ACINO

Application-Centric IP/optical Network Orchestration

ACINO / D6.4

Second year report on dissemination and communication activities

Dissemination level	PU
Version	1
Due date	31.01.2017
Version date	24.02.2017

This project is funded by the European Union

Document information

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Project funding

645127 — ACINO — H2020-ICT-2014

Revision and history chart

Version	Date	Author	Comment
0.1	30.06.2016	Stéphane Junique (ACREO)	First draft, based on the 1st year report (D6.3)
0.2	01.12.2016	Stéphane Junique (ACREO) Victor López Avarez (TID) Domenico Siracusa (CREATE-NET) Thomas Szyrkowiec (ADVA) Mohit Chamania (ADVA) Dimitrios Klonidis (AIT) Ori Gerstel (SEDONA)	Added dissemination activities
0.3	03.01.2017	Stéphane Junique (ACREO) Thomas Szyrkowiec (ADVA) Mohit Chamania (ADVA) Victor López Avarez (TID)	Added Standardisation activities
0.4	24.01.2017	Stéphane Junique (ACREO) Victor López Avarez (TID) Domenico Siracusa (CREATE-NET) Thomas Szyrkowiec (ADVA) Mohit Chamania (ADVA) Dimitrios Klonidis (AIT) Ori Gerstel (SEDONA)	More dissemination and standardisation activities Added planned activities for 3rd year
0.5		Stéphane Junique (ACREO)	Added missing parts Document introduction and conclusion Chapter introductions, Chapter 2 summary

0.6	05.02.2017	Stéphane Junique (ACREO)	Internal review
0.7	06.02.2017	Dimitrios Klonidis (AIT) Stéphane Junique (ACREO)	Internal Review Corrections from plenary meeting 7 (Madrid)
0.8	19.02.2017	Stéphane Junique (ACREO)	Added chapter about contacts with other projects More minor corrections
0.9	22.02.2017	Domenico Siracusa (CREATE-NET) Michele Santuari (CREATE-NET)	Internal Review
1.0	23.02.2017	Stéphane Junique (ACREO)	Final version

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Summary

This ACINO deliverable D6.4 presents the communication and dissemination activities performed by the consortium during the first two years of the project. We have communicated using our website, Twitter account and by various communication actions:

- The website saw over 3000 unique visitors during the first year and over 4000 during the second year;
- The consortium Twitter account had 49 followers at the end of the first year and 80 at the end of the second year. We posted 50 tweets during the first year and 40 more during the second year;
- We also held a press release and an interview in a magazine during the first year, and had three more similar communication actions during the second year.

The dissemination activities have been composed of participation in public events where the goals and concepts of ACINO were presented via publications, presentation, workshops, courses and demonstrations. Overall, over forty different dissemination activities have been performed:

- An article has been published in peer-reviewed, open access Journal of Green Engineering;
- Eighteen articles have been published in conferences: four during the first year and fourteen during the second. One of them was a post-deadline and six were invited papers;
- We have co-organised three workshops: the *workshop on Network Function Virtualization and Programmable Networks* at EUCNC 2015, the *first Workshop on Multi-Layer Network Orchestration* (NetOrch) at ICTON 2016 and the stand-alone *ONOS/CORD workshop*;
- We have held 16 talks, tutorial, courses and demonstrations;
- Consortium members have won two prizes for work related to ACINO: a team of developers won the *3rd prize of the ONOS Build Hackathon*, and Telefónica won the *Best SDN-NFV solution award* at the LTE and 5G World conference by presenting a solution in which Sedona Systems was involved;
- We have contributed to six IETF standardisation documents and done some implementation and test of these standards.
- We have contributed to two open source projects: the NetPhony and ONOS controllers, with the implementation of main features being accepted and merged to the core code of these open source projects.

Finally, the project has devised detailed plans for its dissemination activities for the last year of the project. We have:

- Confirmed plans for the organisation of a workshop, the second edition of the NetOrch workshop, co-located with the ICTON conference;
- A solid plan for continued dissemination in conferences (already five accepted conference papers, five talk invitations and a list of conferences of interest) and in peer-reviewed journals, with one article accepted for publication in the Journal of Lightwave Technology, two articles under review and plans for four more;
- Some more planned contribution to open source projects.

1 Introduction

This document reports on the dissemination and communication activities performed by the ACINO consortium during the first and second year of the project. This report is a follow-up to deliverable D6.3 [D63] provided at the end of the first year. The dissemination and communication strategy presented in D6.3 are not repeated in this document. Concerning the communication tools that were developed at the beginning of the project, this deliverable does not report on those that have not changed (project profile, document models, fact sheet, flyer). However, the usage of the ACINO website and Twitter account are reported upon.

The activities from the first year are repeated in this report: this allows providing a better picture of the project this far. It also shows how much our dissemination activities have increased during the second year.

This document is laid out as follows:

- **Chapter 2** *Communication activities* presents our communication tools and communication actions since the project started;
- **Chapter 3** *Dissemination activities* presents the project's interaction with its peers in scientific forums;
- **Chapter 4** *Standardization and contribution to Open Source activities* presents the project's interaction with standardisation organisations and our contribution to existing open source software projects;
- **Chapter 6** *Planned activities for the third year* provides a view of what lies ahead of the project for its last year of activity: possible publications, workshops, participation in conferences and other events;
- Finally, **Chapter 7** *Conclusion* summarises ACINO's dissemination and communication activities for its first two years.

2 Communication activities

This chapter presents our communication tools: the first section presents the ACINO website, the second section our Twitter account, and the third section lists the communication events (press releases, interviews) that have happened since the project inception.

2.1 Website

2.1.1 Site content

To promote the project, a website (http://www.acino.eu/) [ACIWEB] was developed during the beginning of the project and has been regularly updated. On the front page, shown in Figure 2.1, a top row gives access to facts about the project: the challenges faced and our approach to solve them.

The lower part of the main page presents external data about ACINO and is updated dynamically:

- The **News** section is automatically updated with the title of the five latest news articles that project members have written. The news are short articles related to project activities, our past presence at conferences, or where we point out articles about application-centric networking, Software-Defined Networking (SDN), Internet Protocol (IP)/Optical orchestration, and other matters of interest for ACINO. The news area of the website can be accessed from the menu for an exhaustive list of the news articles.
- A **Meet us at** section lists upcoming events that ACINO members will be present at.
- A **Social** section lists the tweets from the ACINO account. This section is also automatically updated when new tweets are published, allowing minimal maintenance.
- A **presentation of the project** and other facts are also accessible through the menu.
- We list all our **publications** in a dedicated section, allowing visitors to learn more about the project results. Providing references to dissemination in recognised forums such as technical conferences and peer-reviewed journals adds to the project credibility.

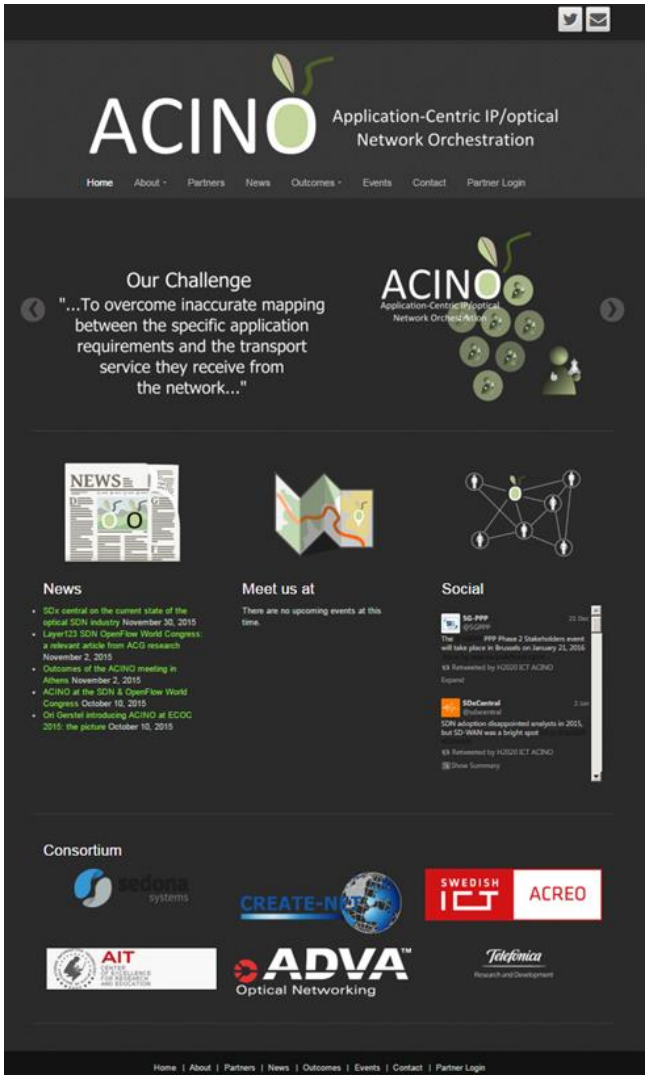

Figure 2.1: Front page of the project website, located at www.acino.eu.

2.1.2 Site statistics for the first year

The site was up and running in March 2015, as early as the second month of the project, and we started gathering statistics on May 27th, 2015). Some key characteristics concerning the number of visits include:

- 3400+ sessions were created by a total of over 3000 visitors;
- Most visits to the site were by new visitors (less that 10% of the visitors were returning visitors);
- The site provided over 4300 pages views;
- The bounce rate was around 85%, meaning that for 85% of the connections user looked only at the main page and did not request another page.

In terms of demographics, it is interesting to see that the site caught interest in many countries outside of Europe, as shown in Figure 2.2: in North America (United States of America and Canada), South America (in

particular Brazil, Colombia, Argentina and Chile), Africa (South Africa, Morocco, Egypt, Kenya and more), Russia, China, India, Japan, Australia and several countries in the middle East. The ten most active countries are listed in Table 2.1.

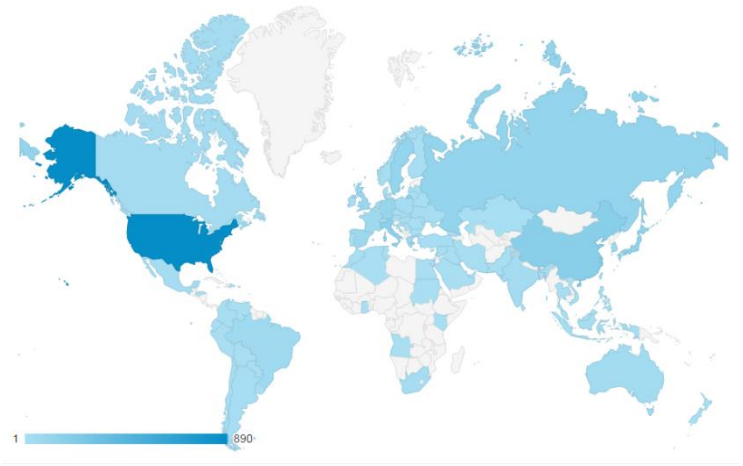

Figure 2.2: Map showing which countries have accessed the ACINO website during the first (from Google analytics).

Table 2.1: List of the 10 countries that created the highest number of sessions with the ACINO website during the first year (from Google analytics).

Country	**Sessions**	**New users**
United States	890	872
(not set)	855	855
China	178	174
Italy	151	66
Japan	134	134
Russia	121	49
Sweden	108	62
Germany	100	88
United Kingdom	84	80
Spain	73	44

2.1.3 Site statistics for the second year

The statistics for the second year were gathered between the 1st of February 2016 and 30th of January 2017. Some key characteristics concerning the number of visits include:

- 4000+ sessions were created;
- Most visits to the site were by new visitors (24% of returning visitors);
- The site provided over 8800+ pages views;
- The bounce rate was around 85%, meaning that for 85% of the connections user looked only at the main page and did not request another page.

In terms of demographics, our website remains of interest all over the world, as shown in Figure 2.3. The ten most active countries are shown in Table 2.2. The main country accessing the website is Russia. Taking into consideration the number of sessions coming from Russia compared to other countries, it can be safely assumed that the attacks that our site has suffered from came from Russia, and that those attacks are masking the real interest for ACINO from that country. However, the website has become or remained of interest in countries where no consortium member resides, such as the United States, the United Kingdom and Brazil.

Table 2.2: List of the 10 countries that created the highest number of sessions with the ACINO website during the second year (from Google analytics).

Country	Sessions	New users
Russia	1989	1611
United Kingdom	349	340
Sweden	297	93
Italy	247	99
Kyrgyzstan	162	128
Germany	124	82
United States	116	98
Brazil	110	110
Spain	94	64
Greece	87	37

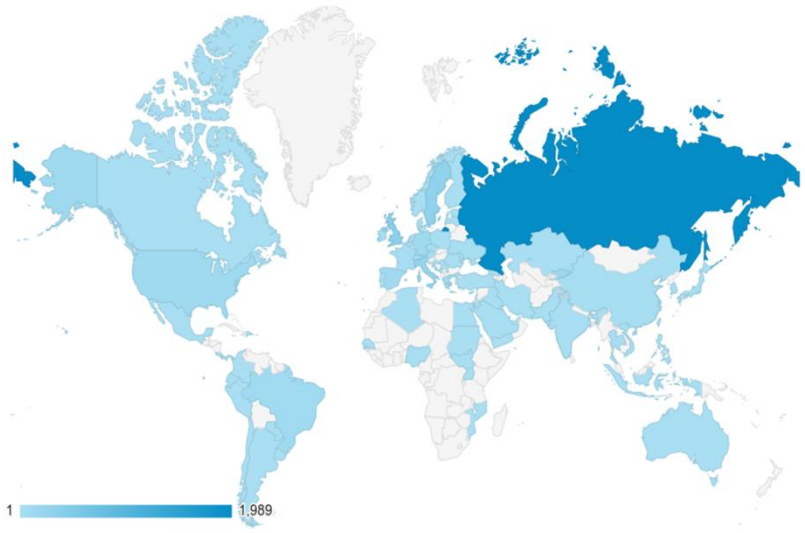

Figure 2.3: Map showing which countries have accessed the ACINO website during the second year (from Google analytics).

2.2 Twitter account

We opened the twitter account **@acinoH2020** [ACITWIT] to raise awareness about the project, create a community of stakeholders and future adopters, and hopefully improve the visibility of our research results. Twitter is an ideal tool to publish ephemeral information about events, and our main focus has been on Software-Defined Network (SDN) events as well as ACINO's own meetings.

Twitter usage:

- At the end of the first year, the consortium had posted approximately 50 tweets and the account had 49 followers.
- At the end of the second year, the consortium had posted approximately 90 tweets and the account had 80 followers.

2.3 Communications

2.3.1 Year one

During the first year of the project, we had two communication actions: a press release and an interview in a magazine:

1. **Short article:** On the 2nd of March 2015, CREATE-NET posted on its website a short article introducing the project and highlighting the main benefits for the operators and users adopting the proposed technology. The post has been produced both in English and Italian languages; the English version is available at [NCRE].
2. **Interview**: On the 10th of May, 2015, Ioannis Tomkos from AIT was interviewed by the Gazzetabyte online magazine for an article on the topic "Optical networking: The next 10 years", in which he also

introduced the innovative aspects in terms of multi-layer networking brought by ACINO. The article can be found at [TOMGAZ].

2.3.2 Year two

During the second year of the project, we had three communication actions: we released our first newsletter in April 2016 and our ACINO concept paper merely days later. And an interoperability test organised by the Open Networking Foundation (ONF) and the Optical Innovation Forum (OIF) led to a press release:

1. **Newsletter**: The ACINO consortium released its first newsletter [NEWSLETTER1] on the 5th of April, 2016.
2. **Concept paper**: The ACINO consortium released its concept paper [ACICONCEPT] on the 7th of April, 2016.
3. **Press release and magazine article**: Telefónica, ADVA and Sedona Systems took part in in 2016 in **a joint interoperability test of the Transport API (T-API) organised by the ONF and the OIF**. They demonstrated the T-API [ONFTAPI] interface using the ACINO laboratory set up. Such interoperability tests are key to establishing a new standard, as they show that the implementations from different vendors are compatible with each other. This work led to a press release by the OIF [OIFINTEROP] and an article in a magazine [LWINTEROP].

3 Dissemination activities

This chapter presents the dissemination activities of the consortium during the past two years. The chapter is laid out as follows: the first section presents the main achievements of the second year of the project. The second section presents our publications in peer-reviewed journals. The third section describes our publications in conferences. The fourth section describes the workshops that we have organised. The fifth section lists the talks that we have held at conferences that have not led to publications in proceedings. The sixth section lists other conferences and events that we have attended, for example with booths at conferences and exhibitions. The seventh section summarises all our dissemination activities for the two years of the project.

3.1 Second year achievement highlights

As the project has led to significant technical results during the second year, the consortium put relevant effort on disseminating them. Our most noteworthy achievements are:

- We published a paper in peer-reviewed journal, open access **Journal of Green Engineering** and we have another paper accepted for publication in the **Journal of Lightwave Technology (JLT)**;
- We published fourteen conference papers, and in particular **one post-deadline paper at ECOC[1] and six invited papers** (at ECOC, ONDM[2], ICTON[3], NOC[4] and OFC[5]);
- **We won two prizes: a** team led by Michele Santuari (CREATE-NET) won a **3rd prize at the ONOS[6] Build Hackathon.** Telefónica won the **Best SDN-NFV[7] solution award at the LTE[8] and 5G world conference**.

3.2 Scientific publications in peer-reviewed journals

We have published in the peer-reviewed, open access **Journal of Green Engineering** an article called **The Role of SDN in Application Centric IP and Optical Networks** [LOPGREN].

The paper presents the ACINO concept: Transport IP/optical networks are evolving in capacity and dynamicity of configuration. This evolution gives little to no attention to the specific needs of applications, beyond increasing raw capacity. ACINO allows applications to explicitly specify requirements for requested services in terms of high-level (technology- and configuration-agnostic) requirements. These requirements are described using intents and certain primitives which facilitate translation to technology specific configuration within the ACINO infrastructure.

[1] European Conference on Optical Communication
[2] International Conference on Optical Network Design and Modelling
[3] International Conference on Transport Optical Networks
[4] European conference on Network and Optical Communication
[5] Optical Fiber Communications Conference
[6] Open Network Operating System
[7] Network Function Virtualisation
[8] Long Term Evolution

Furthermore, the consortium has submitted three more journal articles to the Institute of Electrical and Electronics Engineers (IEEE) Communications Magazine and to the IEEE/Optical Society of America (OSA) Journal of Lightwave Technology (JLT). One of the articles submitted to JLT has been accepted for publication. The two other articles are currently under review (see section 6.3.1).

3.3 Scientific publications in conferences

The consortium has so far given eighteen presentations at international conferences with article publications in proceedings: four during the first year of the project and fourteen during the second year.

3.3.1 Year One

1. **Application-centric networks and the future 5G transport**: This article [SKOICT] was published at the **17th International Conference on Transparent Optical Networks** (ICTON) [ICTON2015] in June 2015. The paper presents the Application-centric IP/Optical network concept pursued by the H2020 project ACINO, and how it could be applied as a future 5G transport network. While 5G concepts are still maturing, the article investigates the envisioned capabilities of a 5G network, the use-cases and the requirements different applications would have on a wired transport network for 5G. Our conclusion is that ACINO could fulfil the bandwidth, low-latency, security, and reliability requirements, in a way that differentiates between different 5G services.

2. **The need for SDN in Orchestration of IP over Optical MultiVendor**: This article [GERECOC] was published at the **41st European Conference on Optical Communication (ECOC)** [ECOC2015] in September 2015. It explains why distributed control lacks the ability to optimally control networks with multiple transport domains or both IP and optical layers. It then proposes a practical architecture to fix these issues and experimentally demonstrate it over commercial IP/transport gear.

3. **Multi-layer orchestration for application-centric networking**: This article [GERPIS] was published in **Photonics in Switching** [PIS] in September 2015. It argues that the implementation of services in an IP-optical network should be driven by the needs of the specific applications, and explains why this requires a centralized orchestration architecture.

4. **Optical Network Programmability - Requirements and Applications**: This article [AUTPIS] was published in **Photonics in Switching** [PIS] in September 2015. It describes the requirements, applications and use cases for optical network programmability. Based on application scenarios, an open northbound Application Programme Interface (API) with different levels of control and abstraction to address different network operator requirements is defined. For its illustration, use cases for optical network programmability show current research directions.

3.3.2 Year Two

Six articles were published by the consortium in the proceedings of the **42nd European Conference on Optical Communication (ECOC)**, which took place in Düsseldorf, Germany, in September 2016:

1. **Latency-aware Multi-layer Network Optimization in IP-over-WDM[9] Core Networks**: This article [ROZECOC] describes the handling of latency-sensitive traffic in an IP/optical core network. It proposes a latency-aware multi-layer network optimization approach, shows that it is superior to current solutions and evaluates the impact of propagation and electronic processing delays.

2. **First Demonstration of an Automatic Multilayer Intent-Based Secure Service Creation by an Open Source SDN Orchestrator**: This article [SZYECOC] was published as a **post-deadline paper**. It presents an automatic intent-based encryption layer selection and configuration for a multilayer network covering IP and optical utilizing an open source SDN orchestrator. Results show that the processing impact of a secure channel creation is negligible.

3. **Transport API: A Solution for SDN in Carriers Networks**: This article [LOVECOC] discusses the ONF Transport API, an interface to enable control of Transport networks, including services such as topology, or connectivity setup. The paper presents the first demonstration of a connectivity service over a Dense Wavelength Division Multiplexing (DWDM) network using the Open Networking Foundation (ONF) Transport API [ONFTAPI].

4. **First demonstration of SDN-controlled Multi-Layer Restoration and its advantage over Optical Restoration**: This article [MAOECOC] presents the full implementation of a centrally orchestrated multi-layer restoration over commercial optical and IP gear. The process considers the behaviour of the IP layer and shows that compared to optical restoration, packet losses are 54% lower.

5. **Techno-Economic Evaluation of Optical Transport Network in Metropolitan Deployments**: Optical Transport Network technology provides multiple benefits to the network operator in backbone networks. This paper [JIMECOC] presents a techno-economic comparison of optical solutions for metropolitan scenarios to assess when Optical Transport Networks should be deployed.

6. **Operator use cases that benefit from multi-layer optimization and application awareness**: This **invited paper** [LOKECOC] discusses multi-layer network optimization and application awareness. Multi-layer optimization enables the operators to optimize their packet and transport resources. Application awareness will provide potential savings as well as offer a better adaptation of network services to applications.

Two articles were published in the proceedings of the **20th International Conference on Optical Network Design and Modelling (ONDM)** [ONDM2016], which took place in Cartagena, Spain, in May 2016:

7. **On the Impact of Transmission Technologies in Metropolitan Networks**: This article [JIMONDM] assesses alternative deployments to upgrade metro networks in terms of cost efficiency. Current metro networks are deployed using IP/MPLS[10] equipment on top of ring physical topologies. Such

[9] Wavelength Domain Multiplexing
[10] Multiprotocol Label Switching

networks are migrating from 10G interfaces to 100G, and both the packet layer and the underlying infrastructure with its limitations must be considered.

8. **A Survey of Multi-layer Network Optimization**: This **invited paper** [ROZONDM] gives an overview of the recent work in multi-layer network studies. First, a classification is provided, followed by the identification of the areas of study that are likely to attract more interest. Finally, a novel objective of future studies is suggested.

Two articles, both **invited papers**, were published in the proceedings of the **18th International Conference on Transparent Optical Networks (ICTON)** [ICTON2016] which took place in Trento, Italy, in July 2016:

9. **SDN application-centric orchestration for multi-layer transport networks**: This concept paper [PEDICTON] proposes the ACINO concept: an SDN-based Network Orchestrator manages multi-layer transport networks while taking explicit application requirements into account. It is based on the observation that modern IP/Optical transport networks are seldom jointly operated and optimized, and do not cater to the usually implicit requirements of applications, which ultimately drive network traffic. Network architecture and requirements are discussed; an interface is proposed to allow applications to explicitly specify their requirements in a network-agnostic manner, as well as possible strategies to optimize the network taking these requirements into account.

10. **The Software-Defined Transport Network: Fundamentals, Findings and Futures**: This paper [KINGICTON] introduces the concept of Software–Defined Transport Networks: SDN is an established network paradigm, architecture and principles that has attracted significant research effort in recent years. An SDN–enabled infrastructure decouples network control from forwarding and enables direct programming. Recently, there is an increasing effort to introduce SDN support in the transport layers of the network operators' WAN[11] infrastructure, like Layer 0 and 1. We refer to this infrastructure as the "Software Defined Transport Network". Benefits include network management devolvement, timely connectivity provision, improved scalability, and open and flexible programmability using a well-defined API. The paper outlines the main elements of Software–Defined Transport Networks and highlights relevant Application-Based Network Operations (ABNO) enabling technologies. It also demonstrates how this technology will benefit network operators, and provides an overview of research results and deployment examples. Finally, some of the technology gaps and future research opportunities are identified.

The following three articles were published in other conferences:

11. **Towards a Transport SDN for Carriers Networks: An Evolutionary Perspective**: This **invited paper** [LOPNOC] was published in the proceedings of the **21st European Conference on Networks and**

[11] Wide Area Network

Optical Communications (NOC) [NOC2016], which took place in Lisbon, Portugal, in June 2016. The paper presents architectures that enable interoperability in transport networks. Some of these architectures are market ready and they have been tried in the field, while there are some approaches which are under standardization. Indeed, network operators have worked in interoperable scenarios for transport networks from several years. The main motivation is to have a rich ecosystem, which encourages the competition to have more efficient network solutions. The bandwidth increment in the transport network puts a lot of pressure to have revenues on an environment where the end-user is willing to pay less and less for the service. Software Define Networks present a new hope to achieve such a desired multi-vendor interoperability.

12. **Multilayer network planning — A practical perspective**: This **invited paper** [AUTOFC] was published in the proceedings of the **Optical Fiber Communications Conference and Exhibition** (OFC) [OFC], which took place in Anaheim, California (United States of America) from the 20th to the 24th of March 2016. The paper presents a pragmatic and practical multilayer network planning approach based on a candidate light path auxiliary graph model. The paper discusses how this approach can be applied to offline network planning as well as dynamic planning and provisioning of services.

13. **The Role of SDN in Application Centric IP and Optical Networks**: This paper [LOGEUCNC] was published in the proceedings of the **25th European Conference on Networks and Communications (EUCNC)** [EUCNC2016], which took place in Athens, Greece, in June 2016. It presents the ACINO concept, which is based on facilitating applications to explicitly specify requirements for requested services in terms of high-level (technology agnostic) requirements such as maximum latency or reliability. Indeed, transport IP/optical networks are evolving in capacity and dynamicity configuration. This evolution gives little to no attention to the specific needs of applications, beyond raw capacity. Using the ACINO concept, requirements are described using intents and certain primitives which facilitate translation to technology specific configuration within the ACINO infrastructure. To support this application centric approach, SDN must have a key role in this evolution. There are representative case studies where SDN gives an added value when considering not only the network but also the application layer.

14. **Policy-based Restoration in IP/Optical Transport Networks**: This paper [SANSOFT] describes a demonstration presented at the **2nd IEEE Conference on Network Softwarization** [NETSOFT2016] in Seoul, South Korea, in June 2016. In case of network failure, optical and IP restoration are two different strategies that present trade-offs in terms of cost, responsiveness and offered capacity. This paper proposes the first demonstration of an IP/Optical SDN control solution (“network orchestrator”) for transport networks, which orchestrates IP or optical restoration based on the policy explicitly requested by the client application. The policy is communicated via intents, as part of the constraints that must be satisfied for a service. The orchestrator uses these intents to identify the restoration mechanism to employ in case of failure.

3.4 Workshop organisation

The consortium has organised or co-organised three workshops so far: one during the first year, and two during the second year, one of which corresponds to the project's milestone MS33.

3.4.1 Year One

Domenico Siracusa (CREATE-NET) participated to the organisation of the **Workshop on Network Function Virtualization and Programmable Networks** that was part of the European Conference on Networks and Communications (EUCNC) held in June 2015. The program of the Workshop is available at [EUCNC2015].

3.4.2 Year Two

During the second year of the project, the consortium organised two workshops: the first Workshop on Multi-Layer Network Orchestration (NetOrch), and ONOS/CORD workshop. Both are described below.

3.4.2.1 NetOrch

ACINO organised the first Workshop on Multi-Layer Network Orchestration (NetOrch), co-located with the 18th International Conference on Transparent Optical Networks (ICTON 2016) [ICTON2016] and held in Trento, Italy, in July 2016. The conference benefited from the technical co-sponsorship of the IEEE and the IEEE Photonics Society.

Figure 3.1: Picture of the NetOrch Workshop: chairs and speakers of the second session.

The organisation of this workshop was planned during the first year of the project and corresponds to our milestone MS33. The scope of the workshop was to create an international table of discussion where researchers and enthusiasts of network control and management were invited to contribute on the topic of multi-layer orchestration and programmability for future converged packet/circuit networks. Application-aware networking and inter data centre communications were also among the central topics.

The workshop was jointly organised with the US-Japan project ACTION [ACTION], represented by Prof. Andrea Fumagalli (University of Texas at Dallas) as workshop co-chair. The other two organisers and co-chairs of the workshop were Domenico Siracusa (CREATE-NET) and Ioannis Tomkos (AIT).

The NetOrch workshop (see Figure 3.1) was divided into two sessions, with speakers from Europe, the United States and Japan. The programme of the workshop is available online [NETORCHWS].

3.4.2.2 ONOS/CORD workshop

CREATE-NET also organised with Telecom Italia and ON.Lab the ONOS/CORD workshop, with the aim of creating an opportunity to discuss about the Open Network Operating System (ONOS) and Central Office Re-designed as a Datacenter (CORD) initiatives and their use-cases and directions, and to empower the ONOS/CORD community in Europe. The workshop was the first one in Europe dedicated to technical leaders, developers, network administrators and engineers from service providers, vendors, research centers and universities interested in using and collaborating with these initiatives. Some of the ACINO use-cases were discussed, followed by a short demonstration on policy-based multi-layer restoration. More information about the event can be found at [ONCORDWS].

3.5 Workshop presentations and tutorials

This section documents the presentations performed at conferences that did not lead to a publication in a proceedings, as well as courses and tutorials held in relation to ACINO. **We held six presentations, courses and tutorials during the first year**.

During the second year, we held **eleven presentations in conferences and workshops** that did not lead to publications in proceedings. In particular, we held four talks in ONOS-related workshops and one at standardisation body ETSI. In addition, **a team led by Michele Santuari (CREATE-NET) won the 3rd prize of the ONOS Build Hackathon**.

3.5.1 Year One

We held four presentations at workshops:

1. **ACINO: Application Centric IP/Optical Network Orchestration**: Domenico Siracusa (CREATE-NET) held this presentation [SIREU] during the workshop on **Network Function Virtualization and Programmable Networks** (see section 3.4.1) introducing the main concepts of the ACINO project and discussing the topic of the network programmability applied in the context of transport networks.

2. **Control and Orchestration for Future IP/Optical Transport Networks**: Domenico Siracusa (CREATE-NET) gave this presentation [SIRPND] at the **Photonic Networks and Devices** 2015 held within the OSA Advanced Photonics Conference, held in June 2015.

   The presentation addressed next-generation transport networks based on novel technologies such as Space Division Multiplexing and their interaction with the advanced applications, which are demanding very high capacities for tailored services. In this context, the ACINO approach to network orchestration has been discussed.

3. **Resource Management in 5G Transport Networks**: Domenico Siracusa (CREATE-NET) gave this presentation [SIRCTTE] at the **Workshop on Convergence of fixed and mobile broadband networks** organised within the Conference of Telecommunication, Media and Internet Techno-Economics (CTTE), held in November 2015.

   The presentation promoted the concept of an adaptive and sharable 5G transport network solution integrating the fronthaul and backhaul segments of the network (the so called Xhaul). In addition, it stressed the need to fulfil applications' requirements on an end-to-end basis, by proposing a study-case that includes the metro/core transport segments and highlights the possible interaction between the Xhaul control solution and the multi-layer/multi-technology orchestrator for transport networks that is proposed in ACINO.

4. **Adding application awareness in flexible optical networking**: Dimitrios Klonidis from AIT gave this presentation [APPAW] at the **i-Can workshop on Information-Centric Access Networks** [ICAN] that took place at the Athens University of Economics and Business in Athens, Greece on 2-3 June 2015. The presentation introduced the ACINO concept.

Ori Gerstel from Sedona Systems was present at the **Optical Fiber Communications Conference in 2015 (OFC)** [OFC], where he held a tutorial and a course:

5. **Control Architectures for Multi-layer Networking: Distributed, centralized, or something in between?**: In this tutorial, Ori reviewed the spectrum of likely centralized and distributed control architectures and explained how different use cases will shape the optimal choice. The conclusion was that practical considerations dictate that network control will not be fully centralized – even in the SDN era.

6. **SC411: Multi-layer Interaction in the Age of Agile Optical Networking**: In this 3 hour long course, Ori provided an overview of multi-layer networking – including physical integration and control plane integration between the layers. He then described the different use cases for multi-layer control and the value that each of them brings to the network operator.

3.5.2 Year Two

3.5.2.1 ONOS workshops

As the ACINO orchestrator is based on the ONOS network controller, the consortium is naturally following the development of ONOS. We were present at three ONOS workshops during the second year of the project:

ONOS/CORD: This workshop [ONCORDWS] took place in Turin, Italy, on September 13th and 14th, 2016. We co-organised it, as reported in section 3.4.2.2. We held two presentations at the workshop:

1. **Application-centric in IP/Optical network:** Domenico Siracusa from CREATE-NET held this talk that presented the ACINO project to the ONOS community.

2. **Demonstration**: Michele Santuari from CREATE-NET demonstrated the ACINO orchestrator, leveraging the policy-based multi-layer restoration use case.

ONOS mini-summit: This workshop [ONMINI], in which we held a presentation, took place in Berlin, Germany, on June 20th:

3. **Network orchestration for multi-layer IP/Optical networks**: Michele Santuari from CREATE-NET held a presentation in front of the ONOS community. In particular, Michele presented the orchestrator and ran a real-time demonstration.

ONOS Build: This workshop [ONOSBUILD] took place in Paris, France, in November 2016. We attended, holding a presentation and participating to the Hackathon:

4. **Intent-based multi-layer IP/Optical networking**: Michele Santuari form CREATE-NET held this talk, in which he described what has been done in the ACINO project to develop an open-source network orchestrator, starting from the ONOS packet-optical case. He then presented some relevant use-cases that demonstrate the capabilities of the developed tool.

3.5.2.2 Talks at standardisation bodies

5. **Presentation of ACINO at ETSI**: Dissemination of ACINO's work, concepts and results at standardisation bodies is a very important means to reach our goals, as it will allow the project's efforts to survive after the end of the project. Luis Miguel Contreras Murillo from TID presented ACINO at the **European Telecommunications Standards Institute** (ETSI) [ETSI] in March 2016.

3.5.2.3 Talks at conferences and workshops

6. **SDN as an enabler of application awareness and multilayer network optimization**: Ioannis Tomkos from AIT gave this invited talk at the **Forum for European ICT and Media Professionals** (FITCE) [FITCE2016], which took place in Athens, Greece in September 2016. Ioannis described SDN as the key ingredient in application-centric multi-layer networking, and he introduced two use cases of the ACINO project.

7. **Future-proof front-haul and back-haul networks**: Juan Pedro Fernandez Palacios from TID gave this talk at **ECOC** [ECOC2016] in 2016. In his presentation, Juan Pedro discusses the potential of the emerging 5G network to meet the needs of rapid growth in bandwidth demand.

   Moreover, the authors were invited to write an article [LOPOCM] with the same content in the magazine **Optical Connections Magazine**. There is no acknowledgement on the magazine version as it is not customary to do so in this magazine.

8. **Towards a Transport SDN for Carriers Networks: An Evolutionary Perspective**: Juan Pedro Fernández–Palacios from TID held this presentation at the **Optical Innovation Forum** [OIF] which took place in Nice, France in June 2016. In this talk, Juan Pedro proposes an SDN architecture that enables

automated and simplified network service provisioning through different vendors, network segments (metro, core, data centres, …) and technologies.

9. **Bringing Application-awareness into Future Transport Networks: the ACINO approach:** Domenico Siracusa from CREATE-NET gave this presentation at the *Workshop 4A* "Workshop on Next generation fronthaul/backhaul integrated transport networks" [EUCNCWS4A] organised by the 5G-PPP [5GPPP] 5G-Crosshaul project at the EUCNC 2016 Conference [EUCNC2016]. The presentation argued about the opportunity to introduce application-awareness investigated in the ACINO project in modern transport networks and how this could be applied on an end-to-end basis, by considering the joint orchestration or multiple network segments, from the core to the fronthaul.

10. **Control Plane for High Capacity Networks**: Juan Pedro Fernández–Palacios from TID held this presentation at the **V International Workshop on Trends in Optical Technologies** [WSTRENDOT], which took place in Campinas-Sao Paulo, Brazil, in May 2016. This workshop gathers researchers, industrial practitioners and operators to discuss innovations and latest developments.

    In his talk, Juan Pedro argues that end to end SDN enables automated and simplified network service provisioning across network segments and technologies, but that it requires 1) transferring multi-domain and multilayer provisioning functionalities from Network Management Systems (NMS) to the control plane (to minimize the number of network configuration points) and 2) unifying network configuration and orchestration mechanisms. This can only be achieved if vendors use common information modelling.

3.6 Other relevant events and participations

The consortium has participated to two events where it has received special distinctions:

1. **3rd prize of the ONOS Build Hackathon**: Michele Santuari led a team of developers from European projects ACINO and GÉANT [GEANT] (GN4-2) during the hackathon that took place at the ONOS Build workshop [ONOSBUILD] mentioned in section 3.5.2.1. During that session, experienced ONOS developers focused on building features and applications on top of ONOS. The team, composed by experts of both projects (with CREATE-NET and ADVA from ACINO), worked on topics that leverage the synergies of the two initiatives on the subject of orchestration of controllers. **The team won the 3rd prize of the ONOS Hackathon!**

2. **Best SDN-NFV solution award**: Telefónica attended the **LTE and 5G world Conference and Exhibition** [LTE5GCONF], which took place in London in June 2016. They presented their End to End SDN Transport Solution with the work done in several EU projects, including ACINO's multi-layer approach and several proof of concepts done with Sedona. **They were awarded the best SDN-NFV solution [**LTE5GAWARD**]**.

3.7 Attended events

In addition to the talks held that have been described in the previous sections, consortium members have been present at conferences, either manning booths or listening to speakers.

3.7.1 Year One

1. **Demonstration at the Optical Fiber Communications Conference (OFC)** [OFC]: SEDONA Systems were present at OFC, as mentioned in section 3.5.1. In addition to the tutorial and course that they held, SEDONA Systems hosted a booth in which they demonstrated early feasibility of multi-layer control over commercial optical and IP gear in the lab of Telefónica. The demonstration showed the ability to interface with multiple controllers for different domains, and the ability to present a unified view of the network and to optimize the IP layer based on changing traffic conditions.

2. **Demonstration at the SDN & OpenFlow World Congress**: SEDONA Systems hosted a booth at the SDN & OpenFlow World Congress [SDNWC]. They presented and discussed the company vision on the topic of multi-layer orchestration. They also demonstrated an implementation of architecture, as well as several important applications. In addition to that, the booth exposed the project flyers, which have been discussed with the interested congress attendees.

   CREATE-NET also attended the congress and promoted the project concepts thanks to the support of the flyers. The congress was an interesting opportunity to share ideas and received the interest of many companies operating in the field of transport networks (e.g. Deutsche Telekom, KT, and others).

3. **Demonstration at the Open Networking Summit (ONS)**: SEDONA Systems hosted a booth at the ONS in Salta Clara, California [ONS], in which they demonstrated the basic capabilities that are needed for multi-layer control, such as the ability to automatically detect how the IP layer and optical layer are connected.

3.7.2 Year two

During the second year of the project, SEDONA systems attended the following conferences:

1. **OFC** [OFC]: Sedona Systems were present at OFC, where they held a booth.

2. **L123 SDN Congress 2016**, which took place at the Hague, Holland in 2016.

3.8 Summary of dissemination activities

This section summarizes the achievements of the project in terms of dissemination during the first two years. Table 3.1 lists the papers published in journals and conferences. Table 3.2 lists the workshops (co)-organised by ACINO. Table 3.3 lists the talks and demonstrations held, and Table 3.4 the prizes that we have won.

Table 3.1: List of papers published in journals and conferences.

#	Year	Title	Conference	Comment
1	1	Application-centric networks and the future 5G transport	ICTON	
2	1	The need for SDN in Orchestration of IP over Optical MultiVendor	ECOC	

#	Year	Title	Conference	Comment
3	1	Multi-layer orchestration for application-centric networking	PiS	
4	1	Optical Network Programmability - Requirements and Applications	PiS	
5	2	The Role of SDN in Application Centric IP and Optical Networks	Journal of Green Engineering	Peer-reviewed journal
6	2	Latency-aware Multi-layer Network Optimization in IP-over-WDM Core Networks	ECOC	
7	2	First Demonstration of an Automatic Multilayer Intent-Based Secure Service Creation by an Open Source SDN Orchestrator	ECOC	Post-Deadline
8	2	Transport API: A Solution for SDN in Carriers Networks	ECOC	
9	2	First demonstration of SDN-controlled Multi-Layer Restoration and its advantage over Optical Restoration	ECOC	
10	2	Techno-Economic Evaluation of Optical Transport Network in Metropolitan Deployments	ECOC	
11	2	Operator use cases that benefit from multi-layer optimization and application awareness	ECOC	Invited paper
12	2	On the Impact of Transmission Technologies in Metropolitan Networks	ONDM	
13	2	A Survey of Multi-layer Network Optimization	ONDM	Invited paper
14	2	SDN application-centric orchestration for multi-layer transport networks	ICTON	Invited paper
15	2	The Software-Defined Transport Network: Fundamentals, Findings and Futures	ICTON	Invited paper
16	2	Towards a Transport SDN for Carriers Networks: An Evolutionary Perspective	NOC	Invited paper
17	2	Multilayer network planning — A practical perspective	OFC	Invited paper
18	2	The Role of SDN in Application Centric IP and Optical Networks	EUCNC	
19	2	Policy-based Restoration in IP/Optical Transport Networks	NETSOFT	Demonstration paper

Table 3.2: List of workshops organised.

#	Year	Workshop	Co-organised with	Co-located in Conference
1	1	Workshop on Network Function Virtualization and Programmable Networks	**FP7**: T-NOVA, UNIFY, NETIDE, MCN, FLAMINGO **H2020**: VITAL, 5Gx, SESAME	EUCNC
2	2	First Workshop on Multi-Layer Network Orchestration (NetOrch)	ACTION (US-Japan project)	ICTON
3	2	ONOS/CORD workshop	Telecom Italia, ON.Lab	

Table 3.3: List of talks and demonstrations held.

#	Year	Talk	Venue	Comment
1	1	ACINO: Application Centric IP/Optical Network Orchestration	**EUCNC** Workshop on Network Function Virtualization and Programmable Networks	
2	1	Control and Orchestration for Future IP/Optical Transport Networks	**OSA Advanced Photonics Conference** Workshop on Photonic Networks and Devices 2015	
3	1	Resource Management in 5G Transport Networks	**CTTE** Workshop on Convergence of fixed and mobile broadband networks	
4	1	Adding application awareness in flexible optical networking	i-Can workshop on Information-Centric Access Networks	
5	1	Control Architectures for Multi-layer Networking: Distributed, centralized, or something in between?	**OFC**	Tutorial
6	1	SC411: Multi-layer Interaction in the Age of Agile Optical Networking	**OFC**	Course
7	2	Application-centric in IP/Optical network	ONOS/CORD Workshop	

8	2	Demonstration of the ACINO orchestrator	ONOS/CORD Workshop	Demonstration
9	2	Network orchestration for multi-layer IP/Optical networks	ONOS mini-summit	
10	2	Intent-based multi-layer IP/Optical networking	ONOS Build	
11	2	Presentation of ACINO	**ETSI**	
12	2	SDN as an enabler of application awareness and multilayer network optimization	**FITCE**	Invited talk
13	2	Future-proof front-haul and back-haul networks	**ECOC**	The content of the talk was published in **Optical Connections Magazine**.
14	2	Towards a Transport SDN for Carriers Networks: An Evolutionary Perspective	**OIF**	
15	2	Bringing Application-awareness into Future Transport Networks: the ACINO approach	**EUCNC** Workshop on Next generation fronthaul / back-haul integrated transport networks	
16	2	Control Plane for High Capacity Networks	V International Workshop on Trends in Optical Technologies	

Table 3.4: List of prizes won.

#	Year	Prize	Comment
1	2	3rd prize of the ONOS Build Hackathon	Michele Santuari (CREATE-NET) led a team of developers from European projects ACINO and GÉANT (GN4-2). They worked on topics that leverage the synergies of the two initiatives on the subject of orchestration of controllers.
2	2	Best SDN-NFV solution award	Telefónica attended the LTE and 5G world Conference and Exhibition in London in June 2016. They presented their End to End SDN Transport Solution with the work done in several

			EU projects, including ACINO's multi-layer approach and several proof of concepts done with Sedona.

4 Standardization and contribution to Open Source activities

This chapter presents the project's contributions to standards and existing open source software projects. We have contributed to IETF standardisation by direct input to six standardisation documents and by the implementation and test of ONF standards.

We have contributed to existing open source software by direct code contribution to projects Netphony and ONOS.

The first section of this chapter describes our contribution to standards. The second section details our contribution to the two open source projects mentioned above.

4.1 Contribution to standards

The consortium has identified opportunities to work on standardisation of interfaces between the technology controllers provided by the equipment vendors and the orchestrator (or hierarchical controller). This is particularly important, as using a network orchestrator requires unifying network configuration and orchestration mechanisms, which can only be achieved if vendors use common information modelling. Therefore, the identification of a common model exposed by equipment vendors is one of the most relevant factors for accelerating the adoption of multi-layer solutions such as the one by ACINO.

Telefónica is actively working on the above mentioned interfaces, and is actively cooperating with the Open Network Foundation (ONF) [ONF] and the Internet Engineering Task Force (IETF) [IETF] bodies. Telefónica has been contributing to the following documents:

1. **Transport API Functional Requirements** (ONF) [ONFAPI];
2. **YANG[12] data model for Flexi-Grid Optical Networks** (IETF) [IETFFLEX];
3. **A Yang Data Model for WSON[13] Optical Networks** (IETF) [IETFWSON];
4. **YANG Data Model for TE Topologies** (IETF) [IETFTETOPO];
5. **Yang model for requesting Path Computation** (IETF) [IETFPCOMP];
6. **Usage of Information Modelling (IM) for network topology to support TE Topology YANG Module Development** (IETF) [IETFIMTOPO].

ADVA is also actively involved in standardisation work related to the interface provided by their optical controller to a potential orchestrator, in order to add support in their own equipment and build solid knowledge about competing standards. In particular, ADVA worked on:

[12] The "Yet Another Next Generation" data modelling language
[13] Wavelength Switched Optical Networks

7. **ONF T-API standard**: ADVA developed tools to support a T-API [ONFTAPI] implementation, i.e., plug-in was written using the YANG validator *pyang* [PYANG]. This plug-in generates the Java Beans for the protocol. A server based on the *akka* [AKKA] framework was also developed.

8. **Evaluation of ONF T-API**: The *ONF T-API* was compared to the *IETF TEAS TE* and the *IETF TE* Topology APIs. As a result of the comparison, an article summarizing the evaluation was submitted to the *IEEE Communication Magazine on Advances in Networking Software*.

4.2 Contributions to existing Open Source projects

ACINO has contributed to The Telefónica Netphony controller during both years, and to the Open Network Operating System (ONOS) during the second year of the project, as described in the two sections below.

4.2.1 Telefónica Netphony Controller

During the first year of the project, ACINO contributed to the **Telefónica Netphony Controller**, as reported in deliverable D6.3, providing improvements to the documentation and bug fixes based on the feedback from the partners and the demonstration done internally to validate its utilization in the consortium.

During the second year, TID has provided several contributions to the Netphony ABNO: the T-API has been integrated, and several services have been implemented (Topology Service and the Connectivity Service) and tested.

TID have been running tests with several queries to demonstrate and stress test the topology and connectivity services. They have been working in provisioning functionalities like delete and create connections between nodes, and to get the Explicit Route Object (ERO) in the connectivity service of the T-API. In addition, there has been a strong effort to fix code errors in the auto-generated code for the T-API integration.

4.2.2 ONOS

After an evaluation at an early stage of the project, it was decided to develop ACINO's orchestrator on top of ONOS, adding features to it as necessary.

4.2.2.1 Presentation of ACINO's orchestrator on top of ONOS

The orchestrator consists of three parts:

- One that is built as an application on top of ONOS and uses the ONOS public API. The API is stable across several ONOS versions, meaning that maintenance requirements are low.
- Some changes to the ONOS core code are necessary to add support for features that ACINO needs (application-centric properties, some hardware drivers, …). It is important that this code gets merged to the main ONOS project, as it would very difficult to maintain it after the end of ACINO. Consequently, the consortium initiated during the first year a close interaction with the ONOS community to achieve this goal:
  - The ACINO concepts, the possible enhancements and contributions that the project activities can provide to ONOS were presented by Domenico Siracusa (CREATE-NET) at the ONOS Technical

Steering Team (TST) meeting of the 27/01/2016. The TST [ONTST] is responsible for all technical decisions in the project. They are responsible for the content and structure of the code base and for all technical priorities with respect to the code base. The ONOS chief architect is the team lead of the technical steering team. Domenico Siracusa (CREATE-NET) got involved in the ONOS Community Steering Team [ONCST], which is a very young team responsible for the care and feeding of the community.

- During the second year of the project, ACINO contributed some code to ONOS following community's procedures. That contribution is described in detail in subsection 4.2.2.2 below.

- The third part of the orchestrator is the network planner and optimizer. Net2Plan was selected for the task, and we chose to develop a separate module called NETRAP that allows Net2Plan and ONOS to communicate (see section 6.5.2).

4.2.2.2 Contributions to the ONOS core code during the second year

The consortium has provided several contributions to ONOS that have been integrated into the main code base. The ONOS community uses the code review system Gerrit [GERRIT] to track code changes: when a new change is submitted, Gerrit assigns a unique identifier called **change number** that can be used to check the submission and its history (e.g., votes, comments, changes), by adapting the following url: https://gerrit.onosproject.org/#/c/<change number >. For example, the url for a review with change number 10703 is https://gerrit.onosproject.org/#/c/10703.

The features that have been integrated so far are listed below. Each feature is briefly described, and the list of corresponding change numbers is provided:

1. **Mapping between topologies and services**: the Orchestrator needs a multi-layer knowledge of the underlying network. For this reason we developed a new ONOS Provider, called LinkDiscovery, able to query the underlying network devices to discover and abstract links to the core. This feature has been implemented through two patches:

   a. **Change number 10703**: Implementation of the new polling provider for Link Discovery;

   b. **Change number 11817**: Fix of the *Buck* system, the new ONOS compilation method, adding support for the Link Discovery provider.

2. **Provider/Protocol for control of controllers**: The current ONOS Representational State Transfer (REST) Provider/Protocol does not support communication with vendor-specific controllers. In ACINO we developed a new Provider/Protocol called RestProxy that overcomes this limitation. We started discussing the idea behind the RestProxy with the TST during the 27/07/2016 meeting. A recording of the meeting is available on YouTube [MEETONOSV] and the slides are available on Google Drive [MEETONOSPR]. The TST was positive about the idea and we decided to submit the logic as an extension to the current REST Provider:

   a. **Change number 12002**: Extend REST subsystem to manage devices under a proxy.

3. **Implementation of the Juniper driver**: This code provides a driver for the ACINO orchestrator southbound interface to control Juniper routers. ONOS drivers support a set of behaviours and functionalities able to abstract the features of a device. The aim is to segment different facets of devices to support sharing via inheritance the behaviours with those devices that have similar characteristics. We developed a new driver that can communicate with Juniper routers available in the ACINO testbed. This driver supports NETCONF configuration and allows the discovery of the devices features (e.g., capabilities, ports, neighbours).

   a. **Change number 11906:** Driver for Juniper MX240 junos 14.2 using NETCONF;

   b. **Change number 12495:** Fix ports representation.

4. **Bug fixes of components used by or related to the ACINO Orchestrator:**

   a. **Change number 10730**: Support for the new compilation method called *Buck* for the NETCONF alarm provider;

   b. **Change number 10825**: Assign correct log level in the AlarmProvider;

   c. **Change number 10901**: Assign routers to the correct layer in the Graphical User Interface (GUI);

   d. **Change number 11479**: Netconf provider basic unit test and fixes;

   e. **Change number 11931**: Fix checkstyle causing the build to fail;

   f. **Change number 12331**: Fix on RestSb provider.

5 Contacts with other projects

ACINO pursues interactions with other projects and national and worldwide forums for the effective dissemination of the project results and the cross-fertilization of ideas and concepts. The liaison with other related national and international research activities is pursued as a normal operational practice.

During the first period, the consortium identified opportunities for liaison and cooperation with projects related to our activities, as reported in deliverable "*First year report on dissemination and communication activities*" [D63]. Some of these opportunities have led to cooperation, while others are planned or considered:

- **USA-JPN ACTION** (JUNO program): the ACTION project [ACTION] enables adaptation of the Internet to changing needs and demands by dynamically adjusting its “optical highway” capacities based on network resource utilization. We organised the first NetOrch workshop together with ACTION in 2016 (as reported in section 3.4.2.1) and are also co-organising the second NetOrch workshop in 2017 (see section 6.1).
- **GÉANT**: GÉANT is the advanced pan-European backbone network that interconnects all National Research and Education Networks across Europe. ACINO and GÉANT [GEANT] jointly participated to the ONOS Hackathon in 2016, where we won the third prize, as reported in section 3.5.2.1. A collaboration is also expected in the context of the Terena Networking Conference (TNC) 2017 conference [TNC2017] organised by GÉANT.
- **5G-CROSSHAUL**: the 5G-CROSSHAUL project [5GCRO] aims at developing a 5G integrated backhaul and fronthaul transport network. There is already some cross-fertilization between the activities carried out in ACINO and 5G-CROSSHAUL since there are two partners in common (TID and CREATE-NET). In addition, ACINO held an invited talk [LOGEUCNC] at the EUCNC 2016 workshop organised by 5G- CROSSHAUL, as reported in section 3.3.2.
- **FP7 EU-JPN STRAUSS:** the STRAUSS project [STRAUSS] aims at defining a highly efficient and global (multi-domain) optical infrastructure for Ethernet transport. In particular, it developed a Control Orchestration Protocol (COP), i.e., a subset of the T-API defined by ONF, which ADVA, Telefónica and Sedona have enhanced in ACINO.
- **FP7 INSPACE**: the INSPACE project [INSPACE] is working on the introduction of the Space Division Multiplexing paradigm in optical networks. The ACINO project is collaborating with INSPACE on the subject of the cost model for the optical network resources that is being used in work package WP2.

6 Planned activities for the third year

As the project ends its second year of active development, there are still many exciting challenges ahead of us that involve technical activities, as well as communication, dissemination and standardisation.

First of all, we will organise a second NetOrch workshop, as described in the first section.

We plan to carry on disseminating the project outcomes through workshops and conferences, and we already have five papers accepted at international conferences and five talk invitations, as presented in the second section of this chapter. We also have a confirmed talk at a workshop organised by GÉANT at TNC 2017 as part of our collaboration with them.

We have submitted completed studies in four peer-reviewed journals, as discussed in section 3.2 and we consider submitting at least four more by the end of the project, as presented in the third section.

Finally, we plan for additional contributions to open source software projects, as discussed in the fourth section of this chapter.

6.1 Organisation of a workshop (Milestone MS34)

ACINO organised the first Workshop on Multi-Layer Network Orchestration (NetOrch), co-located with the 18th International Conference on Transparent Optical Networks (ICTON 2016) [ICTON2016] and held in Trento, Italy, in July 2016.

We can confirm that we will organise a second NetOrch Workshop at ICTON 2017 [ICTON2017] together with project ACTION [ACTION], fulfilling our milestone MS34. ICTON will take place in Girona, Spain from the 2nd to the 6th of July.

6.2 Conferences

For the coming year, the consortium has so far five accepted publications at conferences, and three invited talks at ICTON 2017.

6.2.1 Accepted conference papers

Five paper submissions were accepted by the Optical Fiber Communication Conference (OFC) [OFC] that will take place in Los Angeles, California (United States of America) in March 2017:

1. **A Framework for Dynamic Multi-layer Resource Allocation and Optimization in Application-Centric Networking**: In an SDN-based network, connection requests can be accommodated according to application requirements. This paper [ROZOFC] presents a framework where such requirements drive the Internet Protocol (IP) and optical network resource allocation, dynamic optimization, and instantiation through the ACINO SDN orchestrator.

2. **An Application-Aware Multi-Layer Service Provisioning Algorithm based on Auxiliary Graphs**: This paper [SAVOFC] presents a novel application-aware multi-layer resource allocation algorithm, and it demonstrates that the violation of application requirements (bandwidth, latency, availability,

encryption) is prevented, while keeping blocking probability lower than when using another existing algorithm.

3. **E2E Transport API demonstration in hierarchical scenarios**: This publication [LOPOFC] describes a demonstration that will be presented at the conference that validates the Transport API (T-API) interoperability with a hierarchical orchestration layer. The demonstration shows the end-to-end provision of connections based on the topology and connectivity services of the ONF Transport API.

4. **Intent-Based In-flight Encryption in Multi-Layer IP-Optical Networks**: This publication [CHAOFC] describes a demonstration that will be presented at the conference, showing multi-layer encrypted service provisioning via the ACINO orchestrator. The demonstration uses ACINO's novel intent interface with its ONOS-based SDN orchestrator to facilitate encrypted services at IP, Ethernet and optical network layers.

5. **Techno-economic analysis of transmission technologies in low aggregation rings of metropolitan networks**: This paper [JIMOFC] presents a techno-economic comparison of dark fibre and passive architectures to evolve low aggregation metro rings of 1G. Results demonstrate that there are alternatives more cost-effective than just migrating to 10G.

6.2.2 Invited talks

Three consortium members have been contacted to present invited papers at **ICTON 2017** [ICTON2017] that will take place in Girona, Spain between the 2nd and 6th of July 2017. We plan to hold the following talks:

1. Dimitrios Klonidis (AIT) will take this opportunity to present an overview of ACINO's work package 3 activities: our **application-aware multi-layer resource allocation framework**, and the latest development activities and results.

2. Domenico Siracusa (CREATE-NET) plans to hold a general talk about ACINO.

3. Pontus Sköldström (ACREO) plans to present the integration of Net2Plan as our network planner into ONOS.

Two consortium members have been contacted to present invited papers at **ONDM 2017** [ONDM2017] that will take place in Budapest between the 15th and the 18th of May. We plan to hold talks on the following topics:

4. Achim Autenrieth from ADVA plans to hold a talk about ACINO (precise topic not established yet);

5. Victor López from TID plans to hold a talk about Multi-Layer Network Programmability.

6.2.3 Other planned presence at conferences

During the last year of the project, we will continue to attend relevant conferences, and disseminate our research whenever possible. We keep targeting the main venues related to SDN:

- **OFC** [OFC] will take place in Los Angeles, California (United States of America) from the 19th to the 23rd of Mach 2017. In addition to the five accepted papers mentioned above, ADVA plan to attend and run the demonstration related to paper [CHAOFC]. Also, TID, Sedona Systems and ADVA plan to carry out the demonstration described in paper [LOPOFC]
- **ONS** [ONS2017] will take place in Santa Clara, California (United States of America) from the 3rd to the 6th of April 2017. Sedona systems plan to attend.
- **ONDM** [ONDM2017] will take place in Budapest, Hungary between the 15th and 18th of May 2017. ACINO will give the two invited talk mentioned above.
- **ITG Fachtagung Photonische Netze** [PHOTNETZE] is a German conference and workshop in photonic networks that will take place in May 2017. ADVA plan to attend the event.
- **TNC17** [TNC17]: The 2017 Terena Networking Conference organised by GÉANT will take place in Linz, Austria, between the 29th of May and the 2nd of June 2017. In addition to the confirmed talk by CREATE-NET that is mentioned above, ADVA plan to attend and present an ACINO Intent-based demonstration.
- **EUCNC** [EUCNC2017] will take place in Oulu, Finland, between the 12th and 15th of June 2017. One submission to the conference is expected by CREATE-NET and AIT.
- **IFIP** Networking [IFIP2017]: the International Federation for Information Processing (IFIP) Networking 2017 will take place in Stockholm from the 12th to the 16th of June, 2017. Acreo plan to participate.
- **ECOC** [ECOC2017] will take place in Gothenburg, Sweden, between the 17th and 21st of September 2017. Many partners, including Sedona Systems and ADVA consider participating.

6.3 Journals

6.3.1 Journal papers under review

As discussed with the review comity during the first year review, the consortium has put a large amount of effort to publish in journals during the second year of the project. In addition to the paper [LOPGREN], published in the Journal of Green Engineering, the consortium has submitted **three papers** in high-impact journals. One of them has been accepted and the two others are under review:

1. **On the benefits of multi-layer optimization and application awareness**, accepted for publication in *Journal of Lightwave Technology* (JLT).
2. **First Demonstration of an Automatic Multilayer Intent-Based Secure Service Creation by an Open Source SDN Orchestration**, submitted to *Journal of Lightwave Technology* (JLT). This paper is an extension of an ECOC post-deadline paper.
3. **Optical Network Models and their Application to Software-Defined Network Management**, submitted to *IEEE Communication Magazine, issue on Advances in Networking Software*.

6.3.2 Planned submissions to journals

In addition to the journal papers already submitted, we have established a list of expected technical results that we believe will be worth being published in peer-reviewed journals. The list of articles that we expect to submit is provided below:

1. A paper about intent interface for application-centric network orchestration and in-operation network control: this paper will present the results of our design work on interfaces (task T3.2) and implementation (T4.2 and T4.3).
2. A paper about the application-centric optimization provided by ACINO: this paper will present the full network optimization framework and techniques developed in task T3.4.
3. A paper on the outcome of the techno-economic studies, presenting results from tasks T2.2 and T2.3.
4. A paper about ACINO's final results, that would summarize the main achievements of the project.

6.4 Standardisation

TID and ADVA are the two consortium members that are most involved with standardisation activities. Their plans for the coming year are to carry on with the work done up to now:

- TID will keep working with standardisation of the Transport SDN interfaces (NBI and SBI of the controllers), and contribute to ONF and IETF standardisation documents when the opportunity arises;
- ADVA will keep implementing, testing standards and comparing competing standards to build internal knowledge and provide feedback to the standardisation community about their experience.

6.5 Contribution to other Open Source Software projects

6.5.1 ONOS

The consortium plans to submit several more contributions to the ONOS community. In particular, the following feature is our primary focus:

Investigate and possibly use Domain Intent in ONOS: ONOS provides an Intent-based interface for policy-based network management and configuration, but the framework is mostly focused on OpenFlow-based switching (i.e., per-device configuration) and does not fit very well in the typical architecture of network operators, where technological domains are controlled by vendor-specific solutions, thus preventing the configuration of network devices via a centralized controller. The Domain Intent aims to solve this issue by enabling the provisioning of an intent through a technological domain, so that ONOS is able to communicate with other sub-domains e.g., vendor-specific controllers (ACINO and GÉANT [GEANT] use cases) and SDN domains (ONOS ICONA use case).

6.5.2 Net2Plan

Net2Plan [NET2PLAN] is an open source network planner and optimizer. It uses an abstract, multi-layer network representation, which makes it technology agnostic. It is multi-layer-aware, its network model is

extensible, and it contains a network planner. Net2Plan has been adapted so it can be used by ACINO to perform both (application-aware) optimization and planning.

ACINO is in contact with the Net2Plan authors, and we would like to contribute back: we have developed a Net2Plan to ONOS interface, NetRap, and we are planning to release it. This includes the main module, written as a plugin of Net2Plan, which can be compiled either as a stand-alone module or integrated with the Net2Plan code base. Some minor additions to the Net2Plan core are also included, to allow the proposed module to function properly (e.g., to improve the graphical layout of nodes and links). The NetRap module allows ONOS and Net2Plan to synchronize their view of the network in terms of topology, connectivity demands, and mapping between demands and topology (i.e., configure network paths). NetRap also allows calculation requests and results to be transferred between the two entities.

6.6 Participation to EC-sponsored events

During the final year of the project, the consortium will try to participate to cluster meetings organised by the European commission, as well as other events (for instance, EUCNC [EUCNC2017]).

7 Conclusion

As reported in deliverable D6.3 [D63], ACINO had a very active first year in communication and dissemination. A dissemination strategy was devised, generic communication instrument were designed, and dissemination was prolific: fifteen unique activities, including four published conference articles, talks, demonstrations at conference booths, tutorials and courses, and the contribution to an open source project.

Building upon these results, the project's second year communication and dissemination activities have been very fruitful. Communication-wise, our website and Twitter account are well used, and we have had three further communication actions.

We have also performed over forty different dissemination activities: we have published an article in a peer-reviewed journal (and one more has been accepted for publication), and fourteen conference articles. One of these conference articles was a post-deadline paper at a prestigious European conference and six were invited papers. We have co-organised two more workshops, fulfilling the goal for the entire project. We have held several talks and demonstrations, and won two prizes.

We have also been very active with standardization, with the direct contribution to six IETF standardisation documents, and some implementation and test of standards. We have contributed code to the Netphony network controller. We have also been very active within the ONOS community and implemented features that have been accepted and merged to the ONOS code base.

Finally, the project has devised solid detailed plans for its dissemination activities for the last year: the second edition of the NetOrch workshop will be organised, five conference papers are already accepted and we are invited for three invited talks. We also plan to submit more publications to peer-reviewed journals and to attend several international conferences.

List of abbreviations and acronyms

Abbreviation	Meaning
ABNO	Application-Based Network Operations
API	Application Programme Interface
BGP	Border Gateway Protocol
BGP/LS	Border Gateway Protocol/LinkState
COP	Control Orchestration Protocol
CORD	Central Office Re-designed as a Datacenter
CTTE	Conference of Telecommunication, Media and Internet Techno-Economics
DWDM	Dense Wavelength Division Multiplexing
EC	European Commission
ECOC	European Conference on Optical Communication
ERO	Explicit Route Object
ETSI	European Telecommunications Standards Institute
EUCNC	European Conference on Networks and Communications
FITCE	Forum for European ICT and Media Professionals
GMPLS	Generalised Multiprotocol Label Switching
GUI	Graphical User Interface
ICAN	Information-Centric Access Network
ICT	Information and Communication Technologies
ICTON	International Conference on Transparent Optical Networks
IEEE	Institute of Electrical and Electronics Engineers
IETF	Internet Engineering Task Force

Abbreviation	Meaning
IFIP	International Federation for Information Processing
IM	Information Modelling
IOF	Optical Innovation Forum
IP	Internet Protocol
JLT	Journal of Lightwave Technology
KT	Telecommunications company in South Korea, formerly Korea Telecom
LLDP	Link Layer Discovery Protocol
LTE	Long Term Evolution
MPLS	Multiprotocol Label Switching
NETCONF	The Network Configuration Protocol
NFV	Network Function Virtualization
NMS	Network Management System
NOC	(European Conference on) Networks and Optical Communications
ONDM	International Conference on Optical Network Design and Modelling
ONF	Open Networking Foundation
ONOS	Open Network Operating System
ONS	Open Networking Summit
OSA	Optical Society of America
OSGi	Open Services Gateway initiative
OSPF	Open Shortest Path First
OSS	Open Source Software
OVSDB	Open vSwitch Database
PCE	Path Computation Element

Abbreviation	Meaning
PCEP	Path Computation Element Protocol
PIS	Photonics in Switching
REST	Representational State Transfer
RFC	Request For Comments
RSVP	Resource ReSerVation Protocol
SDN	Software-Defined Network
SSON	Spectrum Switched Optical Networks
T-API	Open Networking Foundation's Transport API
TST	The ONOS Technical Steering Team
WAN	Wide Area Network
WDM	Wavelength Domain Multiplexing
WSON	Wavelength Switched Optical Networks
Xhaul	5G transport network solution integrating the fronthaul and backhaul segments of the network
YANG	The "Yet Another Next Generation" data modelling language

8 References

Reference	Meaning
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[ACITWIT]	ACINO twitter account: https://twitter.com/acinoH2020
[ACIWEB]	ACINO website: http://www.acino.eu
[ACTION]	ACTION project: http://venividiwiki.ee.virginia.edu/mediawiki/index.php/ACTION
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[ICAN]	i-Can workshop on Information-Centric Access Networks: http://mm.aueb.gr/i-can/workshop/index.php
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