising a set of 8 courses with curricula and teaching materials. In FP7 NoE BONE all inherited teaching materials were updated and innovated. Two additional courses were involved. Nowadays in the collection of teaching materials there are 6.343 slides and text pages (compared to 4.962 slides collected within e-Photon/ONe+) created by 77 authors from 19 BONE partners. In ECTS metrics this is an equivalent of 42,29 ECTS credits (average 4.23 ECTS credits per course). All materials are loaded on the private part of BONE web site within WP02 section. There are 36% of materials ready for open access according to the Creative Commons Public License.

Creation of the Common Master Curriculum and providing corresponding teaching materials had to lead to a synergic effect in improving Master and PhD education in the field for BONE partners and establishments outside BONE. Teaching materials are already used in teaching by exchange among partners. Cooperation in preparing materials motivates authors to teachers' mobility and organisation of joint courses. It is expected that Common Master Study will be used even more in students' mobility according to local educational rules and the possibilities of mobility funding. In addition, joint work on virtual master curriculum stimulates initiatives at BONE partners for establishing institutional permanent master study in the field of optical communications and networks.