Message from the General Chair

On behalf of the organizing committee, I am delighted to welcome you from 30 September to 2 October, 2015, to the Fourth European Workshop on Software Defined Networks in the Bizkaia Aretoa of the University of the Basque Country (UPV/EHU) in Bilbao, Spain.

Since the previous edition of EWSDN, software defined networking has been continuously losing its “experimental” and “not-ready-for-deployment” labels and is now part of the underlying fabric of many advanced ICT solutions, like network function virtualization or service function chaining that are being tested and deployed. This last year we have seen a complete SDN ecosystem that covers all steps from the design phase to commercialization of SDN-based solutions, new releases of several controllers, new open-source software that covers other related areas like OpenMANO and OPNFV, and even a Kickstarter project for the smallest OpenFlow capable switch!

This workshop must also keep up with this constant evolution. Last year we introduced a Demos and Posters session and we are pleased to say that after last year’s success, we are expanding in this direction in EWSDN 2015. In addition, the program this year will feature a tutorial presenting the results of the EU–Japan FELIX project as well as the outreach activities of the two technical partner projects UNIFY and FELIX.

This year we introduce the EWSDN Hands-On / Hackathon. Our intention is to present new and relevant open-source software to SDN practitioners and researchers, giving them the opportunity to speak directly with developers and offering the possibility of getting familiar with it by developing an application or even tweaking the code itself. This year ONLab agreed to lead the event and help attendees to understand, learn, and work with ONOS.

Finally, we hope that the mix of papers, posters, demos, keynotes, and industry panel will cover your expectations and be the foundation for fruitful conversations.

Eduardo Jacob, University of the Basque Country
EWSDN 2015 General Chair

Message from the TPC and Demo Chairs

It is our pleasure to chair the Technical Program Committee and the Demos for the fourth edition of EWSDN.

The European Workshop on Software Defined Networks appears to be in a transitional period. From a unique, trend-setting event, we are witnessing an exponential proliferation of SDN-related conferences, with multiple profiles and ambitions. The challenges EWSDN faces to retain its unique flavor have thus increased.

We are happy to see that our community has risen to the challenge, as this year’s program, which includes a diverse and comprehensive set of papers, posters, and demos, testifies. The prevalence of real demos in EWSDN is a distinct differentiating factor, as is the single-track, discussion-oriented nature of the program. EWSDN features 17 full-paper oral presentations, lightning talks introducing 6 short papers presented as posters, and 7 demonstrations, covering a range of topics from wireless to testing, and crossing the popular topics of service chaining and performance evaluation. We are sure they will trigger interesting discussions between all participants. It is of particular pleasure for us to see that, rising from its European-funded origin, the demonstrations today cover projects coming from different backgrounds.

It is also encouraging for the unique flavor of EWSDN that all contributions, including posters and demos, had an acceptance ratio lower than 50%, showing the widespread support for this event. EWSDN is also complemented by tutorials from FELIX and UNIFY and the first ONOS Hackathon. We hope these events contribute to your enjoyment of the event.

The community interaction ambitions of EWSDN are supported by an interesting social program that the local hosts have organized for us. Use this social program as another opportunity to have a more relaxed approach to discuss the future of SDN, NFV, and softwarized networking while enjoying the renowned Basque hospitality.

A final word to our TPC members, who provided invaluable service to the community by reviewing all contributions. Each paper and demo received at least three peer reviews. The event could not take place without the effort of all these volunteers. And, of course, a word of thanks to all contributing authors: your work is the reason for this gathering, and we hope your expectations are fulfilled during these intense days.

Enjoy EWSDN 2015!

Rui Aguiar, Universidade de Aveiro
Eiji Kawai, NICT
EWSDN 2015 Technical Program Committee Co-Chairs

Jon Matias, University of the Basque Country
EWSDN 2015 Demo and Exhibition Chair
Wednesday, 30 September 2015

09:00 Tutorial 1: Federated Facilities for Large-Scale SDN Experiments
11:00 Break
11:30 Tutorial 2: UNIFYing Cloud and Carrier Network Resources: Architecture, Orchestration and Service Provider DevOPs
13:30 Lunch break
14:45 Industrial Patron Introduction
15:00 Keynote by Silvia Almagia and Diego Lopez
16:00 Technical Session 1: Wireless and Testing
17:00 Coffee break
17:30 Technical Session 2: Network and Service Chaining
19:00 End of day 1

Thursday, 1 October 2015

09:00 Keynote by Curt Beckmann
10:00 Technical Session 3: SDN at the Data Center
11:30 Coffee break
12:00 Technical Session 4: Complexity in SDN
13:30 Lunch break
15:00 Panel moderated by Stefano Salsano
16:00 Short Papers and Demos Lightning Talks
17:00 Coffee break
17:30 Posters and Demos Session
19:00 End of day 2

Friday, 2 October 2015

09:00 Keynote by Luc Provoost
10:00 Technical Session 5: Performance Evaluation
11:30 Coffee break
12:00 Technical Session 6: Resource Management and Traffic Engineering
13:30 Lunch break
15:00 Closing Session
16:00 End of day 3

The Fringe of ETSI ISG NFV: Leveraging Proofs of Concepts (PoCs) and Reconciling SDN and NFV

ETSI ISG NFV is currently focusing on building normative specifications around the concepts that shaped the Architectural Framework that has become the core of what is currently known as Network Function Virtualization. But beyond this focus, the ISG keeps looking at the consolidation of those concepts and the practical approach that made the high impact of the original NFV idea. This talk will illustrate two main aspects of these activities, describing how the NFV PoC framework is evolving, and the exploration of the relationship(s) between SDN and NFV.

Silvia Almagia
ETSI

Silvia Almagia is a Technical Expert in ETSI’s Center for Testing and Interoperability since 2012. Her current activities include providing testing expertise, technical management of interoperability events and coordination of Proof of Concept (PoC) programmes in the areas of access, core and virtualised networks. Among others, Silvia is responsible for the Small Cell LTE Plugfest series and actively supporting ETSI Industry Specification Groups for Network Function Virtualisation (ISG NFV) and Mobile Edge Computing (ISG MEC).

Diego R. Lopez
Telefónica I+D
ETSI Technical Steering Committee

Dr. Diego R. Lopez is a Senior Technology Expert on network middleware and services within the GCTO Unit of Telefónica I+D. Diego is currently focused on identifying and evaluating new opportunities in technologies applicable to network infrastructures, and the coordination of national and international collaboration activities. Diego is actively participating in the ETSI ISG on Network Function Virtualization (chairing its Technical Steering Committee), the ONF, and the IETF WGs connected to these activities, acting as co-chair of the NFVRG within the IRTF.
The SDN movement is based on abstracting the data plane to allow device-independent control. The 1.0 version of OpenFlow provided a basis for decoupling in simple situations. But establishing a common interoperable interface for device abstraction has proven more difficult for complex networking using the simple OpenFlow framework. A new richer model-driven framework that describes forwarding behavior in OpenFlow terms promises to bring practical device independence to complex networking. This talk will describe the framework, some challenges, and recent progress at the ONF and in OpenDaylight.

Model-driven Mechanisms for OpenFlow Device Interoperability

Curt Beckmann
Brocade
ONF Open Datapath Working Group Chair

Curt Beckmann is the chair of the ONF Open Datapath Working Group, and is a member of the ONF’s Chipmakers’ Advisory Board (CAB). Mr Beckmann also leads the Table Type Patterns project for the OpenDaylight SDN Controller. He keeps close tabs on the OPNFV project, particularly as it relates to OpenDaylight and MANO. Since being named Brocade’s Chief Technology Architect for EMEA, Mr Beckmann is now based in Paris.

Luc Provoost
Intel

Luc Provoost graduated in 1989 from the Catholic University of Leuven as an engineer in electro-mechanics. He entered the Telecommunications industry more than 20 years ago, by joining Alcatel Bell for developing SW for Public switching networks. Luc joined Dialogic Telecom Europe in August 1998 (acquired by Intel in 1999) as a Technical Consultant and later as engineering manager developing computer telephony and SS7 SW. In 2005, Luc headed the Intel Modular communications Solutions Lab in Belgium, focusing on the introduction of ATCA platforms and IMS. The team was involved in the IMS ETSI benchmarking effort and the implementation of this benchmark (IMS Bench SIPP). The solutions lab extended the expertise of performance characterization on IA HW in the fields of embedded graphics, Fast Packet Handling and Virtualization (Network Function Virtualization). Today, the main focus of the lab is on demonstrating NFV, SDN on Intel technologies & platforms.

Performance Evaluation of NFVI Dataplane: A Practical Approach

With NFV, a large number of potential NFV infrastructure solutions are being proposed. Different sets of HW and SW solutions stacks are helping NFV to mature and to formulate answers to the many requirements of modern networks. In selecting VNF infrastructure solutions, one of the key aspects is dataplane performance of such an NFV infrastructure. In this talk, we are proposing a practical approach on how dataplane performance of an NFV infrastructure can be characterized: a well-defined set of use cases together with a set of open source tools (available on 01.org) to automatically generate reports. These reports can then be used to perform apples-to-apples comparisons of different NFV infrastructures.
5G, as the next generation telecommunications architecture that aims to tackle the explosion of connected devices, services and access technologies, will heavily rely on Software Defined Mechanisms (SDN) to compose its underlying mechanisms. Notwithstanding, despite the need for novel control procedures to support and optimize increasingly challenging wireless mobile scenarios, SDN has been deployed at the core and backhaul sections of the network and is not actively considering its impact directly over the wireless mobile terminals themselves. The challenges associated with the extension of SDN protocols, such as OpenFlow, all the way to the terminal requires the design and evaluation of frameworks that not only provide such mechanisms, but actually evaluate them and their benefits. This paper explores a framework where SDN mechanisms are extended all the way to the mobile node, in heterogeneous wireless environments featuring different mobile nodes with multiple data flows, which act both as consumers and producers of information. In this way, flow-based mobility management becomes available to the network controller entity, through the OpenFlow protocol, allowing as well the assistance of the mobile nodes in the execution of the mobility procedure. The concept framework was implemented over a physical wireless testbed, validating its contribution in a mobile source-mobility use case, with results highlighting the promising benefits of extending SDN approaches for end-to-end flow control in wireless environments.

Implementation of the FELIX SDN Experimental Facility

Umar Toseef, Carolina Fernández, Carlos Bermudo, Gino Carrozzo, Roberto Monno, Bartosz Belter, Krzysztof Dombek, Łukasz Ogrodowczyk, Tomohiro Kudoh, Atsuko Takefusa, Jason Haga, Takatoshi Ikeda, Jin Tanaka, and Kostas Pentikousis

The development of test environments as close as possible to the real world scenarios is becoming a fundamental requirement in designing innovative network applications. This environment must be fully configurable and reliable enough to provide similar results in multiple experiment runs. The federation of existing Future Internet (FI) testbeds is an initiative to fulfill these strict requirements. The FELIX project aims to define, implement, and deploy a control and monitoring framework which allows experimenters to execute their network services in a distributed environment spread across two continents, i.e. Europe and Asia. This paper describes the architecture of the software components developed to manage heterogeneous resources that constitute the FELIX infrastructure, i.e computing, SDN and transport resources. This article introduces the components of a modular architecture with particular emphasis on the provided functionalities, the exported interfaces, the dependencies and the relationship between the internal building blocks. Details of the implementation choices and the workflows to realize user requests are also presented.
HybridTE: Traffic Engineering for Very Low-Cost Software-Defined Data-Center Networks
Philip Wette and Holger Karl

The size of modern data centers is constantly increasing. As it is not economic to interconnect all machines in the data center using a full-bisection-bandwidth network, techniques have to be developed to increase the efficiency of data-center networks. The Software-Defined Network paradigm opened the door for centralized traffic engineering (TE) in such environments. Up to now, there were already a number of TE proposals for SDN-controlled data centers that all work very well. However, these techniques either use a high amount of flow table entries or a high flow installation rate that overwhelsm available switching hardware, or they require custom or very expensive end-of-line equipment to be usable in practice. We present HybridTE, a TE technique that uses (uncertain) information about large flows. Using this extra information, our technique has very low hardware requirements while maintaining better performance than existing TE techniques. This enables us to build very low-cost, high-performance data-center networks.

SynRace: Decentralized Load-Adaptive Multi-path Routing without Collecting Statistics
Arne Schwabe and Holger Karl

Multi-rooted trees are becoming the norm for modern data-center networks. In these networks, scalable flow routing is challenging owing to vast number of flows. Current approaches either employ a central controller that can have scalability issues or a scalable decentralized algorithm only considering local information. In this paper we present a new decentralized approach to least-congested path routing in software-defined data center networks that has neither of these issues: By duplicating the initial (or SYN) packet of a flow and estimating the data rate of multiple flows in parallel, we exploit TCP's habit to fill buffers to find the least congested path. We show that our algorithm significantly improves flow completion time without the need for a central controller or specialized hardware.

High-Performance vNIC Framework for Hypervisor-Based NFV with Userspace vSwitch
Yoshihiro Nakajima, Hitoshi Masutani, and Hirokazu Takahashi

We propose a high-performance virtual network interface card framework for hypervisor-based NFV with userspace virtual switch. We extend the virtio-net framework to achieve high-performance I/O and to provide DPDK-compatible APIs for a DPDK-enabled NFV app on a guest hypervisor-based VM with DPDK-enabled userspace vSwitch. The framework provides a device status tracking mechanism between DPDK-enabled NFV app and a vSwitch as well as service maintenance support such as reboot and restart of a guest VM or in a vSwitch in order to increase flexibility and agility in a carrier network operation for NFV. The vNIC achieved over-120-Gbps throughput and over-14.2-MPPS I/O processing.

Towards Semantic Network Models via Graph Databases for SDN Applications
Talita de Paula Cypriano de Souza, Christian Esteve Rothenberg, Mateus Augusto Silva Santos, and Luciano Bernardes de Paula

At the core of any network control and management system is the representation and maintenance of network topology information. Software-Defined Networking (SDN) treats topology abstractions as one of the cornerstones towards rethinking network architectures and the way they are operated. Recently, motivated by the scalability and performance needs of cloud applications, Graph Databases are being adopted as appealing alternatives to traditional relational models when data is highly interconnected and extensible schemas are called for. In addition, the use of metadata to describe how data is interconnected by means of Web Semantic standards is increasingly gaining ground. At the crossroads of these trends, this paper presents an approach to augment SDN network state with a semantic model leveraging graph database technologies. In particular, our proposal imports the Network Markup Language (NML) model into a scalable graph database (Neo4j). For validation purposes, we evaluate our proof of concept implementation against a representative set of SDN application primitives.

SYMPHONY - A Controller Architecture for Hybrid Software Defined Networks
Vijaya Durga Chemalamarri, Priyadarsi Nanda, and Karla Felix Navarro

As enterprises migrate to SDN, a brownfield network transitional state is inevitable, where both Software Defined and Legacy networks coexist. The aim of this work is to further the knowledge in the area of Hybrid Software Defined Network (SDN) networks, by investigating requirements and challenges involved in building such networks. This work proposes a Hybrid SDN controller architecture to establish, control and interdomain communication between the legacy and SDN domains.

Scalable Software Defined Monitoring for Service Provider DevOps
Wolfgang John, Catalin Meirosu, Bertrand Pechenot, Pontus Sköldström, Per Kreuger, and Rebecca Steinert

Technology trends such as Cloud, SDN, and NFV are transforming the telecommunications business, promising higher service flexibility and faster deployment times. They also allow for increased programmability of the infrastructure layers. We propose to split selected monitoring control functionality onto node-local control planes, thereby taking advantage of processing capabilities on programmable nodes. Our software defined monitoring approach provides telecom operators with a way to handle the tradeoff between high-granular monitoring information versus network and computation loads at central control and management layers. To illustrate the concept, a link rate monitoring function is implemented using node-local control plane components. Furthermore, we introduce a messaging bus for simple and flexible communication between monitoring function components as well as control and management systems. We investigate scalability gains with a numerical analysis, demonstrating that our approach would generate thousands of less monitoring traffic while providing similar information granularity as a naïve SNMP implementation or an OpenFlow approach.
Cross-Platform Estimation of Network Function Performance
Amedeo Sapio, Mario Baldi, and Gergely Pongrácz

This work shows how the performance of a network function can be estimated with an error margin that is small enough to properly support orchestration of network functions virtualization (NFV) platforms. Being able to estimate the performance of a virtualized network function (VNF) on execution hardware of various types enables its optimal placement, while efficiently utilizing available resources. Network functions are modeled using a methodology focused on the identification of recurring execution patterns and aimed at providing a platform independent representation. By mapping the model on specific hardware, the performance of the network function can be estimated in terms of maximum throughput that the network function can achieve on the specific execution platform. The approach is such that once the basic modeling building blocks have been mapped, the estimate can be computed automatically. This work presents the model of an Ethernet switch and evaluates its accuracy by comparing the performance estimation it provides with experimental results.

VBAaS: VNF Benchmark-as-a-Service
Raphael Vicente Rosa, Christian Esteve Rothenberg, and Róbert Szabó

When rolling out Network Function Virtualization (NFV) services, resource monitoring becomes a critical task subject to different cost-accuracy tradeoffs depending on whether continuous monitoring or more static infrastructure resource views are taken. In this context, we propose Virtualized Network Functions (VNF) Benchmark-as-a-Service (VBAaS) to enable not only run-time resource evaluation but also test-before-deploy opportunities for VNFs and NFV Infrastructures. We describe the motivation behind VBAaS and its main value proposition for a number of use cases around the orchestration tasks of VNF Forwarding Graphs. We present the main components of VBAaS along their system interactions and interfaces, discussing the main benefits of adopting VBAaS and open research issues. Addressing the identified challenges and finalizing our proof of concept VBAaS are our main ongoing work activities.

Assessing the Performance of Virtualization Technologies for NFV: A Preliminary Benchmarking
Roberto Bonafiglia, Ivano Cerrato, Francesco Ciaccia, Mario Nemirovsky, and Fulvio Risso

The NFV paradigm transforms those applications executed for decades in dedicated appliances, into software images to be consolidated in standard server. Although NFV is implemented through cloud computing technologies (e.g., virtual machines, virtual switches), the network traffic that such components have to handle in NFV is different than the traffic they process when used in a cloud computing scenario. Thus, this paper provides a (preliminary) benchmarking of the widespread virtualization technologies when used in NFV, which means when they are exploited to run the so called virtual network functions and to chain them in order to create complex services.

Traffic Management Applications for Stateful SDN Data Plane
Carmelo Cascone, Luca Pollini, Davide Santoro, and Antonio Capone

The successful OpenFlow approach to Software Defined Networking (SDN) allows network programmability through a central controller able to orchestrate a set of dumb switches. However, the simple match/action abstraction of OpenFlow switches constrains the evolution of the forwarding rules to be fully managed by the controller. This can be particularly limiting for a number of applications that are affected by the delay of the slow control path, like traffic management applications. Some recent proposals are pushing toward an evolution of the OpenFlow abstraction to enable the evolution of forwarding policies directly in the data plane based on state machines and local events. In this paper, we present two traffic management applications that exploit a stateful data plane and their prototype implementation based on OpenState, an OpenFlow evolution that we recently proposed.

Resource Optimization for Service Chain Monitoring in Software-Defined Networks
Ming Xia, Meral Shirazipour, Heikki Mahkonen, Ravi Manghirmalani, and Attila Takacs

Emerging services enabled by software-defined networking (SDN) and network function virtualization (NFV) are introducing new challenges to network monitoring. One such network service is “service chaining”, where the complexity of the datapath forwarding is coupled with the heterogeneity of service functions. This makes it extremely difficult to monitor and troubleshoot networks with a reasonable resource overhead. We propose a framework that can be applied for service chain monitoring. A monitoring hierarchy is defined, which contains a monitoring intent to monitoring zones and probes for on-demand monitoring. To minimize the cost of probe deployment, we design a heuristic algorithm that conducts dynamic pruning and search. We also identify the possibility for monitoring-rule consolidation when multiple probes are co-located, and introduce the use of Bloom Filters to optimize monitoring resource usage. Our performance evaluation shows reduced probe-deployment cost by our Tree Search algorithm in various settings, and significant memory savings by rule consolidation.

Combined Virtual Mobile Core Network Function Placement and Topology Optimization with Latency Bounds
Andreas Baumgartner, Varun S. Reddy, and Thomas Bauschert

In this paper, a novel mathematical optimization model for virtual mobile core network embeddings with respect to latency bounds is presented. This formulation differs from the classical virtual network embedding (VNE) model as the virtual network topology (i.e., the allocation of e.g. eNodeBs to single core gateways) is not known in advance but subject to optimization. Our formulation can be regarded as network functions/service chaining approach as it relies on the joint embedding of individual core network service chains where a core network service chain denotes the sequence of mobile core virtual network functions (VNFs) a user or control plane traffic flow traverses. Regarding the placement decision of virtual core network functions, we consider upper bounds for the latency caused by processing, packet queueing and propagation. It is assumed that the queueing and processing delay depends on the user/control plane traffic utilization of the node/virtual machine on which the respective VNF is executed and that the propagation delay is proportional to the path length of the respective user/control plane traffic flow. The performance of the proposed optimization model is evaluated for the case of the European example network topology NOBEL-EU as physical substrate network, taken from SNDlib.
The Runos OpenFlow Controller
Alexander Shalimov, Sergey Nizovtsev, Danila Morkovnik, and Ruslan Smeliansky

The Runos is a C++ OpenFlow controller that has been developing since 2014 in order to answer on the well-known question “Could an OpenFlow controller be both easy to develop applications for and also high performance?”. The controller includes the most fruitful techniques from the latest research on simplifying SDN programming such as Pyretic and Maple and combines them in right way to achieve high performance and production quality, programmability, usability. Runos is widely used in different POCs showing interests for third-party developers. The project is in http://arccn.github.io/runos/.

On the Security of Software-Defined Networks
Abhinandan S. Prasad, David Koll, and Xiaoming Fu

To achieve a widespread deployment of Software-Defined Networks (SDNs) these networks need to be secure against internal and external misuse. Yet, currently, compromised end hosts, switches, and controllers can be easily exploited to launch a variety of attacks on the network itself. In this work we discuss several attack scenarios, which—although they have a serious impact on SDN—have not been thoroughly addressed by the research community so far. We evaluate currently existing solutions against these scenarios and formulate the need for more mature defensive means.

Towards a Method for End-to-End SDN App Development
Christian Stritzke, Claudia Priesterjahn, and Pedro A. Aranda Gutiérrez

The ecosystem of software-defined networking (SDN) is still characterized by a multitude of different controller platforms, each with its own programming model, execution model, and capabilities. This creates a danger of a controller lock-in for both developers of SDN control applications and operators of SDN networks. Since no single controller platform appears to dominate the ecosystem for the foreseeable future, there is a need for a method that enables the unification of different controller technologies. This paper describes a preliminary version of the NetIDE method, whose goal is to deliver an integrated process for SDN development that allows developers to write, test and deploy applications independently from the underlying SDN technology.

Concept and Design of SDN-Enhanced MPI Framework
Keichi Takahashi, Dashdavaa Khureltulga, Baatarsuren Munkhdorj, Yoshiyuki Kido, Susumu Date, Hiroaki Yamanaka, Eiji Kawai, and Shinji Shimojo

In general, modern high-performance computing systems are built as cluster systems. We have been investigating the feasibility of optimizing MPI communications by integrating the dynamic network control realized by SDN. In this paper, we present a concept of a generic SDN enhanced MPI framework; an application-aware network control mechanism specifically for MPI applications.

Traffic Engineering with Segment Routing: SDN-Based Architectural Design and Open Source Implementation
Luca Davoli, Luca Veltri, Pier Luigi Ventre, Giuseppe Siracusano, and Stefano Salsano

Traffic Engineering (TE) in IP carrier networks is one of the functions that can benefit from the Software Defined Networking paradigm. However traditional per-flow routing requires a direct interaction between the SDN controller and each node that is involved in the traffic paths. Segment Routing (SR) may simplify the route enforcement delegating all the configuration and per-flow state at the border of the network. In this work we propose an architecture that integrates the SDN paradigm with SR-based TE, for which we have provided an open source reference implementation. We have designed and implemented a simple TE/SR heuristic for flow allocation and we show and discuss experimental results.
This paper describes a new feature of the GEANT Testbeds Service that allows the programmability of external interfaces with DSL based topology descriptions. This feature is now available in version 2.0, but will be even more extended in the next version of GTS with the automatic provisioning of multidomain federated resource pools. The demo will show the users on how to work with testbeds created in GTS and how to be able to develop testbeds that not only connect GTS resources, but also include external domains.

Monitoring Transport and Cloud for Network Functions Virtualization
Farnaz Moradi, Bertrand Pechenot, and Jonas Mårtensson

In this demonstration, we present a monitoring framework for VNFs running inside containers in a cloud system consisting of multiple data centers. We illustrate a use case for the monitoring framework by demonstrating VNF scaling based on monitoring information from both cloud resources and the transport network.

TableVisor: An Emulation Layer for Multi-table Open Flow Switches
Steffen Gebert, Michael Jarschel, Stefan Herrlieben, Thomas Zinner, and Phuoc Tran-Gia

This work demonstrates TableVisor, a proxy layer for the OpenFlow control channel, which emulates a multi-table switch towards the controller. TableVisor uses one single-table switch per emulated flow table and combines all devices with their specific capabilities to a feature-rich pipeline consisting of multiple tables. As the used switches can be chosen by use case specific requirements, even multi-table pipelines can be built that are currently not available in one single device.

DynPaC: A Path Computation Framework for SDN
Alaitz Mendiola, Jasone Astorga, Eduardo Jacob, Marivi Higuero, Aitor Urtasun, and Victor Fuentes

The DynPaC (Dynamic Path Computation) framework has been designed to provide resilient on-demand Layer 2 services with bandwidth constraints in Software-Defined Networks, more specifically in OpenFlow networks. It has been implemented using the OpenDaylight platform as base OpenFlow controller, which has been extended with custom modules that provide resiliency, scheduling, monitoring and network resource optimisation. Thanks to an advanced Path Computation Element, DynPaC is able to take into account the available bandwidth in the network to assign the best possible path, in this case the shortest one, to the requested services. Furthermore, DynPaC supports service reservation, and takes into account already reserved services at the time of computing the paths for new service demands thanks to a powerful and novel scheduling mechanism based on network snapshots. In addition, DynPaC is able to maximise the network resources’ utilisation through a service reallocation and disaggregation mechanism. Of special interest is the flow disaggregation algorithm, which makes use of the OpenFlow’s high granularity to divide the original service into the minimum number of sub-services and reallocate them in the network to free enough network resources to accept new service demands.

A Virtual Service Provider for SOHO Networks
Damien Saucez, Dino Farinacci, Luigi Iannone, and Wassim Haddad

The ability of SOHO networks to connect to the Internet through several Internet service providers, gives high potential to enable rich cloud-based network services for enterprises. Nevertheless, it remains a huge challenge for SOHOs to leverage such multi-homing and cloud networking capabilities. For such a reason, we introduce the vSP concept (virtual Service Provider). The idea of vSP is to hide the technical complexity inherent to multi-homing and allow SOHOs to seamlessly use their cloud resources. The role of the vSP is to orchestrate traffic between the different Internet Services Providers (ISPs) in order to maximize the cloud service performance without requiring any intervention of the SOHO network administrator.

Mantoo - A Set of Management Tools for Controlling SDN Experiments
Stefano Salsano, Pier Luigi Ventre, Francesco Lombardo, Giuseppe Siracusano, Matteo Gerola, Elio Salvadori, Michele Santuari, Mauro Campanella, and Luca Prete

OSHI - Open Source Hybrid IP/SDN networking is a hybrid approach allowing the coexistence of traditional IP routing with SDN based forwarding within the same provider domain. In this demo, we will show a set of Open Source management tools for the emulation of the proposed solution over the Mininet emulator and over distributed testbeds. We refer to this suite of tools as Mantoo (Management tools). Mantoo includes an extensible web-based graphical topology designer providing different layered network “views” (e.g. from physical links to service relationships among nodes). The framework is able to validate a topology, to automatically deploy it over a Mininet emulator or a distributed SDN testbed, to access nodes by opening consoles directly via the web GUI.

SDN and NFV in Telecommunication Network Migration
Hagen Woesner and David Verbeiren

This demo shows a migration scenario from legacy PPPoE/PPP-based Internet access to a plain IPoE network. Telecommunication providers are currently replacing their access/aggregation infrastructure with a thinner protocol stack that does not use tunnels like PPPoE. The demo shows how this migration can be accomplished when using SDN and NFV. It integrates previously developed BNG and BRAS prototypes into an orchestration framework.
Federated Facilities for Large-scale SDN Experiments

Bartosz Belter (PSNC, Poland), Gino Carrozzo (Nextworks, Italy), Carolina Fernández (i2CAT Foundation, Spain), Jason Haga (AIST, Japan), Kostas Pentikousis, and Umar Toseef (EICT, Germany)

Software-Defined Networking (SDN) has altered the network R&D mentality with respect to the time required from concept validation studies to market introduction. In this context, innovative ideas need a test environment as close as possible to real-world scenarios. This has triggered international cooperation spanning leading research centers in Europe, Asia, and the Americas to establish large-scale federated SDN testbeds for experimental research on advanced programmable networking. The EU-Japan jointly-funded project FELIX defines a common control and orchestration framework to manage federated testbeds extended across continents and several administrative domains via dynamic transit network connections. The FELIX framework enables an experimenter to i) request and obtain resources across different testbed infrastructures dynamically; ii) manage and control the network paths connecting the federated SDN testbeds; iii) monitor the underlying resources; and iv) run distributed applications on the federated infrastructures. The geographically dispersed FELIX testbeds are capable of establishing on-demand connectivity through the transit network using the Network Services Interface (NSI), an emerging protocol developed to build common standards for interoperability between network operators. In addition, FELIX implements a modern authentication and authorization mechanism that not only realizes an intuitive user access control but also greatly simplifies the process of testbed federation.

This tutorial is organized into two parts. The first part, targeted for developers of SDN testbeds, will introduce you to the FELIX project, starting with the motivation and challenges addressed, and delving into the salient technical aspects. The goal is to familiarize you with the modular architecture of FELIX with particular focus on the functionalities of the constituent software components, the exported interfaces, the dependencies and the relationship between the internal building blocks. Moreover, broadening the scope on open experimental environments, you will also get an overview of Future Internet Research and Experimentation (FIRE) initiative in Europe, FELIX's position within FIRE and its collaboration with other FIRE projects. The second part is mainly targeted to engineers, advanced-degree students and researchers who are the potential FELIX testbed users. It aims to provide a comprehensive user guide from creating a user account to setting-up and executing an experiment on the FELIX testbed. Furthermore, you will also get an overview of the FELIX open-source Github repository and how you can contribute to it by joining the FELIX developers community. In addition, you will also learn in a few easy steps to setup your own testbed and federate with FELIX. In order to make the tutorial more interactive and enjoyable for the tutorial attendees, active Q&A participation will be encouraged throughout the presentations. Finally, the tutorial participants will get a chance to experience a live use-case created over the FELIX infrastructure.

UNIFYing Cloud and Carrier Network Resources: Architecture, Orchestration and Service Provider DevOps

Róbert Szabó (Ericsson Research, Hungary), Wouter Tavernier (UGent-iMinds, Belgium), and Wolfgang John (Ericsson Research, Sweden)

Cloud networks provide various services on top of virtualized compute and storage resources. The flexible operation and optimal usage of the underlying infrastructure are realized by resource orchestration methods and virtualization techniques developed during the recent years. In contrast, service deployment and service provisioning in carrier networks have several limitations in terms of flexibility, scalability or optimal resource usage as the built-in mechanisms are strongly coupled to the physical topology and special purpose hardware elements. Network Functions Virtualization (NFV) opens the door between cloud and carrier networks by providing software-based telecommunication services which can run in virtualized environment on general purpose hardware. Our main goal is to unify software and network resources in a common framework. In this tutorial we describe a novel UNIFY architecture supporting automated, dynamic service creation based on a fine-granular service chaining model, SDN and cloud virtualization techniques.

Part I: Concepts and Architecture - Róbert Szabó
We introduce the concept and the UNIFY architecture with its main components. The most important benefits are highlighted and compared to other state-of-the-art approaches.

Part II: Service Programming and Orchestration - Wouter Tavernier
This part will focus on the challenge of service programming and orchestration in an NFV context. Two fundamental concepts in which UNIFY handles these challenges will be presented. Service decomposition enables flexibility in programming and while allowing for optimal resource usage in orchestration. Adequate interfaces and programming abstractions allow for scalability in the orchestration while at the same time giving flexibility and dynamic control to service components. When combining both, true service elasticity becomes possible as will be discussed in a practical use case of an elastic software router.

Part III: Service Provider DevOps - Wolfgang John
Increased service-velocity and dynamicity provided by programming and orchestration frameworks will require novel management processes. We specifically identified the need for integration of capabilities related to service and infrastructure verification, observability and troubleshooting. In this tutorial, we will introduce the Service Provider DevOps concept, derived from the DevOps paradigm popular in modern data centers. We will highlight three tools technically supporting SP-DevOps processes: a multi-component troubleshooting tool for supporting both service development and operational phases; a service model verification tool, allowing identification of problems with service definitions and configuration early in the service lifetime; and an automated test packet generation tool that can be used to verify the data-plane functionality of OpenFlow nodes during service run-time.

Part IV: Summary and Q&A - Wolfgang John, Wouter Tavernier and Róbert Szabó
We will revisit the UNIFY architecture in the view of service programming, orchestration and Service Provider DevOps methods and conclude the tutorial with Q&A.
Bizkaia Aretoa  
Avenida Abandoibarra, 3  
48009 Bilbao  
Spain

For detailed instructions on getting to the conference, please visit www.ehu.eus/en/web/bizkaia-aretoa/home.

The registration desk will be open from 8:45 on the first day, September 30.

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