Document Properties

Document Number:	D 6.4
Document Title:	**NetIDE 2nd Year Dissemination and Exploitation Report and Up-to-date plans**
Document Responsible:	Alec Leckey (Intel)
Document Editor:	Alec Leckey (Intel)
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Target Dissemination Level:	PU
Status of the Document:	Final
Version:	1.0

Production Properties:

Reviewers:	Elio Salvadori (CN), Carmen Guerrero (IMDEA), Pedro Aranda Gutiérrez (TID)

Document History:

Version	Date	Issued by	
1.0	22-Dec-2015	Alec Leckey	

Disclaimer:

This document has been produced in the context of the NetIDE Project. The research leading to these results has received funding from the European Community's Seventh Framework Programme (FP7/2010–2013) under grant agreement n° 619543.

Abstract:

The NetIDE project aims to deliver a single integrated development environment to support the whole development lifecycle of network controller programs in a vendor-independent fashion. This deliverable reports on the dissemination activities conducted during the second year of the project. It provides updates to the various Open Source releases of the NetIDE results and also includes updates to each of the individual partners exploitation plans. It also provides updates to the market analysis and dissemination activities reported in D6.3.

Keywords:

cloud, networking, interoperability, FP7, SDN, NFV ...

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List of Acronyms

API Application Programming Interface

BOF Birds-of-a-feather

BU business unit

EPA Enhanced platform Awareness

GCTO Global CTO

GUI Graphical User Interface

I2RS Interface to the routing system

IaaS Infrastructure as a Service

IDE Integrated Development Environment

IETF Internet Engineering Task Force

IMTC International Multimedia Telecommunications Consortium

IRTF Internet Research Task Force

NaaS Network as a Service

NBI Northbound

NBI Northbound Interfaces

NEMO Network Modelling

NETCONF Network Configuration Protocol

NFV Network Functions Visualization

NIC Network Interface Card

OCSP ONF-Certified SDN Professional

ODL OpenDaylight

OF OpenFlow

ONF Open Networking Foundation

ONOS Open Networking Operating System

QoS Quality of Service

RINA Recursive InterNetwork Architecture [5]

SBI Southbound Interfaces

SDI Software Defined Infrastructure

SDN Software Defined Networking

SFC Service Function Chaining

SLA Service Level Agreements

TCO Total Cost of Ownership

TSSG Telecommunications Software and Systems Group

VNF Virtualized Network Function

1 Introduction

The goal of NetIDE is to deliver a single integrated development environment supporting the development lifecycle of network controller programs in a vendor-independent fashion. The project proposes an architecture that allows different representations to be used to program the network and different controllers to execute these network programs. The NetIDE project will now enable rapid innovation by enabling organizations to create new types of applications, services and business models that can create new revenue streams and more value from the network.

Work Package 6 executes the dissemination and exploitation activities, attempting to maximize the impact and outreach of the projects research, innovation and demonstration activities. Our end of year report for year 1, D6.3, *NetIDE 1st Year Dissemination and Exploitation Report and up-to-date plans* [6], reported how this was being accomplished through an active communication strategy and presence online, eg, Github, Twitter, project website. It was through these that the consortium has built a community of interest during the first year of the project which allowed these parties to remain informed and convinced about the value of the NetIDE outcomes. Also included were the strategies for highlighting the projects potential outcomes, in order to show the value of adoption of project results. Each partner provided their own exploitation plans that would ensure an impact beyond the end of the project. Finally, the project spent time identifying potential market niches and potential early adopters of our proposed solution. This was to ensure the results of the project remain relevant for commercial and industrial applications and a positive exploitation strategy. By simplifying the Network Apps development process and ensuring their portability is expected to create commercial potential for telecom operators and network solution providers.

The industrial exploitation activities in NetIDE rely on WP6 continuously scanning and analyzing the market for SDN solutions that would benefit from NetIDE inclusion. We established an Industrial Advisory Board (IAB) which included representative of the business units of each of the industrial partners which are members of the project to support and provide feedback on our proposed results exploitation. Our goal is to always monitor and participate in standardization activities related to Software Defined Networking and identify where potential contributions of NetIDE to such activities could be made. Lastly, the project defined strategies for exploitation and uptake of project results.

The project has had a successful year presenting its research results at over 12 different events, with new papers already submitted for events for 2016. Our web presence sees the project visible on 4 separate portals sharing code, releases, videos, event information and demonstrations. NetIDE became an active project of OpenDaylight this project year with its Network Engine accepted. The project is currently on track to be released in the OpenDaylight Beryllium release due Feb 2016. Our plugins for the Eclipse IDE was accepted as a new project on the Eclipse Marketplace allowing users to download our NetIDE plugins. Finally, our market analysis is showing that the revenue from SDN network applications is set to grow an estimated to $1B by 2019 showing that there appears to be more value in SDN applications than in orchestration and control.

This deliverable has three main sections. Chapter 2 reports on the up-to-date dissemination activities that were performed during the second year of the project, which events were attended and the outcomes of each. As the implementations of our architecture became mature during this second year, the project published Open Source releases of NetIDE results as per our development and opensource strategy. Chapter 3 provides an update to the individual exploitation plans of each of

the partners, how they will consume the potential results etc. Finally, Chapter 4 provides an update to the market analysis performed in year one of the project reviewing the latest drivers/barriers to SDN adoption and also, a detailed analysis of where SDN lies within the Data Centre. A glossary of terms used in this document can be found in the appendix section.

2 Dissemination of the NetIDE Results

This section summarizes the dissemination activities undertaken during the second year of operation, and a plan of events that we would like to attend in the third year of the NetIDE project. These activities are categorized by venue types, such as scientific, industrial, EU-related and so on. An update about the increased activity on our social media is also provided, togheter with a short explanation of few new sections introduced in the project website. The collaboration with other EU projects in this area has become more concrete this year, with a tighter relationship with FP7 PRISTINE project. Finally, some further information about our open-source strategy and roadmap is provided.

2.1 Report of dissemination activities conducted during year 2

Many NetIDE project dissemination activities occurred during the second project year. In the following we will provide an overview of the major events NetIDE consortium members have been attending and presenting the latest outcomes of the project. Compared to the first year of the project, this year some of NetIDE-related works have been accepted at scientific venues, and few more have been submitted to events which will happen in 2016. We have been also presenting NetIDE in key international events like ONS 2015 in USA, the China SDN/NFV Conference 2015 in Bejing, the OpenDaylight Summit 2015 in USA and the SDN and OpenFlow World Congress 2015 in Düsseldorf.

2.1.1 Scientific Venues

ATTENDED EVENTS			
DATE	**EVENT**	**PARTNER**	**CONTRIBUTION**
13-16/04/2015	IEEE NetSoft 2015 (London, UK)	CREATE-NET, TID, IPT, THALES, INTEL, IMDEA, TELCA	Roberto Doriguzzi-Corin (CREATE-NET) has been presenting a work titled "NetIDE: removing vendor lock-in in SDN" accepted as demo paper together with co-authors Elio Salvadori, Pedro Aranda Gutiérrez, Christian Stritzke, Alexander Leckey, Kevin Phemius, Elisa Rojas, Carmen Guerrero.
16-18/06/2015	ACM SOSR 2015 (Santa Clara, USA)	CREATE-NET	Matteo Gerola and Elio Salvadori (CREATE-NET) have been presenting a work titled "An Approach to Exposing and Sharing Network Services in Software-Defined Networking" accepted as demo paper together with co-authors Roberto Doriguzzi-Corin and Michele Santuari.
08/06/2015	IEEE ICC 2015 (London, UK)	TID	Diego Lopez (TID) presented NetIDE at the industrial panel on "CAP theorem challenges and DevOps approaches to operating next-generation virtualized telecom network infrastructure".
29/06-02/07/2015	EUCNC 2015 (Paris, F)	TID, TELCA, UPB, Intel	Elisa Rojas (TELCA) have been presenting a work titled "On Network Application Representation and Controller Independence in SDN" accepted as short paper together with co-authors Holger Karl, Alec Leckey and Pedro A. Aranda.
29/06-02/07/2015	EUCNC 2015 (Paris, F)	TID	Pedro A. Aranda (TID) presented NetIDE major outcomes during the Workshop on Network Function Virtualisation and Programmable Networks.
30/09-02/10/2015	EWSDN 2015 (Bilbao, E)	IPT, TID	Christian Stritzke (IPT) has been presenting a work titled "Towards a Method for end-to-end SDN App Development" accepted as short paper together with co-authors Claudia Priesterjahn and Pedro Aranda Gutiérrez.

2.1.2 IETF and Standardization Venues

ATTENDED EVENTS			
DATE	**EVENT**	**PARTNER**	**CONTRIBUTION**
01/11/2015	IETF 94 (Yokohama, Japan)	Telefonica I+D	Pedro A. Aranda (TID) coauthored an article in the IETF Journal [7] on the NEMO language and the BoF session held at the IETF 93 in Prague, where NetIDE was presented as a use case for it. Pedro A. Aranda (TID) continued the discussion with Huawei about Nemo as an IRF candidate, and participated in the 94' Hackathon [8], co-championing the group that refined the NEMO language and implemented an Eclipse plugin editor for it.

2.1.3 Industrial Venues

ATTENDED EVENTS			
DATE	**EVENT**	**PARTNER**	**CONTRIBUTION**
23/04/2015	China SDN/NFV Conference 2015 (Bejing, China)	Telefonica I+D	Pedro A. Aranda (TID) presented NetIDE project at China SDN/NFV Conference in Beijing which is an educational gathering offering firsthand opportunity to explore, learn and discuss about the SDN and NFV trends and development in-depth.
16/06/2015	Open Networking Summit 2015 (Santa Clara, California)	CREATE-NET	Elio Salvadori and Matteo Gerola have been presenting the latest results of the NetIDE project during the ONS Summit in Santa Clara which was co-located with the ACM SOSR conference this year.
12/10/2015	SDN and OpenFlow World Congress 2015 (Düsseldorf, D)	Telefonica I+D	Pedro A. Aranda (TID) presented NetIDE project with a presentation titled "OpenDaylight as an R&D&I enabler at Telefonica I+D" during the OpenDaylight Forum at the SDN world congress.

2.1.4 OpenSource Venues

ATTENDED EVENTS			
DATE	**EVENT**	**PARTNER**	**CONTRIBUTION**
27-31/07/2015	OpenDaylight Summit 2015 (Santa Clara, USA)	Intel	Alec Leckey attended the 2nd Annual OpenDaylight Summit to include NetIDE in the OpenDaylight (ODL) Beryllium planning process. The summit is also designed to provide a collaboration and education space for innovators, developers, and users in the Software Defined Networking (SDN) and Network Functions Visualization (NFV) space.
28-39/09/2015	ONOS Workshop (Bilbao, Spain)	UPB	Arne Schwabe attended the ONOS Workshop. The workshop included hands on experience and discuisson about ONOS sarchitecture and enables our project to keep a close a eye on the development of this controller platform. The team consisting of Steffen Gebert from the University of Wrzburg, Michael Jarschel from Nokia and Arne Schwabe won the first prize in the second day hackfest.

2.1.5 Submitted papers

2016 EVENTS			
EVENT	**PARTNER**	**STATUS**	**CONTRIBUTION**
IEEE NOMS 2016 (Istanbul, Turkey)	CREATE-NET, UPB	Accepted	A short paper titled "Empowering Network Operating Systems with Memory Management Techniques" whose co-authors are R. Doriguzzi Corin, D. Siracusa, E. Salvadori and A. Schwabe has been submitted.
IFIP Networking 2016 (Vienna, Austria)	IPT, TID	Submitted	A full paper titled "Towards a portable Application format for SDN Apps" whose co-authors are C. Stritzke, Claudia Priesterjahn, and Pedro A. Aranda Gutirrez has been submitted. It advertises the NetIDE Application format as well as a selection of IDE tools.

2.1.6 Website, Social Media

The NetIDE website has continuously been updated with latest news from the project, presentations, collection of approved public deliverables and link to the open-source software already available to be freely downloaded. A better layout for the News section has been included, with a small graphical add-on to facilitate the redability of the news itself (see Figure 2.1). Moreover, the News section has been extended with a subsection on "In the News" where references to articles which are mentioning NetIDE results can be found (see Figure 2.2).

Due to the limited activity performed on our LinkedIN account, NetIDE has preferred to focus its social media activities on two major tools: Twitter and YouTube.

Thanks to an increased number of tweets (more than 80 in 2015) and a wiser policy of networking with key Twitter accounts, the NetIDE twitter account has been witnessing an increasing number

Figure 2.1: NetIDE website: zoom on project news

Figure 2.2: NetIDE website: "In the News" section

of followers across 2015: from less than 30 followers at the end of 2014, NetIDE account is currently followed by 114 followers (see Figure 2.3).

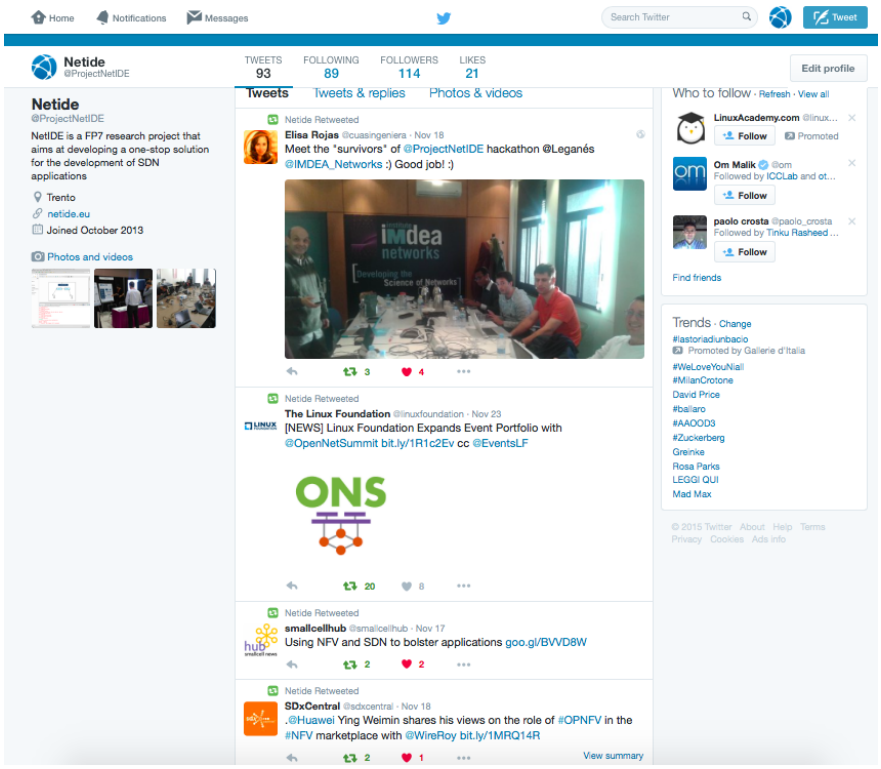

Figure 2.3: NetIDE twitter account: a snapshot

Moreover, NetIDE project has decided to leverage on YouTube to increase the visibility of our outcomes by posting few videos on the operation of both the Engine component of NetIDE architecture as well as the IDE developer toolkit (see Figure 2.4).

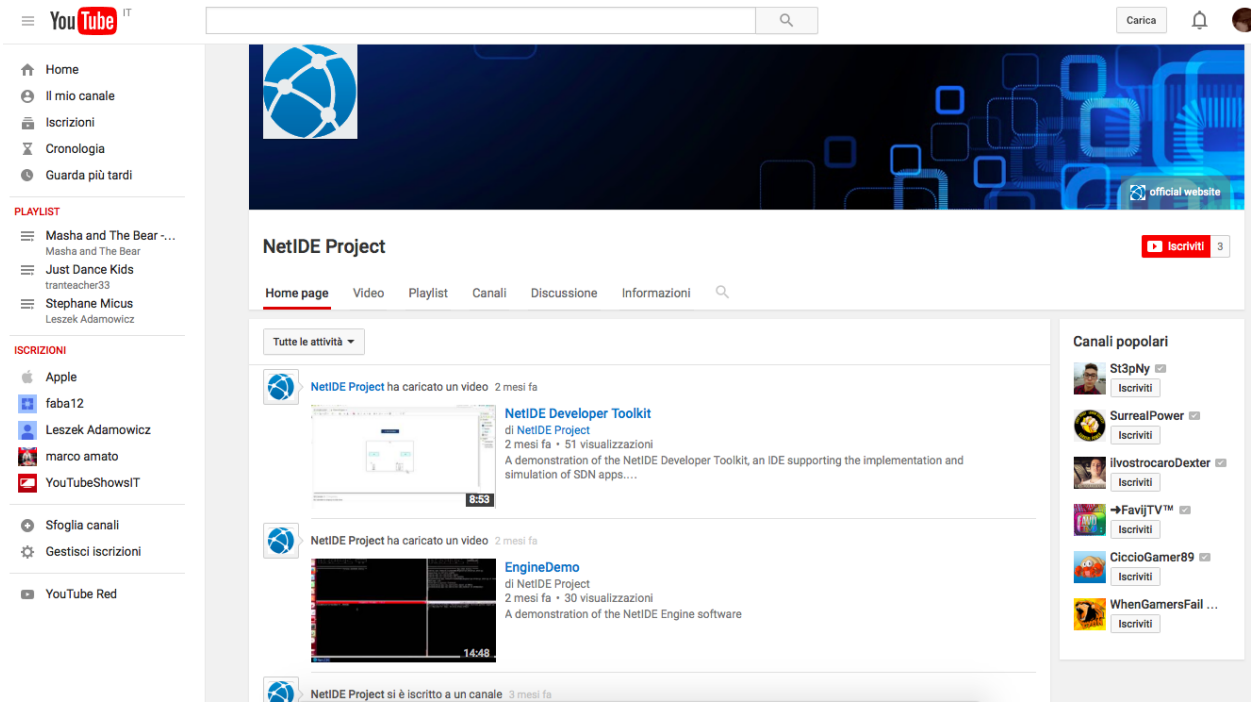

Figure 2.4: NetIDE YouTube account: a snapshot

2.2 Printed Media

The main aim of this type of disseminative material is to reach wider audiences and to disseminate NetIDE results successfully. Hereinafter, there is a description of the most relevant printed media contributions that have been realized throughout the second year of the project:

- Leaflet: a renewed project brochure has been elaborated summarizing the general information about the NetIDE concepts and its objectives, and about the consortium. The brochure has been used as standard dissemination tool during conferences, events and fairs where NetIDE partners have been participating.
- Poster: an improved version of a poster presenting the principal aims of the project has been realised with enhanced graphs and pictures. The poster has been used at both IEEE NetSoft 2015 conference as well as during the co-located ONS/SOSR event in Santa Clara (USA).

Figure 2.5: NetIDE leaflet

2.3 Dissemination targets in 2016

Project partners will attend well-regarded conferences where the project's results can be shown to other researchers. Some events are listed in the next sections. To measure the progress of dissemination activities in NetIDE project, a set objectives have been identified per each event, providing an indicator of the impact assessment of the activity.

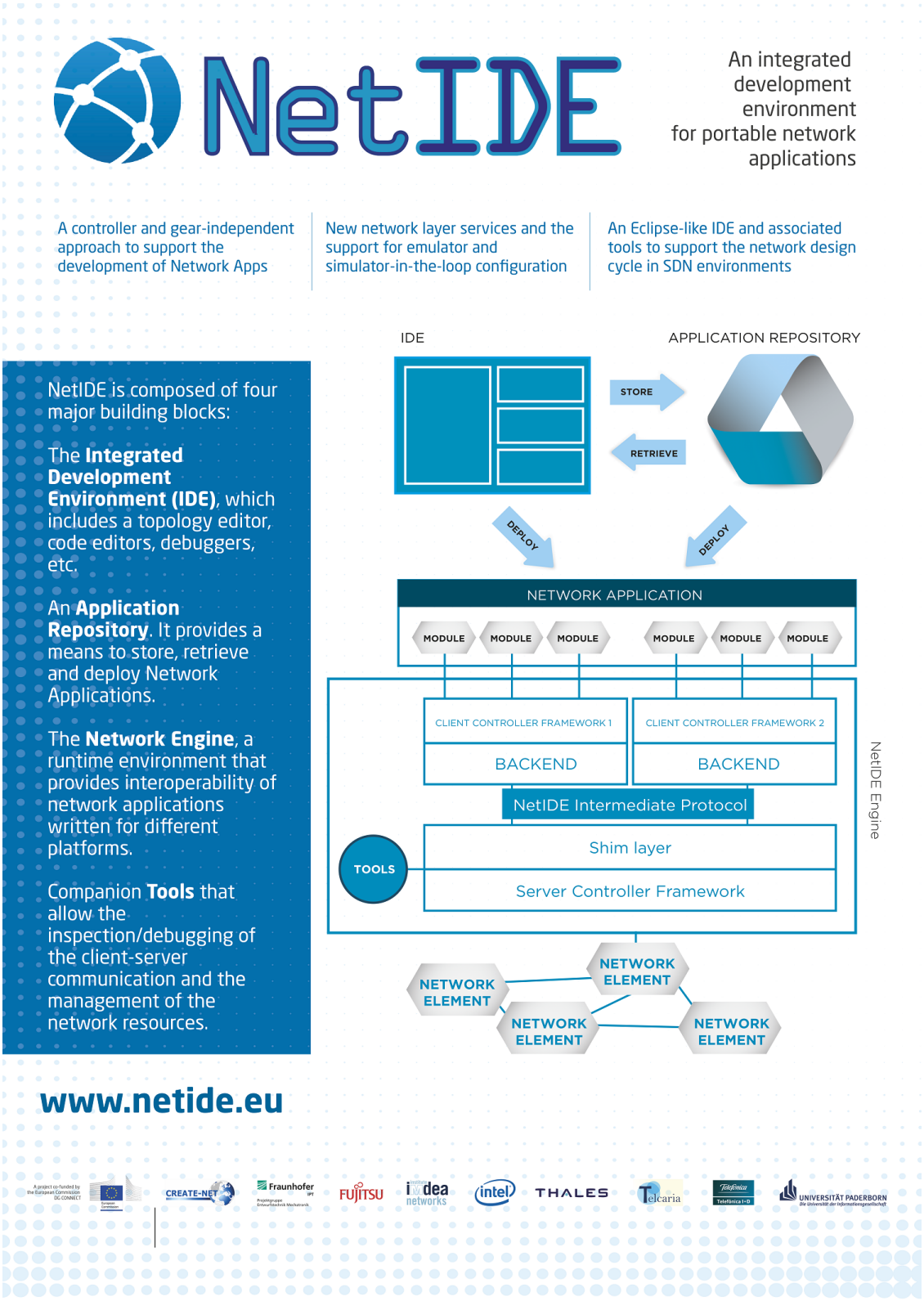

Figure 2.6: NetIDE poster

2.3.1 Potential papers submission from NetIDE partners

In this Section an overview of the major scientific contributions NetIDE project is planning to incoming venues is provided.

- A paper on the NetIDE Engine architecture and some initial performance tests.
  - Potential contributors: TID, UPB, CREATE-NET, TELCA,...
  - Potential venues: EuCNC 2016, EWSDN 2016
- A paper on the IDE architecture, extension of the EWSDN 2015 contribution.
  - Potential contributors: TID, IPT, TELCA,...
  - Potential venues: EuCNC 2016, EWSDN 2016
- A paper on the memory management system architecture, extension of the NOMS 2016 contribution.
  - Potential contributors: CREATE-NET, UPB, TID,...
  - Potential venues: IEEE Globecom 2016, EWSDN 2016
- A demo of the full NetIDE architecture functioning with at least two backends (Ryu and Floodlight) and leveraging on one server controller.
  - Potential contributors: TID, CREATE-NET, UPB, IPT, INTEL, TELCA, ...
  - Potential venues: SDN World Congress 2016, EWSDN 2016, OpenDaylight Summit 2016
- A survey paper on SDN debugging tools based on the analysis on the current state of the art for the project.
  - Potential contributors: TELCA, CREATE-NET, IMDEA, UPB, THALES, ...
  - Potential journals: IEEE Communications Surveys & Tutorials

2.3.2 Interesting venues

In the following, a short description of the potential venues NetIDE partners plan to submit some of their scientific contributions to is provided.

- IFIP/IEEE Network Operations and Management Symposium (NOMS 2016)
  - Type: scientific
  - Web site URL:`http://noms2016.ieee-noms.org`
  - NOMS 2016 will focus on the theme "Managing Everything toward a Secure, Smart, and Hyperconnected World", presenting recent, emerging approaches, and technical solutions for dealing with future network and ICT infrastructures, as well as with novel services provided in smart and hyperconnected environments (e.g., smart cities, Internet of Things).
- European Workshop on Software Defined Networks (EWSDN 2016)
  - Type: scientific
  - Web site URL:`http://www.ewsdn.eu`

  - This workshop emphasizes aspects of Software Defined Networks that come up when extending SDN 'beyond Ethernet'. One goal of the workshop is to bring together industry and academia on the topics of SDN, in particular the workshop features an industry forum, i.e. a session with presentations of key industrial players (manufacturers, telecom operators, ...).

- ACM SIGCOMM Conference on Emerging Network Experiment and Technology (CONEXT)
  - Type: scientific
  - Web site URL:`http://www.sigcomm.org/events/conext-conference`
  - The focus of CoNEXT is around innovative developments on networking technologies, such as internet measurements and modelling, advanced protocols and services, networked games, multimedia services, routing, security traffic engineering, peer-to-peer and overlay networks, wireless and mobile networks, ad-hoc and sensors networks or autonomic and dependable communications.

- NET FUTURES 2016
  - Type: EU-related
  - Web site URL:`http://netfutures2016.eu`
  - NET FUTURES aims to improve competitiveness of the European technology industry, bringing togheter interconnected community involving companies, organizations and people belonging to research, innovation, business development, and entrepreneurship.

- European Conference on Networks and Communications (EuCNC 2016)
  - Type: EU-related
  - Web site URL:`http://www.eucnc.eu`
  - This conference, sponsored by the European Commission, is focusing on communication networks and systems, and reaching services and applications. It aims at showcasing the results of the consecutive programmes on esearch and development and projects co-financed by European programmes, as well as presenting the latest developments in this area.

- IETF meetings
  - Type: standardisation
  - Web site: `http://www.ietf.org/meeting/upcoming.html`
  - 95^{th} IETF meeting is April 2016 (Buenos Aires), 96^{th} IETF meeting is July 2016 (Berlin), 97^{th} IETF meeting is November 2015 (Seoul)
  - In addition to the SDN and NFV research groups, our conflict resolution approaches and other architectural solutions produced by the project can be presented at workgroups working with the Network Configuration Protocol (NETCONF) protocol or similar. Service Function Chaining (SFC) is another candidate, although the direction taken by the work group chairs and the charter will make it more difficult to approach.

- SDN and OpenFlow World Congress 2016
  - Type: Industrial
  - Web site URL:`http://www.layer123.com/sdn`

  - The SDN World Congress is globally recognised as the principal network innovation conference in Europe for the global telecommunications industry. More than 1200 people attend this event every year, mostly coming from leading industries in the networking field. This event is also supported by the Open Networking Foundation.

- NFV World Congress 2016
  - Type: Industrial
  - Web site URL:`http://www.layer123.com/nfv`
  - The NFV World Congress offers an opportunity to examine developments from the market leaders, debate the issues with the thought leaders and showcase the reality of NFV and SDN.
  - NetIDE will look to present the project architecture and open-source software with a goal of setting up collaboration with both research and industrial partners.

- OpenDaylight Summit
  - Type: Industrial/Open-source
  - Web site URL:`http://events.linuxfoundation.org/events/opendaylight-summit`
  - The OpenDaylight Summit is an annual conference designed to provide a collaboration space for innovators, developers, and users in the SDN and NFV ecosystem. The ODL Summit brings together the community, projects, products, and companies in the networking industry that are driving the SDN and NFV ecosystems today, along with best practices from the world of traditional open source.

2.4 Open Source Strategy

NetIDE operates as an open source project with all code released under the *Eclipse Public License (EPL)*. The project source code repository is hosted on Github.com/fp7-netide. The project has already published a number of opensource releases of the Network Engine and the Developer Toolkit, with more releases to follow, including full source code, and documentation for usage, installation and integration.

Four code repositories are currently in use. As the project matured in the second year, our initial repo *PoC* which held our first prototypes and proof of concepts was end-of-lifed as our design and architecture progressed. A new repo has been added this year, the *Tools* repo. https://github.com/fp7-netide

- IDE: This contains releases that provide editor support for various network programming and other specifications languages used in the development lifecycle
- Engine: This contains the Network App Engine whose main objective is to deliver a comprehensive toolkit for Network App developers covering NetIDE methodology.
- Usecases: This contains the implementations of the use cases and target scenarios generated in the project for a range of SDN controllers
- Tools: This contains the tools to enable network application developers to systematically test, profile and tune their network applications.

The current schedule of Open Source Releases is below. As important features become mature, interim releases may be generated and disseminated to interested parties. The project made 2

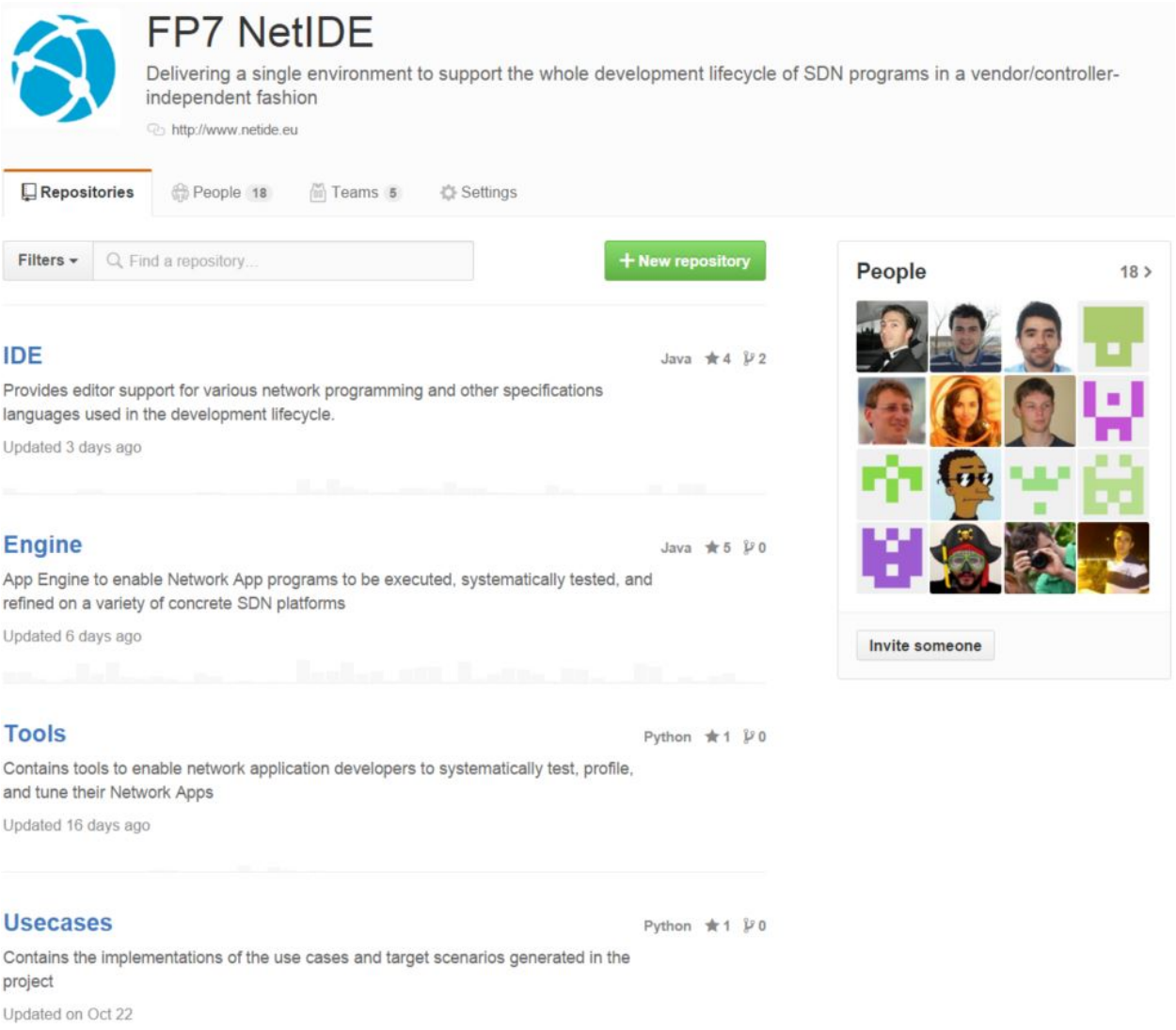

Figure 2.7: NetIDE's Github Presence

releases available for download from their respective Github repositories in the 2015. These included all code and supporting documentation. There are further releases planned for the final year of the project, 2016.

Open Source Release Plan		
Ver	**Features**	**Date**
v0.1	Developer Toolkit v1 (D3.2) NetIDE Network Engine 1st release (D4.1)	Released Jan 2015
v0.2	Debugging Toolset 1st release (D4.2) Includes bugfixes and additional features for Developer Toolkit and Network Engine	Released March 2015
v0.3	Interim Release Includes bugfixes and additional features for Network Engine and Debugging Toolset	Due M24
v1.0	NetIDE App Engine final release and evaluation (D4.3) Includes Developer Toolkit v2, Debugging Toolset, additional features and Bugfixes for Network Engine	Due M36

The project has ongoing collaborations and contributions with other open source projects, eg, OpenDaylight, Eclipse, ONOS. However, as these are exploiting NetIDE results, these are documented in chapter 3 Exploitation, at section 3.4.

2.5 Inter-project coordination and collaboration

The presentation of the project results in the Workshop on Network Function Virtualisation and Programmable Networks at EUCNC'15 referenced in Table 2.1.1 is part of a longer inter-project collaboration with other projects of Framework Programme 7, including FP7-T-NOVA[1], FP7-UNIFY[2] and FP7-MCN[3].

Additionally, we have had two workshops with the PRISTINE project. The scope of the interaction between the two projects is to discuss the applicability of the NetIDE concepts and workflows in the context of the Recursive InterNetwork Architecture (RINA) developments.

The first took place on the 17^{th} of September, 2015 during our Dublin meeting. Participants were Miguel Ponce de León and Michéal Crotty from Telecommunications Software and Systems Group (TSSG) representing the PRISTINE team [4], and Christian Stritzke, Alec Leckey and Pedro A. Aranda on the NetIDE side. During the meeting, Christian gave an overview of the IDE and there was an open discussion on possible reuse by PRISTINE within their project. The second took place on the 8^{th} of October, 2015 in Pisa during a PRISTINE project meeting. There, Pedro A. Aranda presented the IDE and the first version of the NEMO editor to the PRISTINE team. There have been several follow-up interactions between both teams after these meetings.

[1] http://t-nova.eu
[2] https://www.fp7-unify.eu
[3] http://www.mobile-cloud-networking.eu/site/
[4] https://www.ict-pristine.eu

3 Exploitation Plan

3.1 Exploitation Strategy

There is an inherent difference between the exploitation plans of the industrial partners and the research and academics partners. Industrial exploitation's goals is to innovate by creating new products and services that allows a competitive advantage and use the benefits from the result of the project to cater to their targeted users. In addition to the common global objective and exploitation plan of the consortium, each industrial partner has their own strategy for the exploitation.

3.1.1 Exploitation plan TID

The exploitation plan for NetIDE results for TID has evolved during the second year of the project as its road-map has been clarified and first results have become available. However, the high level goals for the project's output have not changed. As stated in Deliverable D6.3 [6], TID targets the following areas to apply the NetIDE results:

- The consolidation of NFV technologies within the Telefonica network, applying it to rapid prototyping, design validation and direct deployment, as well as facilitating the integration of NFV and non-NFV elements.
- Empowering the wholesale and cloud service business units (BUs) with more flexible mechanisms for network infrastructure design and deployment, what will translate into shorter provision times, better infrastructure usage, stronger security and tenant separation, and a more seamless integration with computing and storage management interfaces.
- NetIDE will constitute a breakthrough in the way network infrastructures will be conceived, designed and deployed, and therefore we plan to make it the base for further research.

With regard to the first point, TID is exploring the integration of NetIDE results in the the tool set use at the NFV Reference Lab, a testing facility Telefonica's Global CTO (GCTO) Unit is using to assess NFV solutions, guarantee interoperability among different vendors, and validate NFV applicability to use cases provided by the business units and local operators in the Telefonica's footprint. We are advancing in the formalisation of some of these experiments as proofs of concept within the ETSI NFV ISG framework is under consideration, with the idea of widening the NetIDE user base among our vendors. Contacts made with system integrators focused on SDN/NFV pilots for our European operations in order to apply NetIDE in their development and deployment cycles.

In our contacts with the Cloud Services and Wholesale BUs, we are establishing a demonstration facility for Software Networks application to enterprise networks, together with the business unit in charge of these services and one of our technology partners. We will use the NetIDE Integrated Development Environment (IDE) as one of the elements supporting quick and efficient configuration and deployment of the demonstrators, with the idea of using it as a showcase of the applicability of NetIDE to support specific projects this BU has to accomplish.

In the third direction, NetIDE results and evolution are an integral part of our current plans for further research in Software Networks, and in particular of the projects around the network evolution towards 5G (i.e. the 5G public/private partnership (5GPPP) within the H2020 framework

program). Besides this, we have used internal coordination and training activities to build awareness about NetIDE among other units within the company that would be in the position of applying it to their customer projects and innovation activities.

Telefónica is strongly committed to open innovation, and is promoting technology start-ups through initiatives like Wayra (`http://www.wayra.org/`). NetIDE continues to be well positioned to support new business models that emerge from and can be exploited through these initiatives. We have used these entrepreneurship support platform to announce the first releases of NetIDE to this community and foster the usage of NetIDE among it. Furthermore, our access and participation in the OpenDaylight User Advisory Group is another valuable asset that results from NetIDE and that we are exploiting in our positioning in the Open Source/Open Innovation community as well as internally in the Telefónica group.

3.1.2 Exploitation plan FTS

Fujitsu has a business interest to reduce the cost and complexity of developing, porting, deploying, operating and maintaining network-based applications and services both for itself and for its customers. Fujitsu is a developer and a user of network applications. Fujitsu provides infrastructures for customers in-house and cloud-based network applications. For these reasons Fujitsu is engaged in the NetIDE project which aims to develop a framework and a prototype for more efficient development tools and greater application portability.

Fujitsu is a user and generally not a vendor of development tools. Fujitsu intends to exploit the NetIDE development environment as a user and expects to exploit NetIDE through toolsets provided by 3rd parties. Fujitsu therefore has an interest to see NetIDE adopted by tool providers and is pleased to see NetIDE adopted within the Eclipse environment.

As the NetIDE architecture has stabilized and the NetIDE implementation has progressed, active communication of the results within the Fujitsu group has started. The results of NetIDE are being presented to internal divisions which develop network-related applications for use in Fujitsus data center and cloud solutions. An overview presentation was given to about 50 R&D colleagues in Central Europe in September. It is planned to repeat this exercise with colleagues from Fujitsu Labs (research), Fujitsu Japan (development) and the Fujitsu Networking business in Europe (services).

During the course of the NetIDE project we have seen two major innovations emerge which are enabling the development of new network services: OpenStack and NFV (Network Function Virtualisation). Fujitsu may exploit NetIDE in the context of these technologies. It is known from discussions with a major service provider to the telecom industry that the lack of trouble shooting tools for the emerging software stack is an impediment to the adoption of NFV. Fujitsu will present NetIDE to this service provider as a technology which may help address this issue.

Fujitsu has provided a use case and requirements to the NetIDE project and will later provide reporting on the usability of the NetIDE software based on practical, hands-on experience.

Fujitsus early engagement in NetIDE should help ensure that later NetIDE based products meet the real needs of industrial networking application developers. To this end Fujitsu has contributed to the Industrial Advisory Board by nominating Mick Wilson, a colleague with deep experience in telecommunications networks.

Fujitsu shall contribute to the dissemination of NetIDE by making its engagement and practical experience known to the industry and to customers.

3.1.3 Exploitation plan INTEL

Intels strategy for the data center lies in open source networking which promotes a functional stack in support of the Cloud, Telco and Enterprise across all layers. This strategy requires the exposure of infrastructure and server capabilities and availabilities to the orchestration software (eg, OpenStack, CloudStack) through the use of Enhanced platform Awareness (EPA). An orchestrator maybe unable to proactively load an application onto a platform capable of accelerating its performance, such as assigning an IPsec VPN appliance to a server with cryptographic algorithm acceleration capabilities. The lack of platform and infrastructural awareness is a major drawback since many virtual appliances have intense I/O requirements and could benefit from access to high-performance instructions, accelerators and Network Interface Cards (NICs) for workloads such as compression, cryptography and transcoding. Secondly, the control layers enable the best infrastructure utilization which will enable a lower Total Cost of Ownership (TCO). To support Service Level Agreements (SLA) required by an application and to enable peaceful cohabitance (i.e. avoid Noisy Neighbour scenario) the applications and services need to communicate their needs and requirements of the the infrastructure using a policy. This allows the infrastructure to reserve the resources and guarantee isolation, performance, SLA and high utilization. Within the SDN domain, NetIDE provides a methodology for promoting the creation of new network related applications that can operate over any SDN controller will enhance the acceptance of Software Defined Infrastructure (SDI) to the benefit of customers. Intel are platinum members of the OpenDaylight opensource project as Intel believe it to be the broadest community, largest set of projects, supports the most of the southbound protocols and the closest of the opensource SDN controllers to becoming production ready for Data Center deployments.

Additional strategies include enabling the SDI ecosystem in cross-industry initiatives. In the network and cloud computing domains, Intel works in partnerships to develop reference architectures and to share best practices in the development and deployment of Cloud, SDN and NFV through our network builders (networkbuilders.intel.com) and cloud builders (www.intel.com/cloudbuilders) programs. Intel also plays a leading role in the development and evolution of standards in the industry relevant to networking and cloud computing, eg, ONF, ETSI NFV. As NFV/SDN deployments begin to deploy onto carriers networks, the challenges of interest to Intel are ensuring the orchestration layer within a network environment fully exploits the capabilities of the servers it manages. Typically, orchestration layers can identify only basic infrastructural features (e.g., CPU type, RAM size and host operating system) and are unaware of platform specific features and attached devices, like acceleration cards or network interface cards (NICs). This lack of platform awareness results in reduced intelligence in orchestration process and non-optimal placement of workloads.

The NetIDE project provides an excellent opportunity to implement an interoperability layer that can act as a reference implementation for enhanced platform awareness to enable intelligent deployments of SDN workloads.

Intel exploitation plans of NetIDE focus on:

- The NetIDE project will enable Intel to identify the key challenges for operators to deploy and manage new service offerings based on NFV and SDN architectural approaches. Identification and definition of these challenges will enable Intel to focus and target specific areas for future research and innovation.

- Intel will use NetIDE as a reference implementation which demonstrates platform affinity for Intel architecture for SDN workloads by exposing platform features and attributes that can be used by network orchestration to make intelligent placement decisions with respect to key performance indicators.

- Intel will use the output and learnings from NetIDE to drive contributions to the open source

community building on potential blueprint contributions to OpenDaylight, OpenStack, etc.

- The learnings and findings from NetIDE will be of significant interest to Intel business groups that are developing products to meet the needs of customers who are deploying NFV and SDN solutions.
- Intel will use the output and learnings from NetIDE to develop a greater understanding of how to driving service and SLA awareness into the network/cloud and to reflect these needs in its product offerings such as Data Centre Service Assurance Administrator (DC-SAA) (`http://www.intel.com/content/www/us/en/software/intel-service-assurance-agent.html`)
- Intel will use the NetIDE project to identify and evolve instrumentation and telemetry requirements to improve platform awareness, automation and improve manageability of NFV and SDN workloads at the orchestration layer and above.

3.1.4 Exploitation plan THALES

Thales is a company focused on innovation and uses research projects to improve its products to satisfy the demands of its clients. NetIDE's results will be used for its ability to do rapid prototyping in our research department and presented to the business lines in charge of the Critical Information Systems and Resilient Infrastructure Networks. Thales offering relies on two interesting technological pillars:

- Cloud technologies. Thales has a network of 3,900 IT professionals and 13 Service Centres throughout France dedicated to delivering comprehensive solutions to exacting customers who want to outsource the design, development and/or operation of all or some of their information systems. High value-added results-based SLA shape the framework for Thales's customer commitments, which are anchored in integrity, security, availability, resilience and service continuity.
- Resilient network technologies. The many interconnections needed to exchange information can lead to greater vulnerability to intentional threats (cyber attacks, for example) and accidents such as natural catastrophes. Thales's Nexium solution consists in designing and deploying complex communications architectures that guarantee availability under all circumstances, even in crisis situations, to achieve network resilience, i.e. the capacity of networks to withstand shocks and guarantee high-level end-to-end transmissions that are efficient, dependable, secure and inter-operable.

In order to meet the growing demands of Thales customers for more distributed or hybrid (private/public) information systems with a high level of security, resilience, scalability at a lower cost, Thales has identified SDN as a key enabler for the Cloud and Nexium suites. This promising technology will allow to reduce development life-cycle, increase reactivity to incidents (e.g., cybersecurity attacks, failures), bring more controllability to customer applications (e.g., Network as a Service (NaaS) APIs), and to support, through network virtualisation, multiple security levels in the same infrastructure. NetIDE will allow Thales to have a robust development ecosystem to develop these two activities. Some of Thales' clients are already aware of SDN and ask for solutions based on SDN architectures. This proves that Thales' involvement in this technology is beneficial. Emerging innovative technologies are of primal importance for Thales. In this context SDN, stands as the corner stone between network management and Infrastructure as a Service (IaaS) management, thus enabling NaaS. Decoupling the control plane from the hardware enables to conceive networking as software applications and NetIDE could be integrated in the development cycle of Thales' software either during the elaboration process or in production.

3.1.5 Exploitation plan TELCA

As an advanced network service virtualization and young SME, aiming to serve network operators, Telcaria will benefit from the technology advances generated from NetIDE. Telcaria will acquire the know-how for applying NetIDE technologic achievements to rapid prototyping, design validation and direct deployment on its customers. This will cause a direct growth for Telcaria.

In fact, Telcaria has already been contacted by several companies (including an operator) in relation to its big expertise in SDN/NFV, because many companies are already wondering about migrating their products (many of them currently outsourced) to these platforms and benefiting from their open source origin.

More specifically, Telcaria plans to:

- Leverage the IDE of NetIDE for future SDN developments in the team, as well as in other SDN-related R&D projects to which Telcaria is currently contributing.
- Use the NetIDE project to have the opportunity to strip the OpenDaylight and ONOS projects, know their architecture, main features and limitations. Currently, the market starts demanding specifically products based on these two SDN controller frameworks, which currently are rapidly evolving, and we need to be aware of their capabilities in order to choose the most suitable of them for requested implementations.
- Identify the key challenges for operators to deploy and manage new service offerings based on SDN and NFV architectural approaches.
- Contribute to the some of the SDN open source communities, such as OpenDaylight and ONOS, and also to projects like CoVisor, RUNOS or FlowBricks, so that all of us can benefit from each other.
- Identify the key advantages of YANG and NEMO languages and use the output and learnings from NetIDE to contribute to their evolution, so that they are perfectly suitable for deployment of SDN applications. Also, identify different approaches for a convergent Southbound Interfaces (SBI) protocol than confines: OpenFlow (OF), NETCONF and others.
- Benefit from NetIDE so that our R&D branch can grow with it, as many of our future project proposal will be closely related to SDN and NFV.

In the near future, Telcaria will be particularly focused on the development of the IDE (both Graphical User Interface (GUI) and application deployment), in the evolution of the concept of composition and conflict resolution for composite applications (directly related to the Engine) and in the elaboration of the so-called NetIDE API 2.0, which aims to support different SBI protocols (such as OF and NETCONF) in an agnostic way.

3.2 Other Exploitation Lines

The research and academic partners' exploitation plans, contrary to the industrial ones, are oriented towards maintaining and demonstrating excellence in research to show their relevance in a highly competitive national and international research funding arena. The project's results are aimed to be exploited by these partners to improve the universities curricula and education programs, to attract new MSc students,and initiate PhD theses topics related to the NetIDE project. These exploitation lines are primarily internal but can be used to broadcast the institution place in the European research world.

3.2.1 Exploitation plan CREATE-NET

Considering the highly evolving domain of SDN, there is an important need for tools and solutions which can speed up the prototypation of innovative applications based on this tecnology. CREATE-NET believes that NetIDE outcomes could be a very valuable asset to facilitate the activity of software developers and DevOps to both smoothen the inclusion of new SDN applications but also to anticipate and intercept their potential weaknesses before being deployed in a production environment. Through the activity developed within NetIDE, CREATE-NET researchers are getting a much stronger understanding of the strengths and limitations of several controller frameworks, in primis OpenDaylight and ONOS. Moreover, CREATE-NET is planning to propose a novel memory management system to the ONOS community and it is also evaluating to submit a NetIDE Engine project to facilitate the porting of non-ONOS applications into this SDN platform. Finally, this deep analysis of these two major SDN platforms is extremely helpful in all our ongoing research work we are contributing to in several other EU and national projects in the domains of SDN and 5G (including EC projects: VITAL, ACINO, SESAME, COHERENT).

3.2.2 Exploitation plan University of Paderborn

The results and research questions will be used in our ongoing research and also supplement our courses. For example, the knowledge learnt around SDN technologies and their impact on today's and tomorrow's networking provides valuable material for lectures like "Future Internet". Also the question that are rising in the context of composing applications and modification controllers/SDN to allow coexistence of multiple software program results in multiple further research questions that can be persuaded in the context future work and/or projects if answers to these question are not in the main focus of NetIDE. Furthermore at the University of Paderborn we have student courses called "project group" in which a group of students (usually 6-12) is working on a project that is close to research. We are evaluating the possibility of having NetIDE's software as topic in one of the next groups. This would allow the student to work with the state on the art software of NetIDE and improve/extend the software.

We also currently evaluating the reuse and further developmenet of NetIDE components in the Horizon 2020 research project SONATA. SONATA targets both the flexible programmability of software networks and the optimization of their deployments. The project will support network function chaining and orchestration, make service platforms modular and easier to customize to the needs of different service providers, and introduce a specialized DevOps model for supporting developers. The concepts that SONATA project explores for the virtualized network function can build on the concepts and the experience we collected in the NETIDE project. Especially the IDE component of NetIDE is being evaluated for being resused.

3.2.3 Exploitation plan IMDEA

IMDEA Networks, as an institutional framework promoted by the Regional Government of Madrid, has as general objectives to perform research of excellence in networking science; bring off transfer technology to the industrial sector in order to improve competitiveness; attract the best international researchers and scientists in the networking area to the region of Madrid and finally make Madrid a centre of science, technology and research, positioning it among those knowledge-generating regions at the forefront of innovation. IMDEA Networks has strong liaison with both worlds academia and industry:

- Academia via the collaboration with the University Carlos III of Madrid, where the IMDEA PhD students are affiliated and participate on the studies on M.Sc. and Ph.D. on Telematics Engineering.

- Industry via the collaboration in many R&D projects and initiatives, funded directly by the industry, the EU,the national and regional R&D funding agencies. IMDEA Networks will leverage the NetIDE technology to transfer the knowledge to the current and new R&D projects on SDN/NFV and the new curriculum in the postgrade courses and the university.

More in details, the IMDEA Network exploitation plans of NetIDE are:

- The IMDEA Networks team will collaborate bringing the expertise and results of the NetIDE project to the new ecosystem for innovation and research jointly created by Telefónica and IMDEA Networks: 5TONIC, the Spain's first laboratory of 5G excellence. 5TONIC will work on virtualization software for 5G networks by covering aspects of Network Functions Visualization and Software Defined Networking.
- IMDEA Networks has also just lunched jointly with the University Carlos III of Madrid and in collaboration with Ericsson, a new Master on NFV and SDN. The NetIDE architecture tools and IDE are a case study on the programme of this master course.
- IMDEA Networks will use the experience achieved on NetIDE on SDN open source framework and tools (OpenDayLight, OpenStack, ONOS) to contribute to other current and future projects and academic courses
- IMDEA Networks is disseminating the NetIDE results within all the current and near future research, development and consultant activities.

3.2.4 Exploitation plan IPT

The Fraunhofer Institute for Production Technology works with industrial partners (SMEs and large enterprises) in a large variety of research projects. The research fields in which these projects take place comprise but are not limited to Internet of Things, IT in industrial production processes, intelligent technical systems, and cyber-physical systems. Our projects are usually financed by direct contracting or via national government and EU-wide funding.

Fraunhofer IPT intents to use the IDE and the NetIDE Core in upcoming industry projects in the fields listed above. This includes extending the IDE by new components tailored to the requirements and use cases of our partners. We also see potential for the IDE to assist in consulting activities with regard to the optimization and restructuring of software development processes for SDN application developers. Methods and tools developed in the project are applied and evaluated in research transfer projects and we will use the feedback to extend and evolve them.

We are going to use the expertise gained during the course of the project in industry and research transfer projects. Example projects could be consulting projects assisting the assessment of existing and the migration to SDN-based network infrastructures in SMEs.

Fraunhofer IPT is a research institute with strong connections to the Heinz Nixdorf Institute of the University of Paderborn. We are going to use NetIDE in teaching offering topics for seminars as well as bachelor and master theses to university students. Our focus in teaching lies in the field of model-driven and model-based software development and we see the NetIDE developer toolkit as a good example for applications in this field.

3.3 Industrial Advisory Board Report

The Industrial Advisory Board is a crucial tool to get direct feedback and input from our industrial partners who have a better view of the challenges and needs of potential clients in a more pragmatic way. The board members are:

- Corinne Sieux (Thales) is in charge of network and system program proposals in Thales Communications & Security. Has an experienced background in different signaling and routing protocols.
- José Manuel Carballo (Telefónica): runs Telefonicas Corporative Networks Competence Centre in Specialist Engineering responsible for SDN applications and use cases in datacenter and campus environment
- Uri Elzur (Intel): SDN Architecture Director, Intel Data Center Group. Responsible for long term vision, technical strategy, architectures and products for server platforms. OpenDaylight Board member.
- Mick Wilson (Fujitsu Labs): sits on ETSI Industry Steering Groups on Network Virtualization (ETSI NFV) and Mobile Edge Computing (ETSI MEC)

We had two virtual meetings this year where we asked the board their views on the projects and how it could relate to concrete solutions.

3.3.1 1st IAB meeting

The first IAB meeting took place the 10th of March 2015.

Regarding the Business value of NetIDE's objectives, the IAB sees great interest of most of the customers, who are willing to move towards SDN-based networks and services. The board envisage SDN as a federation of networks. It would facilitates the development of management product. The objectives of NetIDE are in line with their main expectations:

Facilitate management, integration, federation. It could also simplify and shorten product development and evolution as well as service deployment.
The NetIDE Use Cases adequately reflect the needs of the different business lines (data center, campus networks and federated networks).

Service chaining on top of different controllers could be a new use case or another are to explore, in link with ETSI NFV's work.

There are ongoing and forthcoming trends that could impact NetIDE. For example there are several abstraction level definition efforts in the industry (Intent-based; NB APIs; etc). The diversity of open source and industrial controllers should remain very important for the project. Security of applications on SDN and security of the controller could also be of interest. They see no disruption that could affect NetIDE's efforts. They do note that we need to discuss with other FP7 and H2020 projects and with the OpenDaylight Community.

3.3.2 2nd IAB meeting

The second IAB meeting took place the 22nd of September 2015.

During the initial phase of NetIDE, the project was intended as a way to make heterogeneous applications work on a single network; in addition to the original heterogeneous framework project we proposed that NetIDE can be used as a prototyping tool. The board mostly agreed that fast prototyping can be directly valuable, for example to allow portability between platforms (e.g. base stations, aggregation points). Furthermore, the prototyping tools provided by the project can be very useful for introducing SDN in new environments.

Regarding the Cost-benefit / Market analysis of the impact of NetIDE the board had many inputs on this subject using their respective knowledge of the SDN market. First, the board thinks that SDN is mostly a required technology to enable NFV and SDI. The network needs to support virtualization and automation to allow instantiating and providing virtual resources. Secondly, the

potential for OPEX savings mainly comes from the easier automation, the gained business agility (ability to deploy apps in real time, elastic resources provisioning etc.). Thirdly, the CAPEX savings are enabled by the parallel trend towards white box switches. There are combined CAPEX/OPEX savings enabled through the use of Standard High Volume servers for network processing enabled by SDN. While the SDN market is still emerging, NetIDE's potential clients are aware and interested by SDN; they ask questions and request studies on SDN to be integrated in future projects. NetIDE comes at the right time to prepare the shift to these markets.

NetIDE can also be highly useful to build advanced pre-industrial or industrial projects with SDN, define demonstrators to show integration with current programs or create real "pure SDN" projects. If NetIDE succeeds promoting creation of new network related applications - that can operate over any SDN controller (in the Cloud, for Telcos and Enterprises across all the layers) - the acceptance of SDI by customers will be wider and faster.
Finally, the board thinks that it can be of special value if NetIDE can be proven to provide a common layer that application can rely on when deployed over ODL or a commercial/proprietary SDN controller. At this point in time, when it comes to open source SDN controller, the board thinks that ODL provides the broadest community, largest set of projects, supports many and any SB protocols and is becoming production ready.

3.4 Contribution to Open-Source Communities

3.4.1 OpenDaylight Contribution

In the first year of the project, the initial NetIDE Network Engine included an OpenDaylight Shim to allow it to operate as a Server Controller. Feedback for this initial demo was positive from reviewers at the project review but also from the Industrial Advisory Board. It was suggested that this could be exploited as a contribution to Opendaylight. WP6 researched the methods required to contribute and a Project Proposal was created for public comment [1]. NetIDE presented its Project Creation review at the Technical Steering Committee meeting in June and was formally accepted as a new project. The project was represented by Intel at the OpenDaylight Summit in Santa Clara in July. The summit was split up into Day 1: Developer Tutorials, Days 2,3 were Keynotes and presentations and Days 3,4 were Developer/Design sessions (invitation only). Now a Project Team Lead (PTL), Intel received an invite and attended the sessions on integrating with the other OpenDaylight Projects.

The Simultaneous Release Plan for the Beryllium release has key dates where Milestones need to be achieved for projects to be considered still part of the release. Projects are divided into Offset 0, 1, 2 based on a tree of dependencies among projects. A project with offset 0 does not depend directly on other projects. A project with offset 1 depends on projects with offset 0. A project with offset 2 depends on projects with offset 0 and 1, and so forth. NetIDE is considered an Offset 2 project.

Timeline for Milestones [9]

- **M1: 6-Aug-2015** Joining the Release Projects must designate a Test Contact.
- **M2: 3-Sep-2015** Final Release Plan, a Continous Integration process according to Project Checklist.
- **M3: 15-Oct-2015** Feature Test Started, karaf features defined and include in the integration karaf distribution. Distribution build job to verify changes do not impact the integration distribution. Projects must have filled out a basic system test plan template for each top-level feature (karaf and not karaf) and a comprehensive system test template including functionality, cluster, scalability, performance, longevity/stability per stable feature.

- **M4: 3-Dec-2015** Feature Test Continues including all extra SW configuration and resources required for system test installed in the OpenDaylight Continuous Integration environment (Jenkins).
- **M5: 14-Jan-2016** Code Freeze (bug fixes only from here) and Feature Tests Complete (unit/integration test coverage of at least 75%)

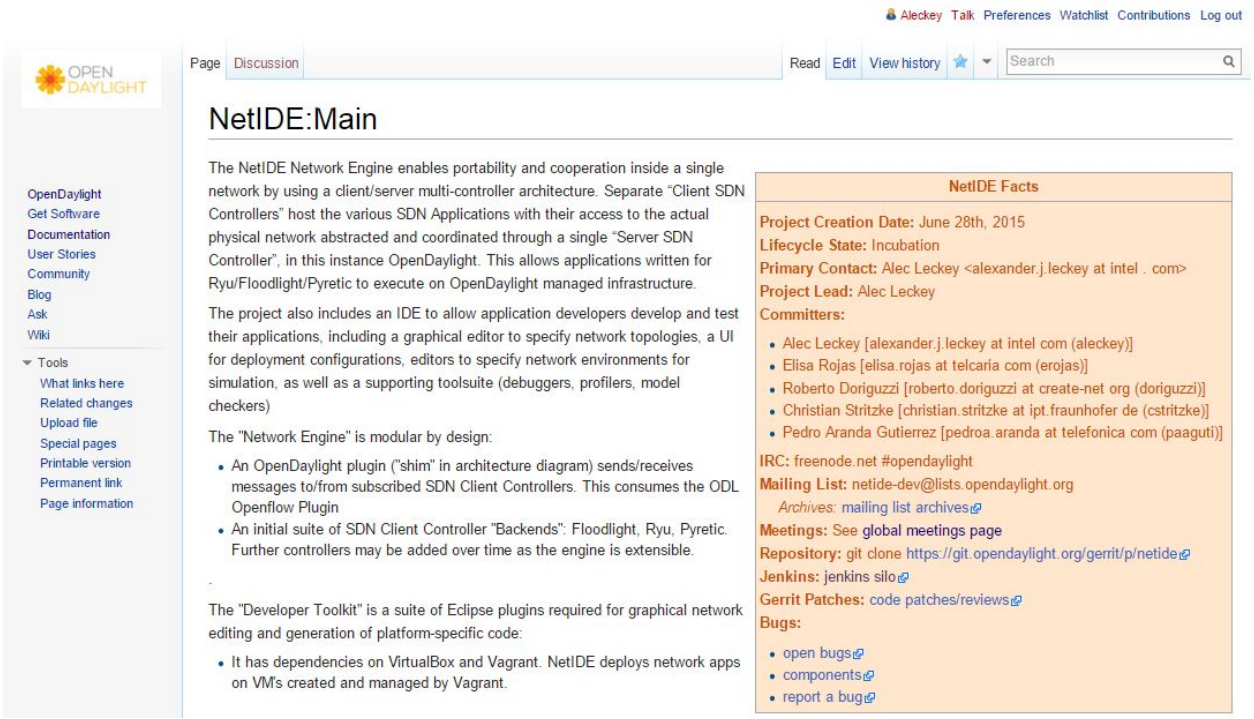

Figure 3.1: NetIDE Project page on OpenDaylight wiki [1]

The 4th OpenDaylight release, *Beryllium*, is currently scheduled for release Feb 2016 and NetIDE's Network Engine Shim is on track to ship with it. This Simultaneous Release process will then begin again for the planned 5th release, *Boron* which will be due Nov 2016. Again, the NetIDE project plans on being part of the Boron release including such features as the NetIDE Intermediate Protocol 2.0 and additional features/bugfixes. A Developer Design Forum for the Boron release is scheduled for early March in Santa Clara, USA to get discussions and decisions off the ground for the Boron release, including timelines and features.

3.4.2 ONOS Contribution

ONOS is an open source SDN network operating system, architected to provide a resilient, high performance SDN control plane featuring northbound (Intent Framework) and southbound (OpenFlow, NETCONF, OVSDB, etc.) abstractions and interfaces for a diversity of management, control, service applications and network devices. ONOS is a multi-module project whose modules are managed as OSGi bundles inside an Apache Karaf framework. Applications interact with ONOS through the Intent Framework, that allows to specify their network control desires in form of policy rather than mechanism. The ONOS core accepts the intent specifications and translates them into device-specific operations (e.g. OpenFlow rules, NETCONF YANG configuration). Since October 2015, ONOS and Linux Foundation established a strategic partnership to create open source SDN and NFV platforms and solutions.

Currently, the community is focusing on several projects and proof-of-concepts, mainly driven by real use-cases faced by service providers and vendors. These scenarios vary from the re-architecture of an ISP Central Office as a Datacenter, to a central management of a multi-layer packet optical network, up to the interaction with standard IP-BGP networks. The full list of PoCs and scenarios is available on the ONOS Wiki pages [10].

Partners and external developers could easily extend and customize ONOS through the following process:

- Design an initial solution, both focusing a new feature or a core improvement and write it down inside the specific section in the ONOS Wiki [11].
- Formulate a brief proposal in writing to the Technical Steering Team (TST) [12].
- Submit new or changed Java APIs for review via Gerrit, following the procedure explained here [13].
- Adjust the Java APIs based on the feedback from the TST and from the broader ONOS community.
- Proceed with implementation and submit code for review via Gerrit.

In NetIDE we designed and implemented an initial prototype for ONOS of the so-called *Garbage Collector* tool, which aims at automatically removing the unused forwarding rules from the memory of the network devices. This tool has been extended to cover a wider scope such as improving the robustness of the network with novel memory management techniques.
Another component for ONOS implemented in NetIDE is the Shim, which allows ONOS to operate as a Server Controller within the Network Engine.
In year 3 of the project, we plan to contribute to ONOS by submitting two feature proposals to the ONOS TST, the memory management system and and ONOS Shim.

3.4.3 Eclipse Marketplace Contribution

The Eclipse Marketplace [14] is a platform for publishing Eclipse plug-ins. Plug-ins listed on the Eclipse Marketplace can be easily installed through the Eclipse user interface. The Marketplace does not host the plug-ins themselves. Instead, publishers can enter a description of the plug-in and provide a reference to a self-hosted repository.

We have set up a repository for the NetIDE Eclipse plug-ins[1]. It features a *nightly* branch with the newest but possible unstable features and a *stable* branch of our development. Users of the IDE can pick one of these branches and add them to their Eclipse installation.

We also registered the NetIDE Eclipse plug-ins on the Marketplace[2]. The Marketplace entry contains a short description of the project, screenshots, and references to user and developer manuals. It also features a comment section and collects statistics on how often the entry has been viewed and how often the NetIDE Eclipse plug-ins have been installed.

The placement of NetIDE in the Eclipse Marketplace makes advertising the project a lot easier as the installation time for potential users is significantly decreased.

Version 0.3 of the IDE is currently published on the marketplace. We plan to release version 0.4 in M30. Version 1.0 is going to be published at the end of the project in M36. In between these releases, we also push bug fixes and minor improvements to the marketplace in the form of point releases.

[1] `updatesite.netide.eu`
[2] `https://marketplace.eclipse.org/content/netide`

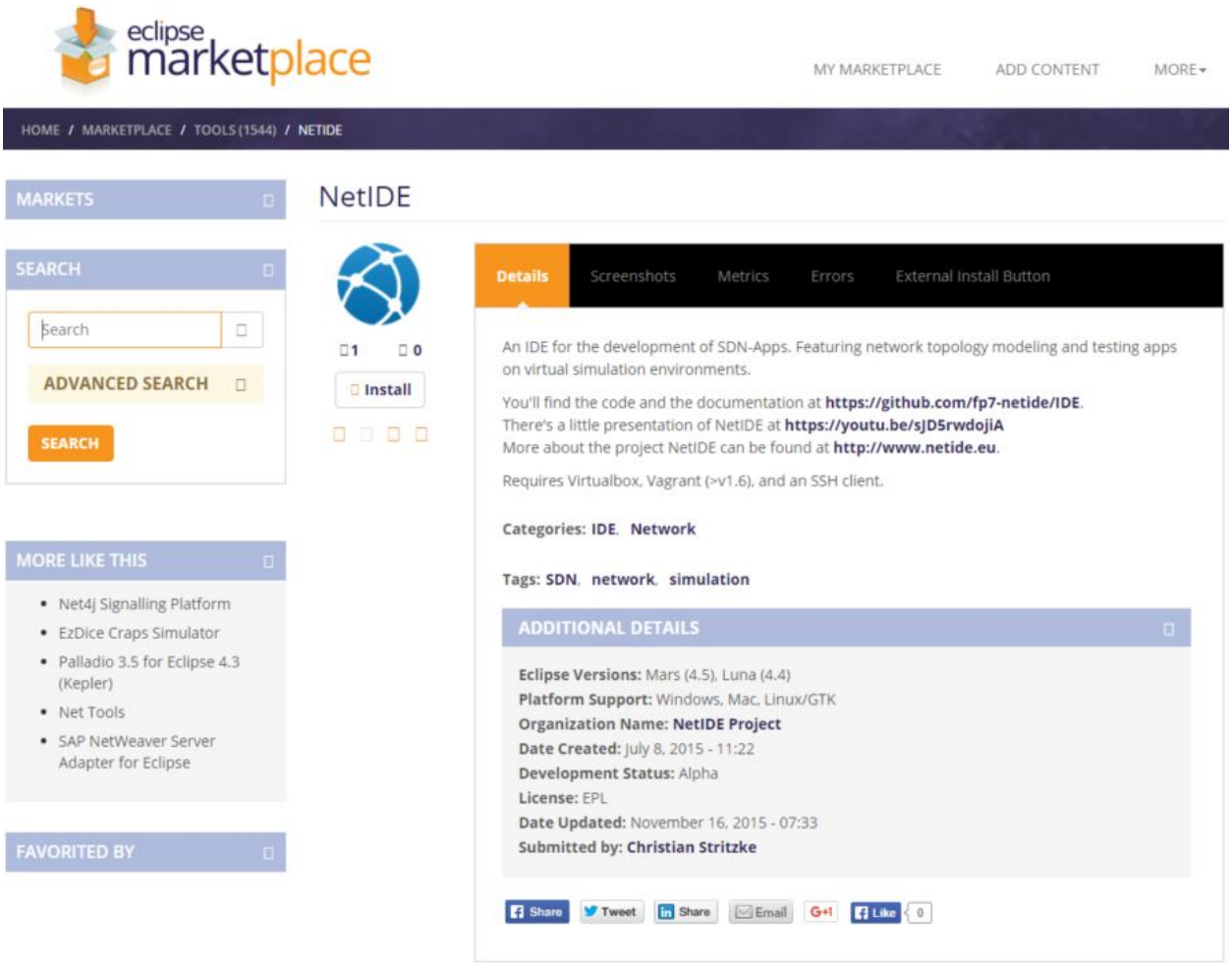

Figure 3.2: NetIDE Portal on Eclipse Marketplace

3.4.4 Pyretic Contribution

After the contributions last year, in 2015 we contacted the Pyretic team on several occasions. Our conversations were mainly about the introduction of a new evolved Pyretic Application Programming Interface (API), closely related with our NetIDE API (in the end, our initial prototype was based on the Pyretic API, although we now have our own API). We exchanged emails about how to introduce new versions of the OF protocol or other SBI protocols, such as NETCONF, because we were thinking of two possible approaches: a simple header that carried the SBI protocol from the server to the client controller or a more complex approach in which all protocols were merged into a single —universal— language. They did not have it clear either, but were quite interested in the evolution of the Pyretic API to at least support OF 1.3 and, as a consequence, they created a wishlist [15] for further ideas.

Some months later, when our NetIDE API was actually ready, we tried to contact them again to show them our progress, but we had no response to our several emails. Eventually, the Pyretic community seems to be winding up: there are scarce contributions to the GitHub repository and the mailing list has not been used for a time. In any case, we will still keep an eye on the project in case it is resumed.

3.5 Plans

The project will continue to monitor the latest trends in the area of SDN to ensure new opportunities for exploitation are incorporated into its plans[3]. In particular will be the ONOS contribution which started in year 2 and will be continued in Year 3 of the project. A new application interface paradigm shift has occurred within SDN. Another area to focus on is Intent Based Networking where applications simply describe their Intent for network behaviors and network policies to the SDN controller through a NorthBound Interface. This is documented in more details in the Market Analysis of chapter 4, section 4.2. This provides generalized and abstracted policies instead of traditional Openflow rules. Key stake holders in this new area include: the ONF's Northbound Interfaces working group, OpenDaylight through its Network Intent Composition [16], ONOS's intent driven API. NetIDE will continue to monitor these projects to see where there are exploitation opportunities.

3.5.1 CoVisor

Thanks to the architectural advances of the Engine during the second year, we have prototyped an Engine (backend, shim and core) which included composition and conflict resolution. During the implementation, we faced a new problem: the so-called "run to completion problem". The concept is the following: if an event coming from the network is distributed to the different applications, they will give a response that later needs to be merged and sent back to the network, but how do we know when all the different applications have finished sending their replies?

We are currently studying this in WP2. However, in the meantime, we contacted the FlowBricks [17] and the CoVisor [18] teams regarding this issue, both of them SDN hypervisors for composition of Northbound Interfaces (NBI) applications. While the former had discontinued the project and could not give us any details, the latter kindly replied and we had a conversation about both prototypes. Apparently, CoVisor only composes applications, but currently does not handle conflict resolution. More specifically, it does not need to wait for all the responses because it builds the state of the switches following an incremental composition approach, but not merging and dealing with possible conflicts in the network. After this, and although CoVisor is also discontinued right now, we agreed to keep in contact for the future advances in the NetIDE prototype.

3.5.2 Englewood

Another project currently being monitored and interacted with is the opensource SDN project called Englewood [19]. Englewood's goal is to define a transport-agnostic Transport API (T-API) framework and to develop a set of software modules that can be used to prototype, test, validate and facilitate the deployment of such T-API in SDN environments where different platforms (either open-source, e.g., ONOS or ODL, or proprietary platforms, including legacy NMSes) are used. This would allow applications to be developed independently from the controller that they need to communicate with and also supporting migration from legacy networks towards SDN networks.

As can be noticed from Fig. 3.3, the Englewood project is potentially an interesting use case for the NetIDE Network Engine, as the T-SDN Client API and the T-SDN Server API layers represented in the Figure have the same roles and functions of the NetIDE Backend and Shim layers respectively. We are currently sharing architectural and implementation details of the Network Engine with the Englewood's team in order to understand whether our expertise can be useful for the design and implementation of the Englewood's framework.
One of the most promising direction for this collaboration is represented by the implementation

[3] In response to review comment R#11 regarding including monitoring plans for 2015.

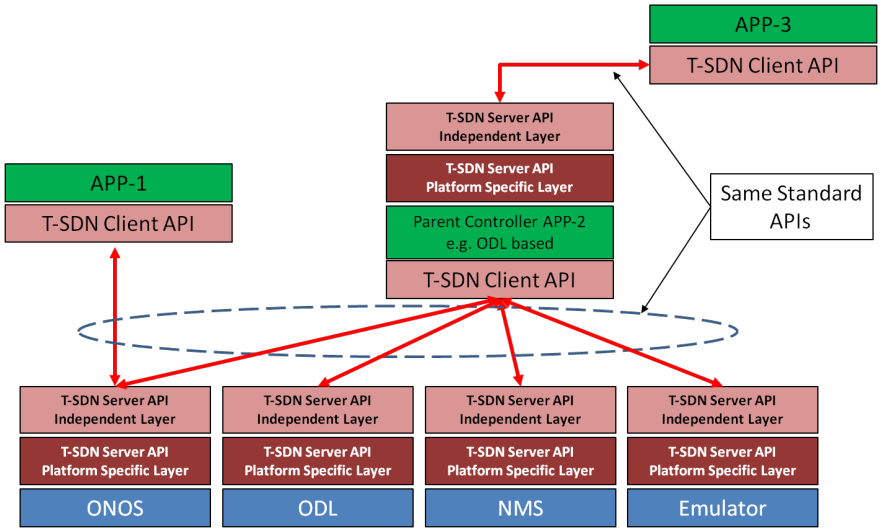

Figure 3.3: Englewood's functional architecture

of a Backend for T-API-based applications, so that these applications can leverage on the conflict resolution and composition mechanisms running in the Core.

3.6 Contribution to Standardization

Our standardisation activities are anchored in the Internet Engineering Task Force (IETF) and Internet Research Task Force (IRTF). We are actively contributing to the creation of a working group for the NEMO language. Additionally, we have started to explore the possibility to contribute our conflict resolution concepts in the Interface to the routing system (I2RS) working group.

3.6.1 NEMO: a network modelling language

NEMO is an effort to provide a simplified modelling language that can be used to describe networking scenarios. This language may be helpful for the NetIDE application format definition and we have been collaborating with the IBNEMO group on a effort to standardise it. We have contributed our virtual datacentre use case for implementation as a proof of concept of the language. During 2015 we have participated in a so-called bar Birds-of-a-feather (BOF) meeting in the IETF'93 to sense the possibility of creating a working group. This meeting has been reflected in the IETF journal [7]. Additionally, we have participated in the IETF 94 Hackathon [8], where we continued our work refining the NEMO language to suit the use-case 1 of WP5.

3.6.2 Next steps: NEMO and I2RS

We plan to continue supporting the creation of a working group that standardises the NEMO language during 2016 and participate in the discussions in the mailing lists. However, this long term goal has found some resistance in their governance mainly due to the lack of maturity of the concepts within the IETF and the layers on which an Intent interface would rely. We have being suggested to try to create a research group in the IRTF and will pursue this aim during the next year of the project.

Additionally, during the IETF'94 meeting, we have started a conversation with the I2RS working group to explore the possibility of contributing our conflict resolution work to their work. A first

presentation from NetIDE and the possibility of an informational draft was planned for the interim between IETF'94 and IETF'95.

4 Market Analysis Updates

According to the networking version of Gartnerś Hype Cycle, the 2015 hype curve is showing that SDN has reached the "Trough of Disillusionment" [2]. This typically means that interest has begun to disappear as current implementations are not delivering on expectations. In reality, it is the marketing folks that are backing away from the technology in question allowing those that actually require it to improve their solutions to satisfy early adopters. The report uses the term "SDN fatigue" to describe what they see as too much literature and marketing, and not enough real-world implementations due to an estimate of less than 2,000 SDN enterprise deployments in the market. Virtual Switches are now considered mainstream, appearing at the top of the "Slope of Enlightenment", but it is the location of SDN Applications that is of interest. SDN Applications appear to still be near the top of the hype cycle providing great potential for new proof-of-concepts to impact usable products.

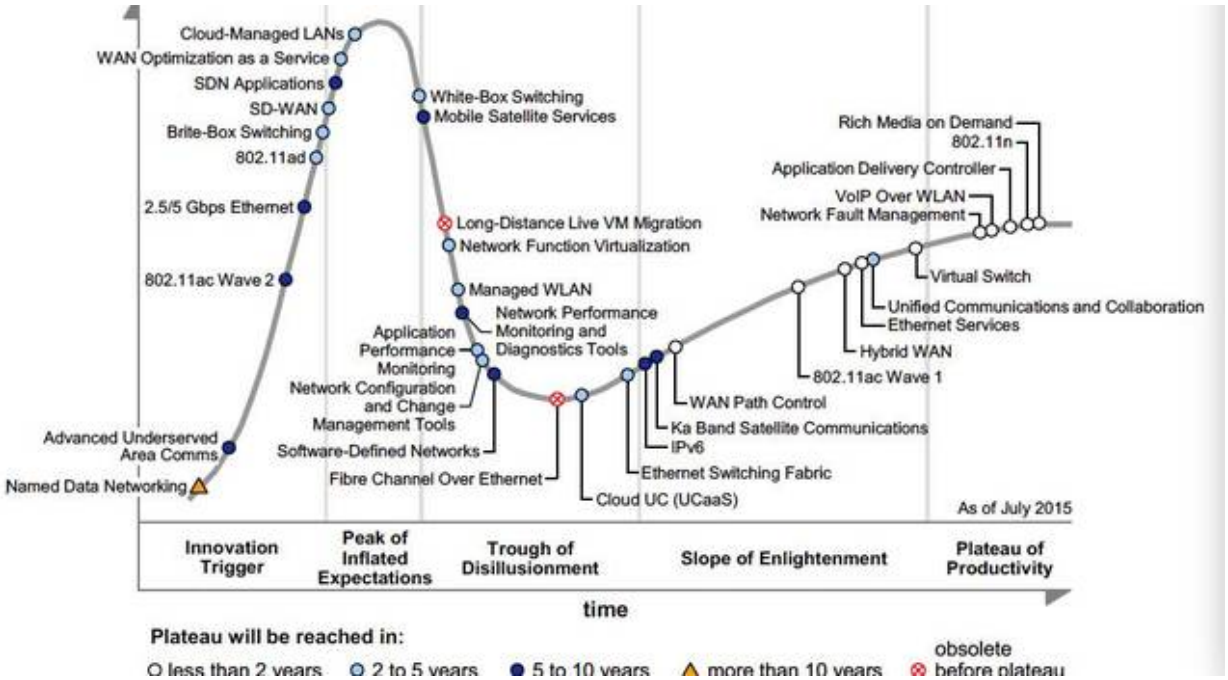

Figure 4.1: Gartner's Network hype cycle 2015 [2]

This chapter provides an update to the market analysis performed in 2014 and contained in D6.3. Again, we review the latest reports examining the adoption of SDN, the impact standards organizations like the ONF have had on the market with their certified professional program and latest updates to the Northbound Interfaces standardization. We re-examine one of the great drivers of SDN, the Data Center and its Software Defined Infrastructure (SDI) strategy. Lastly, we look at Service Function Chaining (SFC) to examine how SDN compliments NFV.

4.1 Market Forcast

In 2014, WorkPackage 6 reported on current technology trends providing detailed descriptions and comparisons. These included market trends (proprietary and open source frameworks), their drivers and barriers to adoption, what industrial roadmaps were available, and the standardization of SDN. We now extend this initial analysis for 2015 by reviewing the latest market analysis reports to see what changes exist with a view to ensuring relevancy for the NetIDE results. The majority of reports focus on SDN for service provider networks, Data Center, Enterprise and Software. SDN software is usually split into orchestration and controller, and the network apps that sit on top of these controllers. A common theme is the primary factors to the adoption of SDN and NFV:

- **Service agility:** This results in quicker time to market (TTM) allowing service providers to quickly add and update the services and applications they offer through using SDN control software and NFV on virtual machines (VMs) on commercial servers.
- **Operational efficiency:** This provides a complete view of the network when provisioning across multi-vendor networks and multiple layers. The control offered by SDN enables carriers to increase utilization, therefore minimizing the amount of equipment required. As a result, capex costs are now reduced.

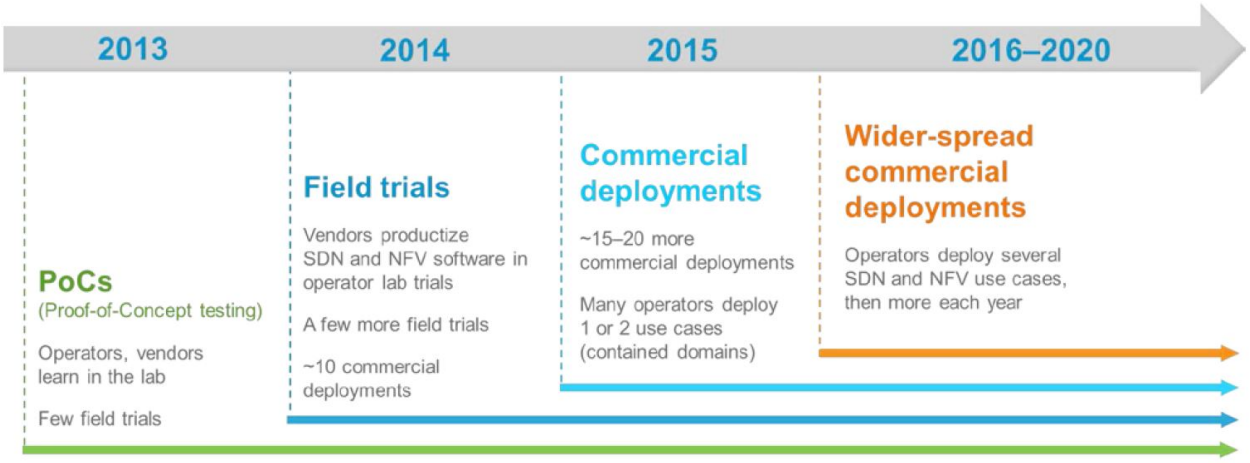

Figure 4.2: SDN & NFV Timeline 2013-2020 [3]

Timeline of SDN and NFV deployments:

- **2013:** Many proof-of-concepts test occurred in labs to check SDN and NFV principles and the use cases.
- **2014:** Vendors took initial product offerings to operator labs to refine. Minimal commercial trials occurred.
- **2015:** Commercial deployments begin with successful field trials occurring. Operators testing 1-2 use cases on live networks.
- **2016:** Even more commercial deployments are expected with operators moving at different rates depending on their expertise.
- **2017-2020:** Operators should begin to become more comfortable with their initial use cases and SDN network domains.

4.1.1 Latest Drivers/Barriers to SDN adoption

There are number of factors driving SDN uptake in the market. A recent Infonetics report suggested these range from strategic to survivability [4]:

- Both SDN and NFV are deemed a necessity to telco survival due to competition from on-demand services, such as mobility, cloud or Over-The-Top (OTT) content delivery of video/audio due to the lack of a multiple-system operator required in the control or distribution of content.
- The larger service providers have public SDN/NFV strategies and investments. As a result, they are demanding their software/hardware suppliers do the same.
- Due to large domain of SDN and NFV, small service providers can become niche providers supplying solutions to the higher priority usecases only, therefore lowering their risk.
- These smaller service providers that are already in the market with solutions are forcing the larger providers to follow suit or risk being left behind

However, the report also indicated the takeup of SDN and NFV was slow due to a number of factors:

- Standards are still in development with some industrial agreement on architectural approaches. There is still a lot to be decided
- Service providers demand full testing of a technology before putting it onto their production networks. This is to have minimal impact on existing revenue streams.
- Back Office solutions are still not considered integrated. To provide agility of new services, Back Office solutions require updating or replacing. However, this is also seen as an opportunity to back office solution providers.
- Carrier grade software is a time consuming process as it requires significant testing/feedback in large production systems. This is seen as work in progress.
- A different skill set is seen as required for operational support of next generation network functions. The known supported processes and skills now need to be replaced with software based skills
- The report hints that the market will not be ready to embrace SDN and NFV until 2016/17 and will not hit full stride until 2019-2020.

The forcast for revenue coming from SDN related software (including orchestration, controller and network applications) is seen to grow from $46M in 2014 to $2.2B in 2019, which is a year on year growth of 117%. First generation SDN controllers were seen as little more than Openflow translation layers for your programming language of choice, eg, Beacon/Floodlight for Java, Pox/Ryu for Python. Next generation controllers included both applications in addition to the original control plane features. These SDK type controllers added much more support for southbound protocols, eg, OpenDaylight, ONOS. Vendors are now looking to include service orchestration features in their SDN controllers.

This forecast breaks down as:

- SDN orchestrator and controller software revenue to grow from $37M in 2014, estimated $109M in 2015 to $1.08B by 2019, a year on year growth rate from 2014-2019 of 97%.

- SDN network apps revenue to grow from $10M in 2014, estimated $43M in 2015 to $1.15B by 2019, with a year on year growth rate from 2014-2019 of 160%.

As reported in D63, there still appears to be more value in SDN applications than actually in orchestration and control. These latest numbers appear to confirm this trend, but that the SDN software segment does not ramp till 2016 and is not mainstream until 2019/20. The key assumptions are that uses of SDN requires a controller/orchestrator; small fees are paid by service providers to host trials and that China will host many early commercial deployments which cause the market to accelerate adoption. SDN applications are slower to start than controller/orchestration software, but that there is more value in applications in the long run, eg, traffic analytics, load balancing.

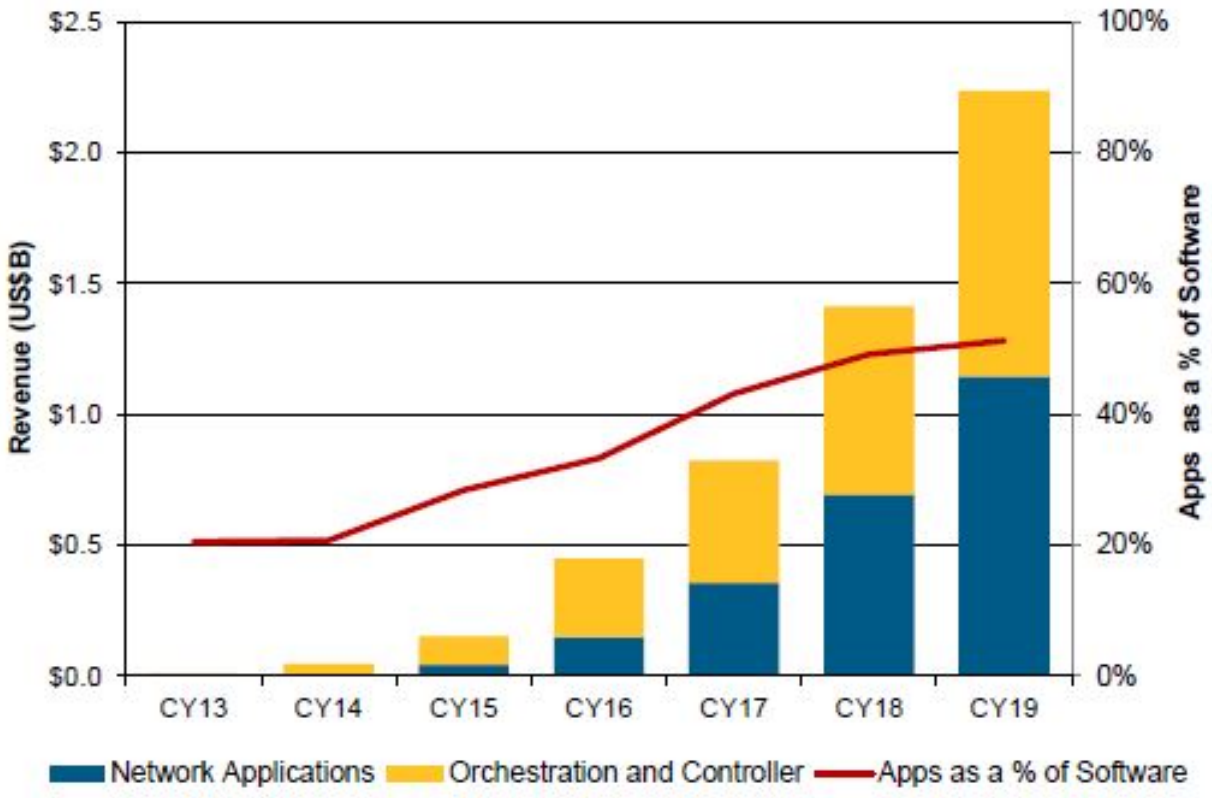

Figure 4.3: SDN Software: Applications vs. Controller/Orchestration [4]

4.1.2 Vendor Lock-in

While SDN is starting to fulfil some of its promises, interoperability is still a way off from being achieved. The project identified two original problem areas that it would focus on: SDN applications are closely tied to a particular controller framework and not easily portable between them; multiple controller frameworks are not usually able to cooperate inside a single network. This still seems to be relevant as a recent survey [3] has shown that carriers still see a multi-supplier SDN and NFV environment of control mechanisms, service orchestration and equipment. This appears to be a trend towards a software-centric, automated environment with customer driven services. However, the responses received show that 86% of respondents will use telecom equipment manufacturers to supply both their SDN hardware and software for their networks, with 75% claiming that they will use NFV software specialists to supply their NFV software. The key output of the survey was that carriers aimed to use a variety of suppliers for both SDN and NFV in an attempt prevent lock-in as

greater than 50% claimed that will purchase from multiple supplier types: specialized SDN, data center equipment, virtualization software, VNF software, network equipment, and open source.

The top criteria service providers intend to use to select an SDN vendor are:

- Product reliability
- Price to performance
- Product roadmap
- Pricing
- Service and Support

Many vendors are now starting to develop commercial controller distributions based on the OpenDaylight opensource controller. The extent to which they leverage OpenDaylight varies depending on their offerings, but according to the SDX Central's 2015 Controller report [20] are usually the base distribution with additional proprietary function included (e.g. Brocade, Ericsson, Ciena, etc) or a foundation for selling integration and development services (e.g. Wipro, TATA Consultancy Services) or part of their infrastructure in a Network-as-a-Service offering (e.g. Telstra, IBM, etc) or elements for use in their solution e.g. ConteXtream (now part of HP). These commercial distributions include the *Cisco Open SDN Controller* [21], a commercial distribution of the OpenDaylight opensource controller. This is a separate build which includes a hardened, validated, and service supported OpenDaylight distribution, ie, high availability clustering, monitoring, metrics collection, and log management. Inocybe also offers a similar commercial distribution, *Pure Play OpenDaylight* [22], with service support packages, training, and enhanced Testing and Security packages. The goal of these offerings is to make OpenDaylight easier to deploy and support. It should be noted that all these vendors are actually significant contributors to the OpenDaylight platform leading 1-2 active projects and contributing development effort to others. The NetIDE Network Engine is due to ship with OpenDaylight Beryllium release in Feb 2016, so seeing large SDN vendors offering support for productized versions of OpenDaylight including the project's Network Engine would be a positive result for the project.

The other Data Center grade controller, ONOS, had it's 4th open source release *Blackbird* in Sept 2015. While focused on the telecom service providers, it is not as widely adopted as OpenDaylight. In Oct 2015 ONOS became an Linux Foundation project which also host OpenDaylight. The project will continue to monitor this as there is potential for these two large projects to merge at some stage in the future.

4.2 Open Networking Foundation

Since the start of the project, NetIDE has been monitoring the efforts of the ONF with a view to ensuring the project uses their recommended guidelines where relevant. For example, the NetIDE Network Engine architecture follows the Client/Server SDN Controller architecture design recommendations and naming conventions that were published by the Architecture and Framework Working Group [23]. The NBI Working Group has been focused on standardizing the Application Controller Plane Interface (A-CPI), traditionally known as the Northbound interface. We report on a number of activities that the organization has been focused on during the year.

4.2.1 Northbound Interfaces for Intent-Based Networking

The Northbound Interfaces working group has been developing requirements, architecture, and working code for NBI in an effort to make SDN application development easier for developers.

WorkPackage 6 had analyzed early versions of the *"NorthBound Interface Framework and Architecture"* draft document in D63 [6], but this document was never published. Originally, the working group proposed the development of an information model and encodings for SDN Controller NBI API's in a programming language neutral manner, as a data model. But given the massive scope of this area, a new working group was created, the Information Modeling Working Group [24]. This new working group is responsible for a Core Information Model that can be used as the basis for developing application-specific and forwarding technology-specific information models by other ONF projects in all areas and external standards organizations. This information model was published in the *"ONF-CIM Core Model base document 1.0 + Model 1.0"* [25].

The work performed in these working groups is now being showcased in several solutions on the ONF sponsored Open Source SDN project portal (opensourcesdn.org). Its goal is the greater adoption of open SDN so each project's code can be viewed on the ONF's GitHub code repository and is available either under the Apache 2.0 public license or Eclipse Public License. The projects of relevance to NetIDE are the community developed Aspen and Boulder projects which use intent based API's.

The ONF collaborated with the Unified Communications SDN Activity Group of the International Multimedia Telecommunications Consortium (IMTC) to develop the Aspen project. The use cases created by this team specified the automating of unified communications quality-of-experience. The project also includes work with HP, Microsoft, and NEC to address automation in multimedia network performance requirements. The initial focus was on unified communications (e.g. Lync, Webex, Skype), but this was subsequently expanded to real-time media apps. The code is available to download under Apache 2.0 license from Github [26]. This code provides northbound interface via OpenFlow allowing applications to automate QoS for real-time multimedia services (eg, voice, video). The traffic is provisioned with relevant priority and bandwidth on the network ensuring separation from non-real-time traffic. This enhances the user's experience.

The NBI working group developed Boulder in collaboration with Ciena, Inocybe Technologies, and HP. Boulder specifies the architecture and information model for an intent-based interface to an SDN controller. The design allows for intent based application portability across different SDN Controllers, yet abstracting the application developer from actual specifics of the controller implementation. Boulder relies on the semantics and information models originally generated by NBI Working Group which allow applications to tell networks what to do (not how to do it) and is designed to provide Intent portability across different controller environments. An additional advantage of this abstraction layer is to reduce the impact on application re-writes as API's change over time or evolve. This provides both a declarative and imperative approach to developing applications through the Boulder scripting environment. Boulder works closely with multiple open source SDN Controllers such as OpenDaylight (Network Intent Composition project [27]) and Open Network Operating System (ONOS) [28]. It is also released under a dual-licensed model, Apache 2.0 and Eclipse Public License.

4.2.2 ONF-Certified SDN Professional Program

At the *SDN and Openflow World Congress*, the ONF rolled out a beta version of its ONF-Certified SDN Professional (OCSP) Program. The course material is designed to provide a strong foundation of vendor-neutral, concept and technical-level credentials in open SDN. The goal is to both integrate with and complement other vendor certifications in networking technologies/ programming languages. The beta exams were available to all attendee's free of charge. Individuals who received a passing score on the exams will receive an official OCSP certification as either an ONF-Certified SDN Associate (OCSA) or as an ONF-Certified SDN Engineer (OCSE) [29].

- **ONF-Certified SDN Associate (OCSA)** This exam certifies that the successful candi-

date has vendor-neutral conceptual knowledge of the major domains of networking practices that support the theory and practice of SDN. The associate certification validates concept-level knowledge of SDN technologies, architectures, and deployment solutions. Designed for entry-level sales and marketing professionals, this certification will confirm their foundational understanding of SDN. In order to pass the ONF OCSA exam, a foundational knowledge of computer networking is assumed, with specific familiarity with various conceptual models of networking and technologies is required. The exam requires 40 questions be answered in 60 minutes.

- **ONF-Certified SDN Engineer (OCSE)** This exam certifies that the successful candidate has vendor-neutral technical knowledge, skills, and abilities in the major domains of networking practices that support the theory and practice of SDN. The engineer certification validates technical and engineering-level knowledge of SDN technologies, architectures, and deployment solutions and is designed for entry-level SDN engineering and networking professionals. This certification certifies technical professionals in the domain of SDN networking.

4.2.3 Report from the SDN & OpenFlow World Congress

Multiple NetIDE partners attended the 2015 SDN & OpenFlow World Congress hosted in Neus, Germany (Intel, Telefonica). A number of dedicated tracks were scheduled including, the first European OPNFV mini-summit. The OPNFV is an open source project focussed on accelerating NFV through a carrier-grade NFV reference implementation. Its first opensource code release, Arno, was released in June with first service pack release in Nov [30]. Its 2nd release Brahmaputra is due Q1 2016. Sessions included the evolution of OPNFV platform, features that were being included in the Brahmaputra release, and current issues and challenges. The solution showcase included 19 demonstrations covering Carrier WAN SDN, Data Center SDN, Campus SDN, SDN Testing and Validation, and SDN/NFV. The "Best in Showcase" award which was an attendee vote went to ONF's Aspen Project. Other demos from the ONF booth were on a multi-vendor wireless transport SDN proof of concept developed by member companies Ceragon Networks, Coriant, Ericsson, Huawei, NEC and SM Optics participated in the PoC.

After the success of the 2014 event, ODL now hosted a dedicated track over two days. Uri Elzur, Director of SDN Architecture for Intel and NetIDE Industrial Advisory Board member spoke on methods to combine SFC, Policy and Network Virtualization, something that is of great relevance to Intel. NetIDE Technical Coordinator Pedro A. Guttierez also spoke on NetIDE's contributions to OpenDaylight and participated in a User Panel.

4.3 Data Centre Strategy

4.3.1 NetIDE in the Context of Data Centre Innovation

NetIDE is being developed during a period of disruptive innovation in the IT industry. The broader economy is recognizing the innovative potential of IT and its ability to disrupt established business models. This goes far beyond the productivity gains within established business models which drove much IT spending in the past. At the same time many enterprises and consumers recognize that they do not need to be IT owners in order to benefit from IT. From a user perspective access is key, not ownership. This leads to the development of new, large scale, IT application delivery models which have to be supported by an IT infrastructure which is very scalable and flexible. Application delivery is provided by a cloud infrastructure public, private or hybrid depending on individual cost/control trade-offs.

The core of the cloud is in the data centre: either in its role as a classic IT data centre or increasingly

as a communications data centre. The purpose of this chapter is to describe some major technical trends in the data centre and to relate them to the capabilities of NetIDE. Several members of the NetIDE industry advisory board are closely involved with data centre developments. They are typical of many industry professionals and are interested to understand how NetIDE can impact their work. We are therefore following data centre trends in order to relate NetIDE developments to their interests.

NetIDE has a particular domain which it addresses well but of course it cannot address all development environment requirements of the emerging data centre stack. However, provided with the right APIs, NetIDE can be integrated into IDEs addressing further layers of the stack and thus be a useful tool either in its own right or as a reusable component.

This chapter first describes the trend to the software defined data centre. One of the major benefits of a software defined data centre is its flexibility: data centre capabilities are packaged as interchangeable software components which can be recombined rapidly to satisfy changing needs. The chapter then describes a specific example of this flexibility in more detail: Service Function Chaining (SFC), which allows telco services to be rapidly developed and deployed.

A developer working on an SFC solution will think at a higher level of abstraction than that supported by NetIDE. However, SFC building blocks will be network applications which are directly supported by NetIDE.

New use cases for NetIDE will emerge in the software defined data centre. For instance, the shim architecture of NetIDE has the charm of bridging the gap between the software abstraction of the networking infrastructure and its implementation in hardware. The NetIDE engine has information about both the logical and the physical network. By integrating NetIDEs capabilities in higher order IDEs it will be possible to develop analysis tools which can relate the failure of a high level service function chain to the malfunction of a specific piece of hardware. This has the potential to greatly reduce the time and cost of troubleshooting in a productive environment.

4.3.2 Software Defined Datacenter Trend

Most datacenters today with their current IT infrastructure management solutions are offering quite static IT infrastructure configurations to their customers. However, mainly driven by the software-definable IT world, the management requirements to IT infrastructure in the data center are changing dramatically these times. Networks have to become as agile as the services they power. *"Service velocity"* is now becoming an ultimate Key Performance Indicator (KPI). In evolving infrastructures *"Service Velocity"* describes the speed by which services can be configured, deployed, modified and retired.(https://devcentral.f5.com/articles/why-sdn-or-something-like-it-was-inevitable-service-velocity)

For being able to deliver the value of the software-defined world, significant effort in next generation infrastructure management with SDN/NFV network orchestration software needs to be developed by the IT industry. As IT customers are reluctant to rely on proprietary solutions by vendor specific implementations, open source based SW with usage of open IT industry standard APIs are becoming the most popular approaches to incubate software definable IT solutions in the data center. Especially OpenStack has become the most frequently used SW stack to provide enterprises and service providers a way to manage their cloud resources. Network and storage resources (southbound) and applications (northbound) within private and public cloud installations can often be managed holistically from such cloud management platforms. Even if the IT indus-

try has made significant progress regarding network management support in cloud management platforms, most operators feel that network management solutions for cloud deployments are still in immature state. Cloud management is today usually supported from different viewpoint levels, coexistive management SW stacks with standardized interfaces are required. Below the level of emerging holistic cloud orchestration approaches, automation solutions based on advanced scripting systems are frequently used to accelerate function deliveries (service updates, policy changes, etc.) in the software defined Data Centre.

4.3.3 IT Infrastructure Management Standards

The Distributed Management Task Force (DMTF) Consortium, formed in 1992 not at least by key IT Industry players, has taken leadership in driving Software Defined Data Center (SDDC) incubation technologies by fostering the definition of open IT management interface models and standards. Beyond main IT industry players, the DMTF is working with lots of Academic and Standardization Body Alliance Partners from all over the world to standardize cloud infrastructure and cloud service management interfaces. Driven by the need to bring down operational costs in the data center, Cloud and other service providers are pushing with DMTF the development of technologies which can make IT systems in data centers highly reconfigurable, scalable and software definable. DMTF URL: http://www.dmtf.org

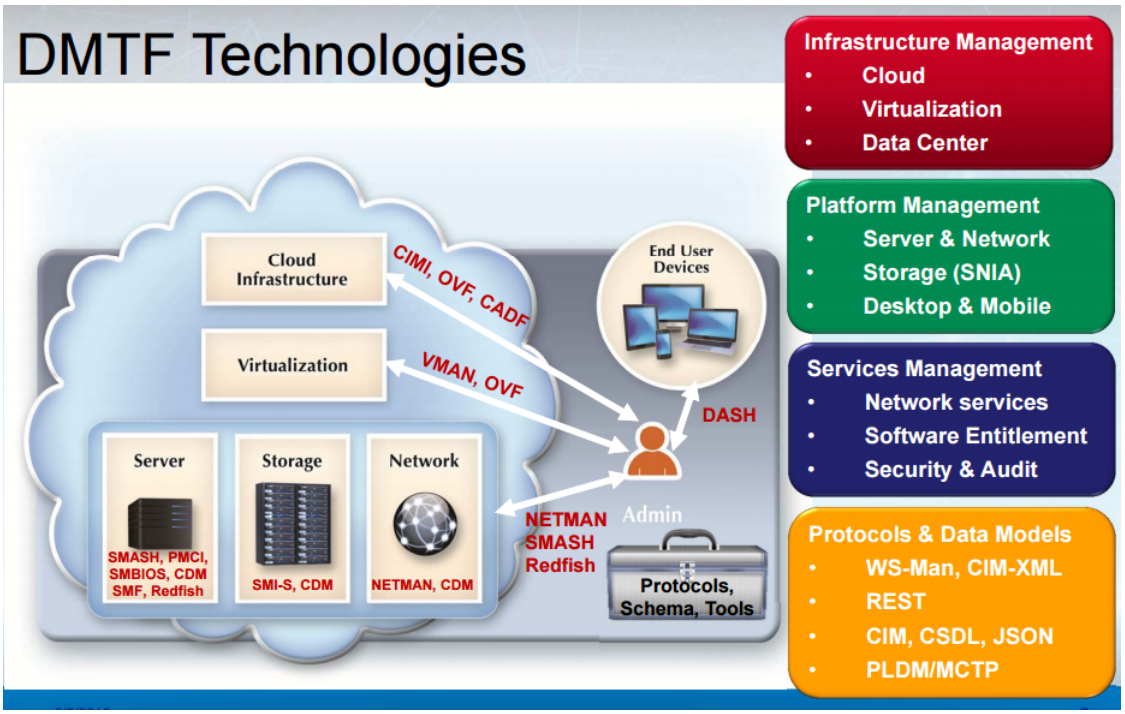

Figure 4.4: DMTF Technology Overview for the Software Defined Data Center

4.3.4 Scalable IT System Platforms

This year the Scalable Platform Management Forum (SPMF) group within the DMTF has released their so called *"Redfish"* interface spec. *"Redfish"* is designed to meet the expectations of end users for simple, modern and secure management of scalable platform hardware. *"Redfish"* specifies an open industry RESTful interface utilizing JSON and OData to help customers to integrate solutions within existing management tool chains in the data centre. DMTF groups are

fostering REST, HTTP and JSON language support based on the fact that systems management applications should use the same skill sets and tool chains than other IT and dev/ops tasks. V1.0 of *"Redfish"* includes for now IPMI level server management functionality. Discovery, observability, event notification capability and control of IT system's with IO infrastructure are supported. The DMTF/SPMF working group intends to evolve *"Redfish"* towards support of a software driven compose of IT system infrastructures from disaggregated Compute, Storage and Networking resource pools in future.

On top of *"Redfish"*, DMTF is continuing the development of its RESTful HTTP-based Cloud Infrastructure Management Interface (CIMI) with essential contributions from the System Virtualization, Partitioning, and Clustering (SVPC) and the Network Services Management (NSM) working groups. CIMI is a self-service interface for software definable cloud infrastructures, allowing cloud users to dynamically provision, configure and administer their cloud resource needs, using a high level interface that abstracts much of the complexity of system management. The NFV and the OpenStack communities are contributing to the CIMI work towards creating not at least a common network management model for cloud infrastructures. DMTF CIMI URL: http://www.dmtf.org/sites/default/files/TechNoteCIMIv6_comments_10.31.12.pdf

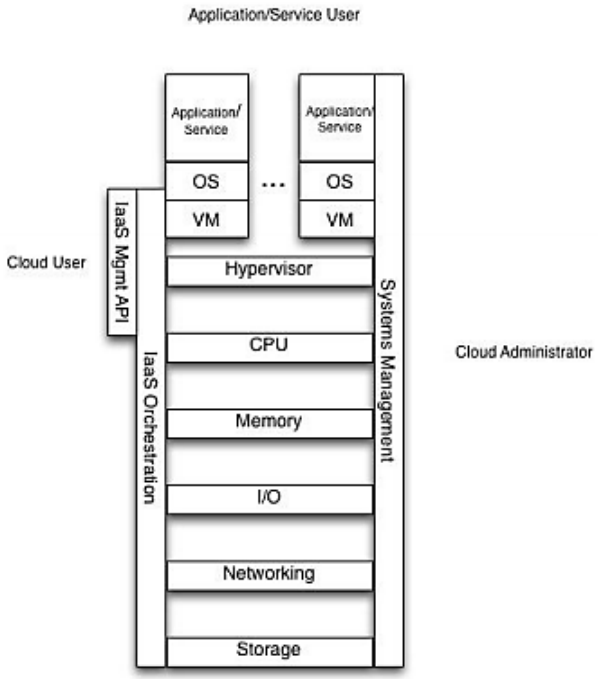

Figure 4.5: Overview - Cloud Infrastructure Management Interface (CIMI)

The NSM working group within the DMTF is driving the NETMAN initiative which intends to facilitate interoperable management across multiple network environments

- Physical, Virtual and Hybrid; including support for the ETSI NFV requirements
- enabling creation of a common management infrastructure for network resources and services across technology domains and management viewpoints
- delivering effective management of the network environment within the Software Defined Data Center (SDDC)

The European Telcomunication Standardization Institute (ETSI) is now in the 2nd Phase of defining standard Network Functions using some of the above mentioned DMTF standards for the underlying Cloud infrastructure management.

4.3.5 Cloud Management Platforms

Most Cloud Management Platforms available today are designed to manage a single cloud while some can manage multi-cloud deployments. OpenStack is the most common platform. It can be deployed to run on a few IT systems or on large resource pools in the data center. OpenStack uses template languages (Heat and TOSCA) for fast deployment and simple integration with a variety of legacy and third party technologies. Beyond OpenStack there are various other software offerings for cloud infrastructure management in the Data Centre. The table below shows some of the many vendor offerings with their different target markets with some example features. We will see a growing number of feature sets supported by cloud management platforms. Most vendors are currently investing heavily to extend the number of manageable resource types, to improve workload placement capabilities, to improve serviceability and to optimize cloud operational performance and costs. Cloud Management Platforms URL's:
http://www.gartner.com/, https://www.sdxcentral.com

	Vendor Offerings	Feature Examples
Public Cloud Management Platforms	- Google / Compute Cloud - Amazon Webservices - Microsoft, Azure - VMware, EMC / Hybrid Cloud	- Bare Metal resource management - Compute/Network/Storage resources - Handling of different/multiple OS'es, Hypervisors and Containers, - RESTful API's for external integration, - Customizable Built-In Service capabilities, - Notification and Exception handling, - Authentication/Role/Security support, - Different Metering capabilities, - Management of Multi Clouds, - Multi cloud location management, - Scaling over Private and Public Clouds, - High Availability of the Mgmnt. Platform, - Automatic Scaling, - Quality of Service Control/Provisioning, - Management of up to NFV SW stacks (HP)
Private Cloud Management Platforms	- OpenStack based offerings from: HP, Mirantis, Fujitsu, Suse, Huawei, Ubuntu, … - VMware, EMC / vCloud - Citrix / Cloudstack - Cisco / UCS Director - Dell / Cloud Manager - Oracle / Cloud Infrastructure - IBM / Cloud Orchestrator - Egenera / Cloud Suite - Rackspace /Cloud Orchestration	
Automation and Lifecycle Management	- Citrix / Lifecycle Management - Citrix / NetScaler - Dell /Active Fabric Manager - Juniper / Contrail - CA / Automations Suits - Puppet Enterprise - Chef	

Figure 4.6: Cloud Management Platforms and Features

Most Cloud Infrastructure Management software like OpenStack with its many commercial product implementations, is based on Open Source Software packages like OpenDaylight (ODL). ODL is increasingly used by Cloud management platforms for network management because ODL can e.g. manage network flows for OpenStack compute nodes via the Open vSwitch Database Management Protocol (OVSDB) south-bound plug-in. The relevance of ODL for future network management of software definable infrastructures is growing with the number of northbound and southbound APIs it supports. This is well recognized by the Industry and the reason why most of the important Industry players working on software definable infrastructures like Cisco, Red Hat, Citrix, HP,

Brocade, Dell, Ericson, Fujitsu, NEC and Intel are extensively supporting the ODL development team up to leadership level.

NetIDE provides a fully integrated environment in which ODL network applications can be executed under development and/or production conditions. The NetIDE framework thus has the potential to become a beneficial tool for cloud management platform developers and operators. NetIDE's capability to easily create a network simulation environment and the monitoring/debugging tool capabilities provided by the ODL Shimlayer will enable network management software developers and Cloud infrastructure operators to improve their development efficiency.

4.4 Service Function Chaining - how SDN complements NFV

While SDN concentrates on abstracting data path networking functionality into software, Network Function Virtualization (NFV) concentrates on the deployment of network functionality in data centers as services implemented in software.
Today's communication networks typically consist of a number of HW appliances such asAccess Control, Firewall, Load Balancer, Deep Packet Inspection and Intrusion Detection systems, all connected in a dedicated, fixed manner. The goal of NFV (as mainly driven by the ETSI NFV ISG) is not only to substitute these expensive HW appliances with Commodity Off the Shelf HW (COTS) and virtual Network Functions (vNF) but, if feasible to divide these Network Functions into smaller pieces, so-called virtual Network Function Components (vNFC) in order to gain maximum flexibility to combine them individually as needed to provide network services specific to certain applications or traffic types.
This new, NFV specific, action of combining vNFC or lower level vNF is a special kind of orchestration called Service Function Chaining (SFC) as it provides the ability to define a series or ordered list of Service Functions (vNF or vNFC, e.g. Firewall >Load Balancer >Intrusion Detection).

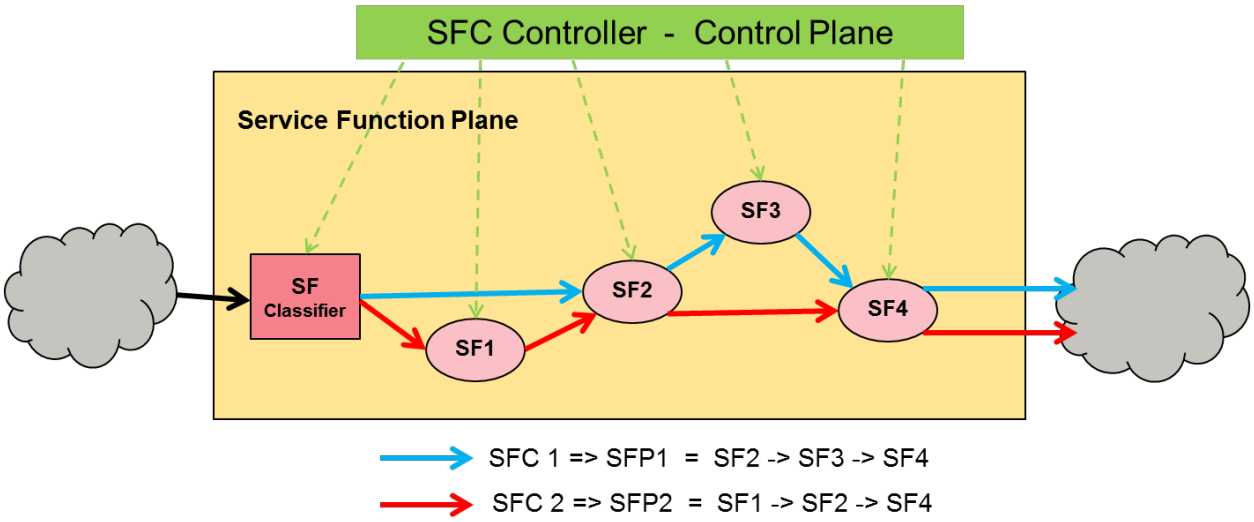

Figure 4.7: SFC Control Plane

A Service Function Chain (SFC) defines the set of individual Service Functions (typically vNFs) and the order in which they have to be traversed by the packets and/or frames and/or flows. The implied order may not be a linear progression as the architecture allows for SFCs that copy to more than one branch, and allows for cases where there is flexibility in the order in which service

functions need to be applied. Of course in principal the Service Functions do not have to be virtualized functions, the concept works with physical Network Functions (pNF) as well and any combination of them, but any physical functions will restrict the flexibility and scalability.
The Service Function Path (SFP) is the actual forwarding path used to realize the service chain. This forwarding path is basically defined by the Network Service Header (NSH) which is created by the Service Function Classifier. The classifier is located at the ingress of the Service Function Plane and classifies any incoming packets according to the policies defined by the control plane. To define the forwarding within a specific SFP the NSH is added to the incoming packets. The Network Service Header (NSH) is a transport agnostic fixed size header which works on VXLAN, NVGRE, MPLS, etc.. The NSH consists of the Service Function Path Identification, the Service Index and optional metadata. While the SFP Id is the unique identification of each SFP, the Service Index defines the actual sequence in which the Service Functions are to be traversed. The first SF always gets the highest number, the last SF in a SF Path per definition gets the lowest number 0. The metadata section of the NSH may transport relevant data (any results) from one SF to the next. On the Forwarding Plane the Service Function Forwarder (SFF) is forwarding the packets to one or more connected service functions according to information contained in the NSH.

4.4.1 IETF SFC Working Group

The Service Function Chaining Working Group within the IETF is working on defining the Problem Space and on a description of the SFC architectural building blocks and their relationships including interconnection, placement of SFC specific capabilities, management, diagnostics, design analysis, and security models, as well as requirements on the protocol mechanisms.
Another topic is defining a generic encapsulation format of the Network Service Header, which has to be agnostic to the layer at which it is applied and the service that is being constructed.
Finally an important focal point is the SFC control and management plane. The intention is to describe requirements for conveying information between control or management elements and SFC implementation points. Any protocol extension work resulting from these requirements will be carried out in coordination in the working group responsible for the protocol being modified. In 2015 the WG already published the first two RFC documents:

RFC 7498: Problem Statement for Service Function Chaining
RFC 7665: Service Function Chaining (SFC) Architecture

Further information about the IETF SFC Working Group may be found at:
IETF URL: https://datatracker.ietf.org/wg/sfc

4.4.2 Open Daylight - SFC

Service Function Chaining is a classical application in the SDN domain. As the controller has a consistent view of the entire network it is easy to provide mechanisms to define, configure and reconfigure Service Chains.

The work of the ODL SFC project is based on the SFC work in the IETF SFC Working Group.
ODL is going to develop the Service Chaining Application which will use the RESTCONF API of the actual Service Chaining Service. The user-facing service chaining application will allow users to define both the Service Chain and the Service Path. The definition – chain or path – is sent via REST API to the ODL Service Chaining Service. The ODL service will in turn:

- Create service paths given a list of service types (i.e. the service chaining app will request

a chain):The service chaining service will dynamically select the specific service instances required to satisfy the service chain requirements

- Create service paths given a list of service instances (i.e. the service chaining app will request a path explicitly): The service chaining service will receive a static list of service instances and will establish the necessary service path through those service instances
- The service chaining service will return a list of all active service paths
- The service chaining service will return the details for a specified path
- The service chaining service will return the details for a specified path
- Define/update (optional) metadata for delivery along service chain

Additionally to the Service Chaining Application and - Service there is a project working on the integration between Group Based Policy and Service Function Chaining. For further information on ODL SFC visit: URL: https://wiki.opendaylight.org/view/Service_Function_Chaining:Main

In particular the Open Daylight activities around SFC underline the potential benefits of realizing the SFC management through SDN. The SFC control plane requires a domain-wide view (controller) of all available service function resources in oder to construct service chains and to control the forwarding between the various service functions.

Service Function Chaining is a good example of a higher level abstraction being built on top of SDN's underlying model of a software controller mediating between the control and data planes of the network. NetIDE focuses today on supporting the controller level of the SDN stack. However, NetIDE has the potential to be further developed into a toolset which directly supports SFC or to be used as a component of a future SFC toolset.

4.5 Update to Cost Benefit Analysis

The deliverable D6.3 had a basis for generating a cost benefit analysis of NetIDE. During the second year of the project, WP5 had the opportunity to test NetIDE and compare it to State of the Art techniques. This work was a positive step in defining a global cost analysis, although based on a small number of data points. But it provide a good approximation of the benefits of using NetIDE in a production environment.

One of the identified **Drivers** of the adoption of SDN was to propose *Rapid Application Deployment*. It has been confirmed that NetIDE does allow for the quicker development, as demonstrated with Use Case 3 in D5.3 [31]. In this deliverable, the speed of developing an existing Floodlight application on an OpenDaylight platform was compared to porting it with NetIDE. A net gain of greater than 50% in development time was obtained on this example. This also had an effect on another NetIDE driver that is the *Reduction of CAPEX*. Time and effort gains are directly reverberated in cost reduction as a developer time is the main [marker] in a financial point of view. A third identified driver was the advances in *Network Virtualization*. By reusing building blocks easily with NetIDE Use Case 1 show that the adoption of virtualization techniques can be ubiquitous.

Another identified aspect in D6.3 was the **Barriers** of adopting SDN. One of the biggest challenges was reduce the *Interruption of Critical Network Operation* for testing new applications. NetIDE provides an environment capable of emulating network and test applications in an integrated manner. Another point was the lack of *Compelling Use Cases* in SDN. We believe that the

three WP5 Use Cases clearly show typical problems in today's industry and that NetIDE can solve them. Lastly the *Complexity of Deploying* SDN solution and the lack of interoperability is often mentioned. NetIDE provides an IDE and tools to ease the deployment of SDN applications and one of the core value it provides is to operate on multiple SDN platforms at the same time.

After looking at the Drivers and Barriers to SDN adoption, the consortium made claims in D6.3 (and other material from the project) about the capabilities of NetIDE. Some of them were tested and documented in WP5's D5.3 [31]:

- Improving the Time to Market: rapid application porting was confirmed in Use Case 3. This means that a company can produce results in a shorter time by lowering the time spent on developing the application.
- Choice of development platform so as to avoid vendor lock-in: NetIDE proposes a variety of shims and backend on popular SDN platforms. NetIDE is easily extendable and thanks to the abstractions done in the Core, developing a new shim or backend for a new controller platform is easy.
- Cost of adaptation to new tools: NetIDE allow to rapidly test and deploy Network Applications and doesn't necessitate a lot of pre-requisite.
- Cost of runtime choice: The NetIDE Core uses a portable technology base on OSGi. This means that development can be platform agnostic[1]
- Comparison of efficiency (control group testing): NetIDE had the ambition of doing a lot of control group testing with developers using State of the Art method while other would use NetIDE. This was done with a low number of developers (see D5.3 UC3) and confirmed the benefits of NetIDE. We hope to reproduce this test with a larger sample size.

Quantifying these benefits and cost savings requires control group testing with large numbers. While WP5 provided initial results for this, only minimal groups sizes were used to generate the initial indicators for the project's 3 primary use-cases, ie, Vendor Agnostic Datacentre, Integrated IT System, and Hybrid Environment Application Development. When in fact multiple groups with large numbers in each would actually be required to be statistically valid. These measurements would be required for each of the identified phases of the application cycle: Development, Test and Deployment. Running such large experiments is outside of the scope of this research project.

[1]The NetIDE Core has been successfully tested on Windows as well as Linux. It should also work seamlessly on Mac.

5 Conclusion

During the 2nd project year, WP6 has been responsible for ensuring the projects research, innovation and demonstration activities were disseminated as publicly as possible as per the plans we set out in D63. We are constantly monitoring which portals are providing the best value and making decisions appropriately. Our web presence sees the project visible on 4 separate portals sharing code, releases, videos, event information and demonstrations. Our project website is continuously updated with latest news from the project, presentations, and deliverables. An improved layout for the website was implemented this year to ensure readers had a better experience reviewing the project updates and results (ie, News). We removed our LinkedIn NetIDE portal due to limited activity, instead focusing our attention on Twitter and a new presence on YouTube. We have seen an increase in followers this year as a direct result of an improved policy of networking with key Twitter accounts and tweeting regular updates, as opposed to the sporadic updates of the first project year. Our YouTube presence has allowed us to increase visibility through posting demonstration videos on the operation of the Network Engine and the Developer Toolkit.

The project has had a successful year presenting its research results at over 12 different conferences and events, with new papers already submitted for events occurring in 2016. A number of key conferences have been identified with the relevant call for paper dates captured to ensure that we have sufficient time to submit our proposals. The project has created 2 opensource releases during 2015, with further releases planned for the final year of the project. These are available for download from our source code repositories on Github.com. These included all code and supporting documentation.

The exploitation plans of each partner are now beginning to mature as partners see where the value lies and where they can exploit the project's results. There has also been a number of successful project level exploitation activities occur. NetIDE became an active project of OpenDaylight with its Network Engine accepted as a new feature. The ODL-Shim component (of the NetIDE Network Engine) is currently on track to be released in the OpenDaylight Beryllium release due Feb 2016. The plugins created in WP3 for the Eclipse IDE were accepted as a new project on the Eclipse Marketplace allowing users to download our NetIDE Developer Toolkit to aid in SDN Application design and deployment. Revised versions including advanced features are due to be completed in the final project year. We have received invaluable feedback from our Industrial Advisory Board which was setup this year. During the 2 meetings we hosted, the IAB assessed the project's progress advising the consortium on new directions and opportunities for innovation in order to ensure the relevance of the project's results to the needs of the consumer and also external international bodies.

We performed an update to our market analysis by reviewing the latest market analysis reports to see what changes exist with a view to ensuring relevancy for the NetIDE results. The majority of reports reviewed focused on SDN for service provider networks, Data Center, Enterprise and Software. It showed that the revenue from SDN network applications is set to grow to an estimated $1B by 2019 indicating that there appears to be more value in SDN applications than in orchestration and control. This is an important indicator as NetIDE is providing an interoperability layer for different SDN controllers. We also reported on the latest drivers and barriers to SDN adoption. Finally, we reported on one of the key drivers of SDN, the Software Defined Infrastructure paradigm within the Data Centre. A Key Performance Indicator for this being Service velocity describing the speed by which services can be configured, deployed, modified and retired of which SDN is a

core component.

The project has now setup all the required features to be successful going into its final project year. The output of each feature will be documented in the final year deliverables, including open source releases, demonstration video's, exploitation opportunities and conference presentations.

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