Lightness

Low latency and high throughput dynamic network infrastructures for high performance datacentre interconnects

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SEVENTH FRAMEWORK PROGRAMME

Deliverable D6.4

Mid-term report on dissemination, standardization, and exploitation activities

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Author list: Nicola Calabretta (TUE), Wang Miao (TUE), Harm Dorren (TUE), Salvatore Spadaro (UPC), Fernando Agraz (UPC), Giacomo Bernini (NXW), Nicola Ciulli (NXW), Shuping Peng (UNIVBRIS), Reza Nejabati (UNIVBRIS), Dimitra Simeonidou (UNIVBRIS), Jose Carlos Sancho (BSC), Alessandro Predieri (IRT), Matteo Biancani (IRT)

Dissemination Level		
☒	**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)

Abstract

In this deliverable the dissemination, standardization, collaboration, and exploitation activities of the LIGHTNESS during the second year of the project are presented.

In terms of dissemination activities, high visibility of the project concepts and results is assessed by the several scientific publications and disseminations in highly impact and prestigious journals and magazines, international scientific conferences, tutorials, and workshops (promoted in collaboration with other EU projects).

For what concern the standardization activities in the second year, the LIGHTNESS project concepts and technical achievements have also been promoted to the Cloud, Data Centre and Future Internet industrial communities by the active participation and contribution of the LIGHTNESS partners to identified standardization bodies.

In the second year, LIGHTNESS has established active collaborations with other EU FP7 projects with activities ranging from joint publications, workshop organization, sharing the technical approaches and vision developed in each respective project.

Finally, the novel concepts, findings, and technical achievements delivered by LIGHTNESS in the second year provide additional expertise as well as new hardware and software that have been fruitful exploited by the industrial and academic project partners.

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0. Executive Summary

The main objective of the LIGHTNESS project is the design, implementation and experimental evaluation of a high-performance network infrastructure for data centres in order to fulfil the emerging requirements of Cloud computing and storage applications. LIGHTNESS project aims to propose novel solutions for both data and control plane of the Data Centre Network (DCN).

In LIGHTNESS, the Work Package 6 (WP6) is in charge of promoting the project concepts and technical results of the project. This is carried out by concentrating the efforts in four main activities, namely dissemination, standardization, collaboration with other EU projects, and exploitation activities. In the dissemination activity, the technical outcomes of LIGHTNESS are presented to Cloud, Data Centres and Future Internet industrial, research and academic communities. It is achieved via scientific publications in major journals and magazines, as well as presentations in international conferences, workshops, tutorials, and technical events. In the standardization activity, LIGHTNESS partners participate and contribute to major standardization bodies in order to promote the technical solutions adopted by the LIGHTNESS project. In the collaboration activities, LIGHTNESS has established active collaborations with other EU FP7 projects for workshop organization and joint publications sharing the technical approaches developed in each respective project. Finally, WP6 is also in charge of the exploitation of the LIGHTNESS concepts in terms of data and control architectural solutions, prototypes and proof of concepts.

This document entitled “Mid-term report on dissemination, standardization and exploitation activities” reports all the dissemination, standardization, collaboration, and exploitation activities that have been performed during the second year.

1. Introduction

The aim of this document is to report all the WP6 activities carried out during the second year of the project, in particular the dissemination activities in LIGHTNESS for spreading the concepts and technical solutions to a wide industrial, research and academic community; the standardization activities for promoting the project concepts and technical results to standardization bodies in which the LIGHTNESS partners are actively participation; the collaboration activities with other EU projects for sharing technical approaches and initiate common research activities and joint publications; the exploitation activity aiming at identifying potential routes for the deployment of LIGHTNESS concepts and results in the Cloud and Data Centre networking field, with the final objective of transferring the project outcomes into new market opportunities.

1.1. LIGHTNESS dissemination activity

The technical outcomes obtained during the second year of the project have led to many dissemination activities. First of all, several technical publications in major journals and conferences have been produced. This way, the consolidation of the acceptance of the proposed novel architectures for data and control plane of future DCN has been achieved. In this context, special emphasis must be devoted to the achievement of the Best Booth Award in the framework of the EuCNC'14 Conference. The interest generated by the LIGHTNESS project DCN solutions are also witnessed by the several invited talks given by LIGHTNESS members about the topics covered by the project. Finally, a technical workshop in cooperation with the IP COSIGN project has been organised, with the basic aim to jointly discuss the view about the European Vision for Future Optical Data Centre Evolution.

1.2. LIGHTNESS standardization activity

In the second year, we have finalised the LIGHTNESS architecture design, developed the key elements in both data plane (i.e. AoD node, OPS, and ToR switches) and control plane (i.e. SDN controller based on ODL, Southbound Interfaces based on extended OpenFlow protocols and Northbound APIs). We have demonstrated the integration of the optical data centre solution and got the best demo award in European Conference on Networks and Communications. The research outcomes generated from LIGHTNESS have attracted a high attention in the data centre and cloud industries, and they are of great interest of the standard organisations (SDOs). We have created a list of target standardisation bodies for LIGHTNESS

contributions taking into account all the potential SDOs relevant to the activities carried out in the project. Among the identified standardization bodies, we have contributed the research outcomes of LIGHTNESS to ONF working groups. We have also planned additional contributions towards IETF and IRTF for the third year of the project.

1.3. LIGHTNESS collaboration activity

The direct collaboration with other European projects and research initiatives is a further channel that LIGHTNESS is exploring and actively using to guarantee a proper and wide dissemination of the project results. Moreover, the tight interaction with European projects targeting similar and compatible research and technological areas allows LIGHTNESS to foster its impact in the research and industry communities by enabling closer and wider contacts with main European academia and industry actors.

During this second year, following the collaboration plans defined at the end of the first year and reported in deliverable D6.3 [1], LIGHTNESS established fruitful collaborations with three FP7 projects: COSIGN, STRAUSS and PACE. So far, these close interactions have been carried out in two main directions: first by sharing the technical approaches to similar research challenges with the aim of gathering feedbacks and possibly finding a common understanding and vision (e.g. on use cases, architectures, deployment scenarios), then by participating, or even organizing joint dissemination initiatives (e.g. workshops) to enable a wider acceptance and knowledge of common views, outcomes and results in key technical areas.

1.4. LIGHTNESS exploitation activity

The exploitation activity aims at identifying potential routes for the deployment of LIGHTNESS concepts and results in the Cloud and Data Centre networking field, with the final objective of transferring the project outcomes into new market opportunities. LIGHTNESS exploitation activities are organized into individual partner and joint consortium activities, to cover both individual and project-wide exploitations. Here, the organization of workshops and public demonstration events has been valuable mean to widely disseminate the project outcomes in this second year, while establishing new contacts with other industry players and research experts.

Specific activities for commercial and non-commercial exploitation have been carried out during this second year of the project. Commercial exploitation mostly refers to industrial partners, with the aim of identifying potential applicability of LIGHTNESS results into new products and services. On the other end, non-commercial exploitation has been performed by universities and research institutes, to foster their knowledge and know-how and consolidate their position and reputation in the international research community.

2. Dissemination outcomes

During the second year of the project, the LIGHTNESS project partners achieved to disseminate the technical activities through several publications in international and prestigious journals and magazines and leading conferences. Among them, special mention should be devoted to the achievement of the Best Booth Award obtained in the framework of the EuCNC'14 Conference. Moreover, a public Workshop has been organised in cooperation with the Integrated Project (IP) FP7- COSIGN (Combing Optics and SDN in future Data Centres) that allowed to LIGHTNESS partners to spread their activities and at the same time to further learn about future services and requirement of multi-tenant data centres. Another Workshop to be co-located with OFC 2015 Conference is being organised and supported by LIGHTNESS.

In the following Sections, the details of the dissemination activities carried out during the second year of the project are fully reported.

2.1. Publications

2.1.1. Journals and Magazines publications

1. P. De Heyn, J. Luo, S. Di Lucente, N. Calabretta, H.J.S. Dorren, and D. Van Thourhout, "In-Band Label Extractor Based on Cascaded Si Ring Resonators Enabling 160 Gb/s Optical Packet Switching Modules," Journal of Lightwave Technology, Vol. 32, Issue 9, pp. 1647-1653, 2014.
2. W. Miao, J. Luo, S. Di Lucente, H.J.S. Dorren, and N. Calabretta, "Novel flat datacenter network architecture based on scalable and flow-controlled optical switch system," Optics Express, Vol. 22, Issue 3, pp. 2465-2472, 2014.
3. W. Miao, S. Di Lucente, J. Luo, H.J.S. Dorren, and N. Calabretta, "Low latency and efficient optical flow control for intra data center networks," Optics Express, Vol. 22, Issue 1, pp. 427-434 (2014).

2.1.2. Conference publications

1. S. Peng, R. Nejabati, B. Guo, Y. Shu, G. Zervas, S. Spadaro, A. Pages, D. Simeonidou, “Enabling Multi-Tenancy in Hybrid Optical Packet/Circuit Switched Data Center Networks”, paper Tu.1.6.4, ECOC 2014, Cannes, France, September 21-26, 2014.
2. F. Agraz, W. Miao, A. Ferrer, G. Bernini, H.J.S. Dorren, N. Calabretta, N. Ciulli, J. Perelló, S. Peng, G. Zervas, D. Simeonidou, G. Junyent, S. Spadaro, “Experimental Assessment of an SDN-based Control of OPS Switching Nodes for Intra-Data Center Interconnect ”, paper We.2.6.5, ECOC 2014, Cannes, France, September 21-26, 2014.
3. W. Miao, S. Peng, S. Spadaro, G. Bernini, F. Agraz, A. Ferrer, J. Perelló, G. Zervas, R. Nejabati, N. Ciulli, D. Simeonidou, H.J.S. Dorren, N. Calabretta, “Demonstration of Reconfigurable Virtual Data Center Networks Enabled by OPS with QoS Guarantees ”, paper P.6.4, ECOC 2014, Cannes, France, September 21-26, 2014.
4. N. Calabretta et al, “Lossless Wavelength Selector based on Monolithically Integrated Flat-top Cyclic AWG and Optical Switch Chain”, paper Tu.4.2, ECOC 2014, 2014.
5. S. Peng, D. Simeonidou, G. Zervas, S. Spadaro, J. Perelló, F. Agraz, D. Careglio, H. Dorren, W. Miao, N. Calabretta, G. Bernini, N. Ciulli, J. C. Sancho, S. Iordache, Y. Becerra, M. Farrera, M. Biancani, A. Predieri, R. Proietti, Z. Cao, L. Liu, S. J. B. Yoo, “A Novel SDN enabled Hybrid Optical Packet/Circuit Switched Data Centre Network: the LIGHTNESS approach”, to be presented in EuCNC 2014 conference, Bologna, Italy, June 23-26, 2014.
6. Y. Yan, G. Zervas, B. R. Rofoee, D. Simeonidou, “FPGA-based Optical Network Function Programmable Node”, to be presented in Optical Fiber Communications (OFC) 2014 conference, San Francisco, USA, March 9-13, 2014.

2.2. Invited talks

1. N. Calabretta, Wang Miao, Jun Luo, S. Di Lucente, H. Dorren, “Experimental assessment of a scalable and flow-controlled optical switch system for flat datacenter networks,” 16th International Conference on Transparent Optical Networks (ICTON) 2014, Graz, Austria.
2. G. Zervas, B. Rofoee, Y. Yan, D. Simeonidou, “Network Function Programmability and Software-Defined Synthetic Optical Networks for Data Centres and Future Internet”, to be presented at Photonics in Switching (PS) 2014, San Diego, CA (US), July 13-17, 2014.
3. Nicola Calabretta, “Scalable and Low Latency Optical Packet Switching Architectures for High Performance Data Center Networks,” Photonics in Switching (PS) 2014, San Diego, CA, US, 13 – 16 July 2014.
4. G. Bernini, “LIGHTNESS: An SDN enabled hybrid optical packet/circuit switched data centre network”, PACE workshop on “New Uses for Path Computation Elements”, Vilanova i la Geltru, June 16 2014
5. R. Nejabati, S. Peng, M. Channegowda, D. Simeonidou, “SDN an Enabler for Multi-Dimensional and Multi-Tenant Optical Networks, in Proceedings of 8th International Conference on Optical Network Design and Modeling (ONDM 2014), Stockholm, Sweden, May 19-22, 2014.

2.3. Public demonstrations

The LIGHTNESS partners presented a demonstration entitled "SDN-enabled all-optical and programmable Data Centre Network for low latency server-to-server connectivity", in the framework of the *Exhibitions and Demos Session* of the European Conference on Networks and Communications (EuCNC) 2014, held in Bologna (Italy) on 24-26 of June, 2014.

In particular, LIGHTNESS data plane technologies, network architecture and the interworking between the data plane and the SDN-based control plane have been successfully demonstrated. More specifically, the data plane technologies included: a) advanced optical switches (OCS and OPS) to route traffic flows between DC servers/racks; b) high performance and all-programmable FPGA-based Network Interface cards (NIC) able to directly generate optical circuit/packet traffic, and c) an end-to-end all-optical network testbed to demonstrate flexible, low-latency, and high-capacity DCN services. Regarding the integration with the control plane, the communication between the ODL based SDN controller and the optical switches, implemented through the extended OpenFlow (OF) protocol, has been also demonstrated. More specifically, the SDN controller was deployed on top of the OF-enabled optical switches (with dedicated OF agents) for switch configuration and monitoring performed through the OF protocol messages.

The scenario and technologies used for the tested are reported in Figure 1.

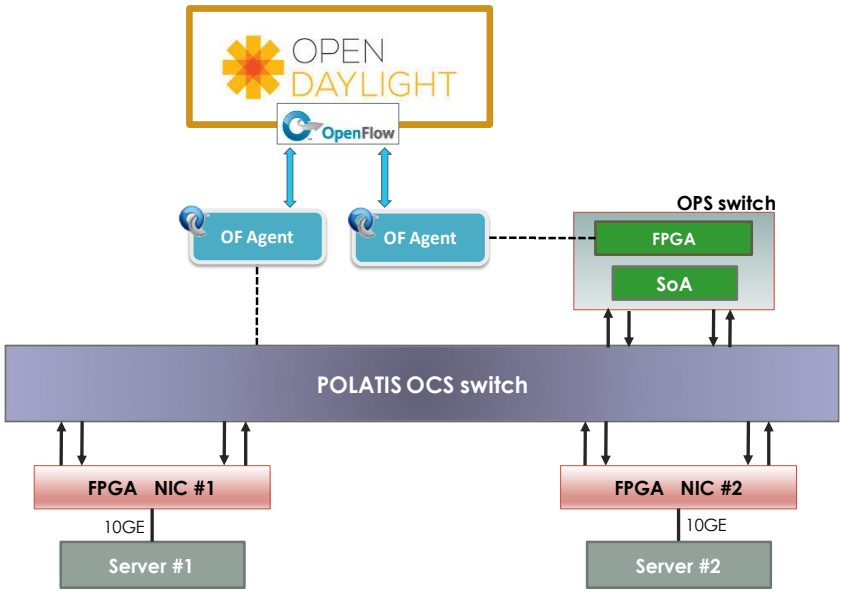

Figure 1: EuCNC'14 LIGHTNESS demonstration scenario

The provisioning and reconfiguration of virtual slices mapped onto the optical switches was successfully demonstrated.

It worth to mention that the LIGHTNESS demonstrator has been awarded with the Best Booth Award (among a total of 40 demos). The selection has been made through the participation of the EuCNC'2104 attendees (http://www.eucnc.eu/2014/www.eucnc.eu/index7a24.html?q=node/155).

2.4. Organization of international workshop

The LIGHTNESS partners organised a technical Workshop entitled "Creating European Vision for Future Optical Data Centre Evolution", in cooperation with the EU FP7 IP project COSIGN. The workshop was held in Barcelona on May 14th, 2014. The programme of the workshop is reported below, in Table 2-1. The main aim was to share between the two EU-funded projects their view about both data and control plane solutions to be adopted in future data centres. The agenda of the joint workshop is reported below.

14:00 - 14:15	*Welcome & Introduction*	
Invited Talks		
14:15 –16:15	• LIGHTNESS overview • COSIGN overview • LIGHTNESS software architecture • COSIGN software architecture	George Zervas (University of Bristol) Lars Dittman (DTU) Giacomo Bernini (Nextworks) Katherine Barabash (IBM)
16-15- 16:45	*Coffee - Break*	
16:45 – 18:00	Panel discussion	

Table 2-1: LIGHTNESS-COSIGN joint workshop: Programme

The workshop allowed deep discussions about the services to be offered and supported in future data centres and it was really useful to discuss with the IP COSIGN project.

On the other hand, LIGHTNESS partners are organising the Workshop on "Do small, large, and mega data centers need advanced photonics technology?", co-located with the Optical Fiber Conference (OFC) 2015, in Los Angeles, 22-26 March, 2014.

2.5. Tutorials

During the second year, LIGHTNESS project members have given the following tutorials, in line with the project topics/achievements:

1. Harm Dorren, "High speed switching for computer and communication networks", OECC/ACOFT 2014, Melbourne, Australia, 6-10 July, 2014.
2. Harm Dorren, "Reality and Challenges of Photonics for Datacom", ECOC 2014.

3.Standardization activities

LIGHTNESS has generated solid results of high interest for the data centre and cloud industries, including the standards communities. In D6.2, an initial list of target bodies for LIGHTNESS standard contributions was identified taking into account all the potential SDOs relevant to the activities carried out in the project, while D6.3 revised the initial selection of target SDOs to narrow down the focus of the project contributions. At this time of the project, we have finalised the LIGHTNESS architecture design, developed the key elements in both data plane and control plane, and demonstrated the integration of the optical data centre solution. Among the identified standardization bodies, we have mostly contributed the research outcomes of LIGHTNESS to ONF, while additional contributions towards IETF and IRTF are planned for the third year of the project.

3.1. IETF and IRTF

The Internet Engineering Task Force (IETF) is the Internet's leading technical standards body. It is an open forum that collects a large international community of network designers, operators, vendors and researchers with interest in the evolution of the Internet architecture and its smooth operation. The mission of the IETF is to make the Internet work better by producing high quality, relevant technical documents that influence the way people design, use, and manage the Internet, and this happens for a wide spectrum of technical areas. Compared to IETF, the Internet Research Task Force (IRTF) focuses on longer term research issues related to the Internet. IRTF is composed of Research Groups, which work on topics related to Internet protocols, applications, architecture and technology typically not yet mature to be included in official IETF standardization initiatives (either I-Ds or RFCs inside and outside Working Groups).

Deliverable D6.3 [1], released at the end of the first year, presented the LIGHTNESS roadmap for potential contributions from the projects towards standardization initiatives in IETF and IRTF. First, contributions to the IRTF SDN Research Group (SDNRG) were planned for the end the second year and above all the third year: SDNRG investigates SDN from various perspectives with the goal of identifying new approaches for deployment and usage of SDN in the near term, as well identifying future research challenges. Key areas of interest include solutions for scalability, resource abstraction, programming languages and paradigms particularly useful in the context of SDN, including data centre environments. Moreover, D6.3 identified potential standardization initiatives towards the IETF PCE Working Group, mostly based on the PCE-enabled functions for dynamicity, flexibility and network optimization provided by the LIGHTNESS SDN control plane, and that could feed some relevant I-Ds in the area of stateful and active PCE.

However, during this second year, LIGHTNESS did not submit any official standardization contribution in IETF and IRTF. The main reason is that both these bodies, even if open and easily accessible with individual I-Ds initiatives, are typically not keen to carry on (more than the first submission) any new idea that is proposed outside the main (often rigid) tracks of the specific Working or Research Group. In particular, LIGHTNESS decided to not submit during this year any individual I-D (to either IRTF or IETF) just to tick the box of a new standardization initiative

performed, and that dies after the first submission and is not considered for future development. For this reason, the consortium agreed to focus its efforts during this year towards the development of a first integrated prototype of the full LIGHTNESS solution, even if the close interaction with the FP7 PACE project (see section 4.3), a CSA project supporting and coordinating the standardization effort from different European projects around the convergence of SDN and PCE concepts, could have opened good opportunities to submit a set of individual LIGHTNESS-branded I-Ds to both IETF and IRTF.

Instead, during this year, the collaboration between LIGHTNESS and PACE, mostly focused on support actions, inputs and feedbacks for the identification of PCE topics and functions suitable for an hybrid optical data centre scenario. While, at the time of writing deliverable D6.3, the PACE project was not yet officially started, and the collaboration with LIGHTNESS was foreseen as mainly concentrated towards the support for the standardization efforts.

Therefore, the plan for the next year is to leverage on the support from PACE to pave the road of successful standardization initiatives in IRTF and IETF related to LIGHTNESS SDN and PCE topics and outcomes. In particular, a slightly revised standardization plan for the third year is presented in Table 3-1.

SDO/WG	Standardization elements	Contribution	Priority	Partners
IRTF *SDNRG*	Requirements, architectural choices and approaches, deployment frameworks for SDN control of multi-technology and hybrid optical data centre networks	New I-D submission / Contributions to existing I-Ds	High	NXW, UNIVBRIS
IETF *PCE WG*	Requirements and applicability of stateful and active PCE in data centre scenarios	Contributions to existing I-Ds	Medium	NXW

Table 3-1: IETF and IRTF standardization plan for the third year

3.2. ONF

Open Networking Foundation (ONF) is dedicated to the promotion and adoption of Software-Defined Networking (SDN) through an open, collaborative development process.

The working groups (WG) in ONF that LIGHTNESS can contribute to have been listed in D6.3, that is, Architecture and Framework WG, Configuration & Management WG, Extensibility WG, and Northbound Interface WG. Through the work that we have done in the past two years, LIGHTNESS has proposed a flat optical DCN architecture empowered with optical packet/circuit switching technologies and a SDN control solution for it. We will develop OpenFlow extensions for the OPS, OCS and hybrid ToR switches.

As a research associate of ONF, University of Bristol has shared with ONF director and ONF optical transport working group (OTWG) the latest development in LIGHTNESS project on the following areas:

- Key functions development in OF controller based on OpenDaylight (ODL) to support LIGHTNESS scenario.
- Openflow extensions to support the SDN controller southbound interface for the optical network technologies used in LIGHTNESS.
- Optical network abstraction model supporting LIGHTNESS scenario.

4. Collaborations with other relevant projects

Following the plans for collaborations with other research projects defined at the end of the first year in deliverable D6.3 [1], during this second reporting period LIGHTNESS kicked-off some fruitful collaboration initiatives with the following FP7 projects:

- FP7 Combining Optics and SDN In next Generation data centre Networks (**COSIGN**)
- FP7 Scalable and efficient orchestration of Ethernet services using software-defined and flexible optical networks (**STRAUSS**)
- FP7 Next Steps in Path Computation Element (PCE) Architectures (**PACE**)

4.1. FP7 COSIGN

COSIGN [2] is an FP7 project designing and developing an innovative Data Centre architecture that adopts advanced optical technologies at the network data plane and defines new SDN solutions to enable joint abstraction and virtualization of IT and network infrastructures and end-to-end service orchestration. The main motivation behind COSIGN is that scale and complexity of modern data centres have grown tremendously, increasing the costs of infrastructure equipment, management, and operations. Consequently, it is extremely critical to revisit the data centre network architecture and develop appropriate network technologies so that future data centres achieve the required large scale at low cost, as well as enabling multi-tenant services, flexibility, ease of management and operations. Moreover, today's data centre network hardware technologies lead to architectures that impose unsustainable overheads in terms of capacity, connectivity and energy consumption requirements. COSIGN aims to address these challenges by leveraging on proper integration of advanced optical hardware and SDN technologies for improving performance, scale, and management of network and IT resources towards streamlining the processes of deploying and operating the contemporary dynamic, multi-tenant, and resource-savvy workloads. More in detail, at the data plane, COSIGN proposes a fully optical server-to-server interconnection (within and across racks) by means of large and large and scalable ToR optical switches, and high spatial dimensioning to support large port density and scalability of the architecture utilizing new data-com fibre technologies such as multi-core fibres. At the data centre control, orchestration and management level, the COSIGN solution is built around SDN, to leverage the added value of emerging optical technologies and implement the concept of 'DC Infrastructure as a Service' by implementing the required mechanisms for composition and operation of multiple isolated and concurrent virtual data centres sharing the same physical infrastructure.

The collaboration with COSIGN during this year has been enabled by two key factors. First, the research topics and challenges of the two projects are aligned and convergent, and both LIGHTNESS and COSIGN aim to address limitations and bottlenecks of current data centre architectures, and design and prototype the next generation data centres. Second, most of the partners in the LIGHTNESS consortium are also members in the COSIGN project (Interoute, TUE, Nextworks, UPC, University of Bristol), therefore bilateral discussions and collection of feedbacks have been extremely facilitated.

From a technical perspective, the close collaboration between the projects started since the beginning of COSIGN (i.e. January 2014), by means of a deep and intensive exchange of information about technical approaches, finding and outcomes, mostly from LIGHTNESS towards COSIGN at this initial stage. On the other end, the presence in COSIGN of key industrial players in the software market, like IBM, has been a source of fundamental feedbacks for LIGHTNESS, in particular concerning the SDN approach to data centre network virtualization, that is tackled by both projects, even if with different scopes and targets (i.e. much wider and including orchestration of network and IT for COSIGN). The main driver for these cross-project exchange of visions and technical discussions have been the joint workshop "Creating European Vision for Future Optical Data Centre Evolution" organized by LIGHTNESS and COSIGN in Barcelona, on 14th May 2014. Here, representatives from both projects met and presented the technical solutions envisaged by each project, with particular emphasis given to hardware and software architecture discussions. As a main outcome of this joint workshop, the project coordinators of LIGHTNESS and COSIGN found an official agreement to transfer part of the LIGHTNESS data plane technology to COSIGN, specifically concerning the hybrid ToR switch designed and developed in LIGHTNESS.

4.2. FP7 STRAUSS

The STRAUSS project [3] aims to define a highly efficient and multi-domain optical infrastructure for Ethernet transport, covering heterogeneous transport and network control plane technologies, enabling an Ethernet ecosystem. It will design, implement and evaluate, via large-scale demonstrations, an advanced optical Ethernet transport architecture. The proposed architecture leverages on SDN principles, on optical network virtualization as well as on flexible optical circuit and packet switching technologies beyond 100 Gbps. In particular, STRAUSS focuses on the integration and development of: i) Cost/energy efficient and extremely fast-performing switching nodes, based on variable-capacity and fixed-length OPS technology for data centre, access and aggregation networks, and on flexi-grid DWDM OCS technology for long haul transport; ii) Highly integrated and scalable software defined optical transceivers supporting bandwidth variable multi-flows for flexible Ethernet transmission; iii) a virtualization layer for dynamic and on-demand partitioning of the optical infrastructure offering virtual optical Ethernet transport networks (slices); iv) legacy (e.g. GMPLS) and new (e.g. OpenFlow based) control plane approaches for control and management of virtual slices and finally; v) A service and network orchestration layer for the interworking and coordination of heterogeneous control plane and transport technologies to offer end-to-end Ethernet transport services.

In particular, STRAUSS addresses the orchestration of heterogeneous control planes using a hierarchical PCE, defining an SDN architecture and the related interfaces to interconnect distributed data centres (deploying variable-capacity and fixed-length OPS switches) by means of GMPLS/OpenFlow enabled transport networks. For this, a centralized SDN enabled orchestrator handles the automation of end-to-end connectivity provisioning, working at a higher, abstracted control level and coordinating the heterogeneous domains. Specific per-domain SDN controllers map these abstracted end-to-end functions into the specifics primitives of the underlying control plane technologies (i.e. for intra data centre and transport network segments), such as network resource discovery, topology management, connectivity provisioning and monitoring.

The collaboration between LIGHTNESS and STRAUSS is in its preliminary stage, and it is mostly facilitated by the presence of the University of Bristol in both the consortiums. Moreover, some initial technical discussions on potential collaborations took place in the context of the PACE workshop on "New Uses for Path Computation Elements" (see next section 4.3), where both projects were invited and presented their views and approaches on potential new applications of PCEs in a wider scope of network management and control, specifically in the context of intra and inter data centre connectivity. The idea is to concentrate the collaboration between LIGHTNESS and STRAUSS on the integration of the SDN orchestration for inter data centre connectivity provisioning with the LIGHTNESS SDN enabled control plane for hybrid optical data centres. This is enabled by LIGHTNESS SDN approach itself that is conceived to natively support an end-to-end SDN orchestration when the core/transport network is controlled by means of legacy GMPLS control planes, as detailed in deliverables D4.1 [4], D4.3 [5] and reported in [6]. The plan for the next year is to consolidate this initial idea for the LIGHTNESS-STRAUSS collaboration, possibly by investigating a common technical approach for the integration at the data plane level.

4.3. FP7 PACE

PACE [7] is an FP7 project focusing on research, development and standards in the broad area of PCE-based architecture. It provides an open source portal with PCE open source software and documentation repository, as well as sustained collaborative action within a concentrated community of industrial leaders, developers, and academics. PACE is an open forum for ideas exchange about current and future uses of PCE aimed to bring out radical new proposals and to consolidate existing research. PACE is also committed to innovation and is created to shape, secure and sustain the standardization leadership beyond the era of SDN and NFV, by promoting the idea of PCE as a widely applicable tool in the areas of: core packet Internet, mobile backhaul networks, Content Distribution Networks (CDN), next generation optical transport networks, sensor networks, wireless mesh and Internet of Things (IoT).

During this year, PACE, as a CSA project, supported and provided inputs and feedbacks to LIGHTNESS for the identification of PCE topics and functions suitable for an hybrid optical data centre scenario: the PACE support activities have been enabled by a couple of shared partners in the consortiums (i.e. Nextworks and UPC). Moreover, PACE organized a workshop on "New Uses for Path Computation Elements" in Vilanova i la Geltru, on June 16 2014 [8], and invited LIGHTNESS to present the technical approach towards the application of PCE concepts to data centre scenarios. Main LIGHTNESS PCE related work facilitated by the PACE collaboration and support activity is related to:

- enhanced path computation services on top of the basic ones implemented by a centralized SDN controller (e.g. stateful active PCE for data centre network optimization functions)
- computation of dedicated hybrid OPS/OCS partitions and intra data centre network slices to facilitate application-to-application connectivity with proper QoS guarantees
- SDN based end-to-end orchestration of inter-DC network services in cloud scenarios, to achieve a consistent host-to-host network configuration across data centres.

In particular this latter research activity is the first step towards a closer collaboration with the FP7 STRAUSS project, planned to be consolidated in the third LIGHTNESS reporting period. Moreover, as a further action and plan for the next year, LIGHTNESS expects to receive support from PACE concerning in its standardization efforts towards the submission to IRTF and IETF of use-cases, requirements, and deployment frameworks for SDN-based control of multi-technology and hybrid optical data centre networks, as well as for the applicability of stateful and active PCE in data centre scenarios. This is in line with the standardization roadmap defined in deliverable D6.3 [1], where potential LIGHTNESS initiatives and contributions to IETF and IRTF were planned for the end of the second year and above all the third year of the project.

5. Exploitation activities and future plan

The LIGHTNESS consortium comprises several organizations with complementary roles and expertise, acting in different markets and motivated by different missions: a cloud service provider and data centre owner (Interoute), a dynamic SME with strong know-how in the IT and Telecommunications sectors (Nextworks), an HPC research centre (Barcelona Supercomputing Center), and three universities (TUE, University of Bristol, UPC). In this context, the exploitation of results in LIGHTNESS addresses diverse business and research sectors.

The first year of the project has been dedicated to the selection of relevant use cases with the aim of identify technical requirements and drive the specification of the LIGHTNESS architecture, at both control and data planes. Therefore, during this second year, with the LIGHTNESS approach and technical solution consolidated at the design level along with preliminary prototypes available at both SDN control and data plane levels, the consortium started to carry out some relevant activities to exploit the outcomes of LIGHTNESS. However, since most of the technical solutions still need to be fully evaluated and consolidated in the LIGHTNESS testbed, the core part of the exploitation activities is planned to take place during the third and final stage of the project.

The exploitation initiatives carried out during this second year of the project can be classified in two major categories: joint exploitation activities and individual ones. The former refer to those initiatives of the LIGHTNESS team as a whole, jointly carried out by the consortium, such as organization of workshops, public demonstration events, publication of joint articles in top-level journals and magazines, and joint evaluation of technical solutions and prototypes in the LIGHTNESS testbed (more for the third year phase). On the other end, the individual exploitation initiatives are carried out individually by each partner in the consortium, by means of internal development of new activities, products and services as direct application of the project results, and also consolidation of background and acquisition of new foreground for an enhanced competitiveness of individual market initiatives.

5.1. Joint exploitation initiatives

LIGHTNESS organized two events during the second year: a joint workshop with the FP7 COSIGN [2], and a public demonstration co-located with EUCNC14 conference. Both these initiatives contributed to foster discussions with major industry players and scientific experts on the technical aspects to be addressed for next generation data center infrastructures.

A brief description of these second year joint exploitation initiatives is provided hereunder:

- ***LIGHTNESS workshop "Creating European Vision for Future Optical Data Centre Evolution", 14th May 2014, Barcelona***

  This workshop was organized in collaboration with the FP7 COSIGN project, and aimed to share views, approaches and solutions among the two projects, both focused on future data center network architectures. LIGHTNESS participated with two technical presentations

showing different building blocks of the overall project solution, with main focus on the SDN-enabled control and orchestration framework and the hybrid optical packet/circuit technologies developed in the project. The workshop was conducted as a forum for DC service and software providers, equipment manufacturers, and academia participating in both projects to discuss requirements, challenges and solutions for next-generation data centres. In particular LIGHTNESS collected fundamental inputs and feedbacks on the technical solutions that will be translated and transferred in the final prototypes..

- ***LIGHTNESS demonstration at the EUCNC conference, Bologna, June 2014***

  The LIGHTNESS booth was a great opportunity to show and explain the project rationale and preliminary prototypes for the SDN-enabled and Programmable Optical Data Centre, with hardware technologies deployed and running on-site. The booth, selected as the Best Booth at the EUCNC exhibition with lot of votes from conference participants, was an excellent mean to promote the LIGHTNESS solutions for the participating partners (Nextworks, University of Bristol, TUE, UPC), and for the project as a whole, pushing a good awareness on the project to the experts from industry and academia. We received a lot of positive feedbacks from network operators and vendors, and attendants were very keen to discuss the LIGHTNESS technical approach and solutions.

5.2. Individual exploitation initiatives

The individual exploitation initiatives have been carried out by the LIGHTNESS partner independently, each with its own strategies and routes mostly depending on the nature of the partner (i.e. industrial vs. academic). While industrial partners concentrates their exploitation activities to apply LIGHTNESS outcomes to either existing or new market products and services, the academic (and research based) partners typically aim at consolidating their position in the research community while renewing their foreground and background knowledge, in the specific LIGHTNESS case on data centre network technologies and solutions.

These two different types of individual exploitation also reflect into different roadmaps and timings. Commercial exploitation for industrial partners is typically a mid-term process, that needs to take into account complex business and deployment aspects, as well as market evolutions which are normally slow processes. On the other hand, non-commercial exploitation for academic partners is a faster process that allows to apply and leverage the project results in the short-term, for example by transferring the major outcomes into new research initiatives (e.g. new projects) or new education activities (e.g. seminars, tutorials, etc.).

During this second year of the project, Interoute concentrated its individual exploitation initiatives towards an initial technical analysis of the applicability of LIGHTNESS technologies in the company portfolio. For the development of new services and solutions, Interoute’s effort is focused toward platforms integration and interoperability, with the aim to introduce new solutions, like the ones proposed in LIGHTNESS for a flexible management, operation and orchestration of the Interoute’s IT

infrastructure. Current Interoute's flagship and most innovative product is the Virtual Data Center (VDC), which is the Interoute's scalable, fully automated Infrastructure as a Service (IaaS) solution. VDC provides on-demand computing, cloud hosting, cloud storage and applications integrated into the heart of Interoute's IT infrastructure: VDC delivers virtual IT infrastructure as an on-demand service and provides connectivity across Europe using Interoute's virtualised MPLS fibre optic network. The VDC cloud computing solution can be deployed with the simplicity and convenience of the public cloud, combined with the security and confidence that a private cloud brings, and the ability to offer public, private and hybrid cloud on the same platform makes VDC unique. The exploitation activities carried out by the Interoute team during the second year mostly focused on a preliminary analysis of the applicability of LIGHTNESS technologies to the VDC service, with a twofold scope. First, Interoute identified high interest in enhancing the programmability and flexibility for the operation of its DC and IT infrastructures, by means of the LIGHTNESS SDN-based management, control and orchestration framework where data centre network virtualization mechanisms and strategies could be integrated in the VDC service. Second, Interoute identified the deployment of optical technologies in its DC infrastructures as a viable option, even if this migration is foreseen as applicable in the medium-long term with strategies (e.g. based on partial migration inside properly selected DCs) to be accurately defined. However, Interoute plans to concentrate most of its exploitation activities during the third year of the project, when the LIGHTNESS solutions (at both SDN and hardware levels) will be fully evaluated and consolidated in the testbed.

Similarly, Nextworks, as an R&D SME, leveraged on its active participation in the definition of the LIGHTNESS architecture approach and the implementation of the LIGHTNESS SDN controller software prototype to improve its consulting portfolio in the SDN area. The SDN approach adopted in LIGHTNESS is aligned with the current trends in the SDN and NFV markets, specifically when applied to data centre environments. The usage of OpenDaylight as the reference SDN controller to build the customized LIGHTNESS control solution allowed Nextworks engineers to improve their know-how and hands-on experience with the widest adopted open source initiative in the SDN realm: this opened opportunities for new consultancy activities during this year, with new contacts established with a couple of customers (an equipment vendor and a network operator, not mentioned for confidential reasons) interested in applying SDN for their products and services. On the other end, the strong commitment of Nextworks in the implementation of LIGHTNESS SDN functions and applications within the OpenDaylight framework is paving the road towards the development of customizable SDN products which can be composed to provide complex functions and services tailored to the customers' needs. Target products and areas of applicability aligned with the LIGHTNESS research topics could be management and control systems for small-medium size data centre operators interested in investing on SDN solutions.

BSC as a HPC research center is focused on how HPC applications could exploit this new network proposed by LIGHTNESS. BSC is the largest research center on High Performance Computing in Spain and it is also hosting the largest supercomputer. BSC runs thousands of HPC applications from various domains such as genomics, weather forecast, and astronomy, with different traffic network demands. These application requirements are pushing the need of high bandwidth and low latency networks. Nowadays, HPC networks are vastly based on traditional electronic switches deploying the InfiniBand network architecture that substantially limits the achievable network bandwidth and latency. On the other hand, optical network technologies like the one provided by LIGHTNESS could significantly improve these current HPC networks. In this context, BSC's exploitation activities were

focused on twofold activities on the second year. First, it continued to identify potential HPC applications that could significantly benefit of the LIGHTNESS network. It was found that for example Big Data applications could also qualitatively benefited from the heterogeneous optical network. And secondly, it has developed a simulator to accurately quantify the potential benefit of optical networks in HPC applications. The insights obtained through simulations will be publish in international conferences during the third year of the project and will be very valuable to identify future exploitations plans for LIGHTNESS in the HPC community.

During this second year, UPC incorporated some of the LIGHTNESS concepts and scenario to Master Degree courses; more specifically, the data centre network technologies and solutions is now part of the course on “Optical Networks”, in the framework of the Master in Telecommunications Engineering at Escola Tècnica Superior d’Enginyeria de Telecomunicació (ETSETB) of UPC-Barcelona Tech and of the course on “Wired Networks” in the framework of Master of Telecommunication Engineering and Management (MASTEAM) of the Escola d'Enginyeria de Telecomunicació i Aeroespacial de Castelldefels (EETAC) of UPC-Barcelona Tech. Moreover, a new PhD student has been enrolled; his PhD will be devoted to studies and implementation on control plane solutions for intra/inter DCs connectivity services.

The expertise gained from LIGHTNESS in the second year led to expand the knowledge and know-how in the field of low latency and high throughput optical packet switch architectures and network infrastructures enabling high performance computers and data centres interconnect networks. TUE is exploiting this expertise in two directions. The first direction is the introduction of state-of-the-art educational programmes in Optical Communication course with specific lectures on advanced data center networks to preparing Master and PhD students for innovative R&D positions in Europe, who will subsequently deploy their skills to strengthen the industrial activities in Europe. Moreover, those gained expertise are attracting several PhD and Master visiting students from other universities with the aim to acquire the specified knowledge developed in the contest of the LIGHTNESS. The second direction is to exploit the fast optical packet switch prototype enabled by SDN developed so far in LIGHTNESS to consolidate its reputation in the international research community by offering unique and state of the art photonic switches.

Based on LIGHTNESS research studies on optical data centres, the HPN group at the UNIVBRIS, as an academic partner, has designed research projects for MSc students, e.g. on data centre traffic analysis and data centre resource orchestration. Three MSc students have passed their thesis examinations. One new PhD student's topic has been defined as Programmable Optical Data Centre. Two international visiting students have been attracted to work on the optical data centre research in the HPN group on optical data centre simulation platform and traffic scheduling. Besides creating education materials for students, the developed SDN controller based on OpenDaylight together with OpenFlow agents for optical devices and extended OpenFlow protocols have become essential elements for Bristol City testbed being supported by Bristol City Council and Bristolisopen. The LIGHTNESS approach has attracted a lot of attention from both academia and industry. A few potential collaborations are under discussions.

6. Conclusions

This deliverable reports the dissemination, standardization, collaboration with other EU projects, and exploitation activities carried out during the second year of the LIGHTNESS project.

The LIGHTNESS partners have consolidated and improved the already quite wide dissemination reported in the first year and therefore visibility of the project objectives and technical solutions through several publications in major journals, magazines and conferences; and the several invited talks and tutorials given by LIGHTNESS partners. In the context of dissemination of the LIGHTNESS concepts and results, special emphasis must be devoted to the achievement of the Best Booth Award in the framework of the EuCNC'14 Conference.

In order to promote the discussion and collaboration about the technical solutions promoted by the project with service and content providers, equipment manufacturers, and academic communities a joint workshop has been organized with FP7 project COSIGN, and participation and dissemination of the LIGHTNESS results have been presented at the workshop organized by FP7 project PACE. The organization and participation to joint workshops is in line with the collaboration activities strategy defined in the first year. Active collaborations with the EU projects COSIGN, PACE, and STRAUSS are also testified by a number of joint scientific works published in the second year.

In the second year, the LIGHTNESS approach, architecture and solutions have been promoted by the active presence of some of the LIGHTNESS partners to the international standardization bodies. To be mentioned, the University of Bristol has shared with ONF director and ONF optical transport working group (OTWG) the latest development in LIGHTNESS project on the key functions development in OF controller based on OpenDaylight to support LIGHTNESS scenario, the Openflow extensions to support the SDN controller southbound interface for the optical network technologies used in LIGHTNESS, and the optical network abstraction model supporting LIGHTNESS scenario.

Finally, the exploitation of the project results will be pursued by the partners, both at individual partner level and at overall consortium level to promote the LIGHTNESS results and their suitability to match the requirements of future Data Centres. Specific activities for commercial exploitation from industrial partners have been conducted with the aim of identifying potential applicability of LIGHTNESS results into new products and services. Similarly, universities and research institutes have exploited the concepts and outcomes of LIGHTNESS to foster their knowledge and know-how and consolidate their position and reputation in the international research community.

7. References

[1] LIGHTNESS Deliverable D6.3 “First year report on dissemination, standardization and exploitation activities”, October 2013.

[2] FP7 COSIGN http://www.fp7-cosign.eu/

[3] FP7 STRAUSS http://www.ict-strauss.eu/en/

[4] LIGHTNESS Deliverable D4.1 “The LIGHTNESS network control plane architecture”, September 2013.

[5] LIGHTNESS Deliverable D4.3 ”The LIGHTNESS network control plane interfaces and procedures”, June 2014.

[6] N. Ciulli, G. Carrozzo, G. Landi, G. Bernini, "An SDN framework for the orchestration of cloud and network services across data centres", Asia Communications and Photonics Conference (ACP) 2013, Beijing, China, November 12-15, 2013

[7] FP7 PACE http://www.ict-pace.net/

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8. Acronyms

AoD Architecture on Demand

API Application Programming Interface

CDN Content Distribution Networks

DC Data Center

DCN Data Center Network

DWDM Dense Wavelength Division Multiplexing

FPGA Field Programmable Gate Array

GMPLS Generalized Multi Protocol Label Switching

HPC High Performance Computing

IaaS Infrastructure as a Service

IETF Internet Engineering Task Force

IoT Internet of Things

IRTF Internet Research Task Force

MPLS Multi Protocol Label Switching

NIC Network Interface cards

NFV Network Functions Virtualization

OCS Optical Circuit Switching

ODL OpenDaylight

OF Open Flow

OGF Open Grid Forum

OIF Optical Internetnetworking Forum

ONF Open Networking Foundation

OPS Optical Packet Switching

OTWG Optical Transport Working Group

PCE Path Computation Element

QoS Quality of Service

SDN Software Defined Networking

SDNRG SDN Research Group

SDO Standard Development Organizations

ToR Top of the Rack

VDC Virtual Data Centre