IT and Optical Network Orchestration Framework
An industrial research project

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Abstract

This paper presents an overview of the most recent evolutions of the Orchestrator Systems, Software Defined Network (SDN) and Network Function Virtualization (NFV) paradigms that will be developed in the framework of an industrial research project funded by the Puglia Regional Government. The project aims at creating an integrated software platform for Optical Network and IT infrastructure simulation and management. Furthermore, the open framework will be used to build and prove advanced application and services. Among the huge range of applications, Power Management will be the first issue addressed by the project.

The software platform being developed will be an integral part of the innovative line of SM Optics products and will be an important asset of Experis Lab for future business development.

In this paper an overview of the project and the specific goals to be pursued within the project framework are presented basing on the most recent research results in the scientific literature.

1. Introduction

Telecom services show an increasingly dynamic behavior, causing network operators and service providers to ask for a more unified and elastic deployment approach, involving previously ignored features such as portable software packaging, flexible resource allocation and dynamic application placement. Moreover, interoperability issue is also a strong request of the market.

The current Internet architecture evolved to a complex system, which is very far from the lean design of the original TCP/IP protocol stack. This complexity sinks its roots in the key innovation drivers brought by the Internet over the last two decades [1]. They include the shift from host centric to content centric services with the consequent set up of proprietary content delivery network overlays that embrace the world wide web, raise of the Internet of Things (IoT) with its billion devices scattered everywhere, coexistence of IPv4 and IPv6 network realms, explosion of mobile radio networks currently evolving towards the 5G, and pervasive adoption of cloud/edge/fog computing platforms [2]. The pressure generated by the Internet innovation pace cannot be sustained by an ossified architecture born in the past millennium, but requires adaptability, flexibility, reconfigurability, and autonomic capabilities within each layer of the protocol stack [3]. For these reasons, "network softwarization" emerged as the angular stone of next generation network architectures: it is based on representing the physical resources of a packet switching networks on a standardized virtual floor, from which all the entities involved in communication and networking operation can be orchestrated and configured to keep the Internet working around the desired equilibrium point [1]. In particular, NFV allows the realization of network functions on non-dedicated hardware; in general, such functions are executed in dedicated expensive systems. Adopting the NFV paradigm, commercial off-the-shelf servers can deploy network operations reducing costs and improving flexibility [4]. This approach could be more effective together with the adoption of the SDN technology where logically centralized control enables the network programmability of devices by decoupling data and control planes [5]. The abstraction plane offered by SDN improve the interoperability among different vendors' devices and it is particularly useful when the concept of "slicing" is introduced to create multiple coexisting networks (e.g., in 5G networks [6]).

This trend has been recently extended to optical transport network which are fundamental for supporting the high bandwidth requirements of the future Internet infrastructure, as well as additional key features (i.e. latency), which are enabling the new applications and services foreseen by 5G evolution. It is well known that optical transport networks are evolving rapidly from the static and classical Dense Wavelength Division Multiplexing (DWDM) systems towards more flexible and elastic switching. This requires the development of innovative network control and orchestration mechanisms to reduce deployment and operational complexity [7], [8]. The NFV and SDN solutions perfectly agree with these requirements introducing the new concept of programmable optical network.

One of the main issue to be solved in order to achieve such an ambitious goal is the design of a very capable orchestrator element that could interact with optical nodes modifying their behavior according to users' and network's needs.

Theoretical studies in the field of IOPE (Input/Output/Preconditions/Effects) model for common composition of elementary resources can be applied. Given a network goal and a set of available services/resources both described using a subset of logic-endowed languages, it can be possible to carry out discovery and composition simple components covering as much as possible the needs of the system. Moreover, to increase the fault tolerance, the composition protocol integrates an automatic substitutability among resource components [9]. In this context one of main goal of the project is to prove that it is possible to apply in real systems the above described technologies, improving at the same time obtained performances.

2. Software-Defined Networking, IT resources and Virtualisation

SDN got its start on campus networks with the idea of making the behavior of the network devices programmable, allowing them to be controlled by a central element. This led to a formalization of the principle elements that define SDN today [10], that mainly lies in:

- Separation of control and forwarding functions
- Centralization of control
- Ability to program the behavior of the network using well-defined interfaces

The subsequent success for SDN was due to the recourse of cloud-based data centers. As the size and scope of these data centers expanded a better way was needed to connect and control the explosion of virtual machines. SDN soon candidate to be the solution in the field of improvement of data centers.

The SDN approach to network operation tries to shift all the previously firmware-based routing decision to a central software entity able to perform a global network optimization based on the several monitored parameters and the many possible goals to be reached. The computation algorithm able to pursue such tasks is centralized and coordinated to perform high-speed computation on very large data in very short execution times, thus fulfilling the performances of the global network to be optimized in several parameters. This approach moves away from specific hardware at central locations and shift toward resource virtualization, i.e. new network cloud-based infrastructures to enhance efficiency in the network performances to respond to the user needs.

Each type of softwarized network function requires its own peculiar mix of CPU, memory, storage, and connectivity resources, whose availability may have to satisfy constraints on location, time, reliability, priority, and cost. These resources are often provided and managed by separate systems, "domain managers" – classic example is a cloud manager for the IT resources and a network manager for the connectivity resources – which is convenient to put under control of a central entity called an "orchestrator" capable of dealing at high level with the lifecycle and rules of the overall services deployed on the intelligent network rather than lifecycle and rules of the elementary resources they require.

An orchestrator is also often capable of creating an abstraction called a "network slice" which presents to upper level systems a portion of the underlying network, intended to support a certain service type, satisfying its resource requirements.

All the intelligence of such a network is thus shifted toward a "virtually centralized" system and software algorithms pursue the global performance of the entire network.

From the point of view of the business logic of all services deployed across the network, a network node is thus seen and managed as something with more and more resemblance with a general-purpose cloud node, but with the additional asset of strong local networking capabilities that can be remotely programmed just like the IT resources of that same node are – making it what is often referred to as a Telco cloud node.

3. Resource Composition and Substitution

In order to achieve an automated decision about resource optimization, it is mandatory each element involved in the optimization strategy can be described with a machine understandable formalism and have a non ambiguous meaning. Hence, it should be defined both the goal to be reached and each available resource within the network as concepts in a well-known logic. Both should be referred to a shared vocabulary assuming a taxonomic structure (ontology). The service composition model in [11] to deal with highly heterogeneous scenarios as the one of the project. For the sake of clarity, main elements and definitions are recalled here. We define Resource a triple $\langle RD, P, E \rangle$ where RD is the description of the managed resource, P its preconditions it requires and E the effects it produces. Furthermore, indicating with AI_i the available information for the i-th resource r_i and with E_j the effects produced by r_j, with $j < i$, the following relation ensues: $AI_i = P0 \sqcap E1 \sqcap E2 \sqcap ... \sqcap E_{i-1}$.

Based on the definition of resource flow w.r.t. some initial preconditions P0 –from now on RF(P0)– it is possible to define a composite resource as complex element including elementary sources properly orchestrated among them by taking into account the IOPE paradigm.

Non-standard reasoning services in [12] can be adopted for an automated compliance verification in quasi real-time.

An executable resource r for RF (P0) is a resource which can be invoked after the execution of RF (P0), i.e., its preconditions are satisfied after the execution of RF(P0), and such that its effects are not already provided by RF (P0).

The composition algorithm receives in input the preconditions that must be satisfied as well as the parameters setting the discovery depth and duration.

The first composition attempt is performed using already available resources. The algorithm outputs the composite resource CR as well as the uncovered part Runcovered. If the covering level is under an acceptable threshold, the uncovered part as well as the temporary resulting CR are stored, and a novel orchestration is solicited through the discovery of new resource descriptions.

4. The industrial research project

The project target is to develop a simulation framework according to the architecture depicted of Fig. 4.1.
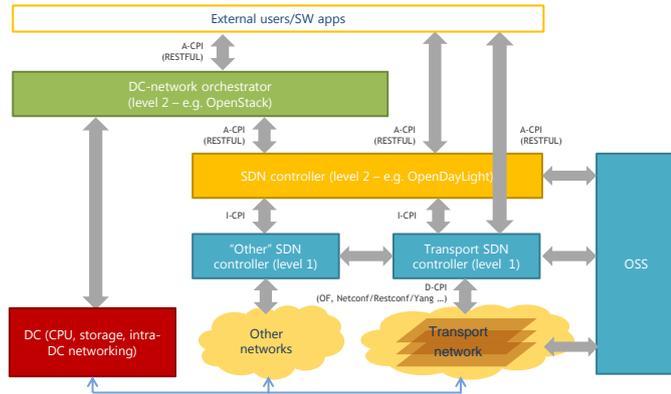

Figure 4.1 – Project Architecture

In order to build the overall platform the following issues has to be addressed:

a. Identification of most suitable technology for each subsystem, according to the most promising standard
b. Choice of interface and communication protocols (e.g. netconf, restconf) to ensure the compatibility with existing network paradigms, standards, and common practices.
c. Include the multiple network layers (i.e. L1-L3) and the related multilayer management
d. Develop node models according the most promising standard (e.g. Yang, Openflow)
e. Identify NVF management infrastructure and how it will be merged inside the architecture
f. Design the infrastructure to be open and "easy-to-use" for service and application development. This is a key point for the enablement of future applications and service developments, which justify the initial big investments.

All these aspects will be addressed in the project, mainly focusing on the definition of the best solution (hardware and software) to obtain the complete infrastructure.

5. Test architecture and application development

According to Fig. 5.1, the latest part of the project will address the demonstration of the capabilities of the implemented orchestration framework, which will incorporate the SM Optics optical metro access nodes, the hierarchical SDN controller and the orchestration layer.

A mix of real nodes and simulators will be used to reach very high node count, being be able to test very complex network. The actual setup will be based on virtualized hardware resources hosted at Experis/SM Optics premises and accessible from the project partners. The goal of the proposed experimental setup is twofold.

First, we aim at demonstrating the overall framework capability of simulating a complex infrastructure management, including optical layer design and planning, multilayer (DWDM / OTN / Packet) management [13].

Second, thanks to the open framework architecture, advanced applications will be selected and tested. In particular, one of the goal of the project is to evaluate the effectiveness of possible Network Virtualization Function (NFV), which may be hosted in the optical nodes. In particular, the first application will address the power management issue [14] of the overall framework, including monitoring and optimization capability. A set of suitable Key Performance Indicator (KPI) will be defined in order to quantify the achievable saving. Among the numerous applications that may be considered we identified vCPE (virtual Customer Premises Equipment) [15] and Network Caching" [16].

vCPE consists in substitution of one or more dedicated hardware device (appliance), deployed on the enterprise network edge, with virtual network functions (VNFs) software. Some of the typical network functionalities residing at business customer can be routing, security, virtual private network (VPN) or WAN optimization but any other network service that can be virtualized. Nowadays, the reference architecture for vCPE implementation are:

a) centralized mode, where VNFs run on COTS (commercial of the shelf) hardware, like a remote Service Provider DataCenter, and the customer is connect via broadband to Service Provider with a WhiteBox optical switch (bright box switch);
b) distributed mode, where VNFs run directly on customer service router with x86 servers. Each approach has its benefits and for that is also present a mix of both mode named hybrid mode.
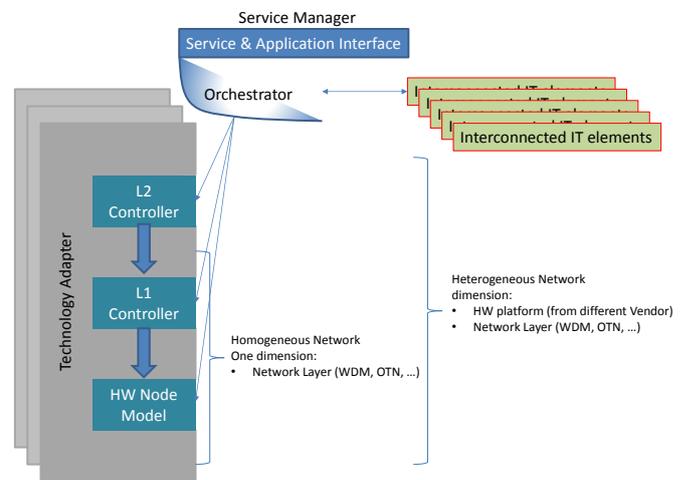

Figure 5.1 – Test Environment Architecture

The simulation framework will be help to study pros and cons of the two approach and to select the best solution.

Network Caching [17] allows transfers and stores multimedia contents near the customer network side. This solution is used to improve QoS/QoE (Quality of Service/Quality Of Experience) by reducing the Round Trip Time and Packet Loss and then the latency, while bandwidth resources can be significantly reduced as a consequence. The Project platform will be used to carry out complex simulation, to identify the best resource allocation and to quantify the performance and the advantages of such approach.

6. Conclusion

The paper presents a short description of the NFV/SDN technology, the main goals to be pursued and the challenges to be faced during the just started industrial research project with the partnership of Experis, SM Optics and Politecnico di Bari. The project aims at developing a complex simulation environment, which includes all the relevant hardware and software components, ranging from optical nodes, to the network management system to the overall infrastructure management. Thanks to the use of open source software, standard interfaces, it is worth to underline the openness of the infrastructure for applications and services development, which can enable future application and service developments. Among the numerous possibilities three possible application ha been addressed, namely Power Management, vCPE and Network Caching.

Results of the proposed approach will be presented in a future paper.

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References

[1] F. Y. Wang, L. Yang, X. Cheng, S. Han and J. Yang, "Network softwarization and parallel networks: beyond software-defined networks," in IEEE Network, vol. 30, no. 4, pp. 60-65, July-August 2016.

[2] K. Samdanis, A. Prasad, M. Chen and Kai Hwang, "Enabling 5G verticals and services through network softwarization and slicing," in IEEE Communications Standards Magazine, vol. 2, no. 1, pp. 20-21, MARCH 2018.

[3] I. Afolabi, T. Taleb, K. Samdanis, A. Ksentini and H. Flinck, "Network Slicing & Softwarization: A Survey on Principles, Enabling Technologies & Solutions," in IEEE Communications Surveys & Tutorials. 2018.

[4] R. Martinez, A. Mayoral, R. Vilalta, R. Casellas, R. Munoz, S. Pachnicke, T. Szyrkowiec, and A. Autenrieth, "Integrated sdn/nfv orchestration for the dynamic deployment of mobile virtual backhaul networks over a multilayer (packet/optical) aggregation infrastructure," Journal of Optical Communications and Networking, vol. 9, no. 2, pp. A135–A142, 2017.

[5] Derrick D'souza, Krishna Prabhu, Sundharan Savithru Lokanath, Vivek Mittal - Capstone Research Paper: "Improving QoS in a Software-Defined Network" - April 30, 2016

[6] Alexandros Kaloxylos, "A Survey and an Analysis of Network Slicing in 5G Networks", IEEE Comm. Standards Mag., vol. 2, no. 1, pp. 60-65, 2018.

[7] D. King, A. Farrel. N. Georgalas, "the role of flexible optical networks; current status, challenges and opportunities," Proc. Of Int. Conf. on Transparent Optical Networks, ICTON, 2015.

[8] R. Casellas, R. Martınez, R. Vilalta, and R. Munoz "Control, Management, and Orchestration of Optical Networks: Evolution, Trends, and Challenges," J. of Lightwave Tech., vol. 36, no. 7, Apr., pp. 1390-1402, 2018.

[9] M. Ruta, G. Zacheo, L. A. Grieco, T. Di Noia, G. Boggia, E. Tinelli, P. Camarda, E. Di Sciascio, "Semantic-based resource discovery, composition and substitution in IEEE 802.11 mobile ad hoc networks", Wireless Networks, 16(5), pp. 1223-1251.

[10] Open Networking Foundation (ONF), "SDN architecture overview (Version 1.1)," ONF TR-504, Nov. 2014.

[11] M. Ruta,T. Di Noia, E.Di Sciascio, F.M. Donini, "Semantic enabled Resource Discovery, Composition and Substitution in Pervasive Environments". In proc. Of the 13th IEEE MELECON 2006, pp. 754–760. IEEE, 2006.

[12] Floriano Scioscia, Michele Ruta, Giuseppe Loseto, Filippo Gramegna, Saverio Ieva, Agnese Pinto, Eugenio Di Sciascio, "A mobile matchmaker for the Ubiquitous Semantic Web", International Journal on Semantic Web and Information Systems (IJSWIS), 10(4), pp. 77-100.

[13] Rodolfo Alvizu,, Guido Maier, Navin Kukreja, Achille Pattavina, , Roberto Morro, Alessandro Capello, Carlo Cavazzoni "Comprehensive Survey on T-SDN: Software-Defined Networking for Transport Networks", IEEE Communications Surveys & Tutorials, Vol. 19, No. 4, Fourth Quarter 2017

[14] "Environmental Engineering (EE); Green Abstraction Layer (GAL);Power management capabilities of the future energy telecommunication fixed network nodes", ETSI STANDARD 203-237

[15] CORD Design Notes, Central Office Re-architected as a Datacenter (CORD), March 14, 2016, see https://opencord.org/

[16] Yaning LIU, Jean Charles Point , Konstantinos V. Katsaros, Vasilis Glykantzis , Muhammad Shuaib Siddiqui, Eduard Escalona "SDN/NFV based Caching Solution for Future Mobile Network (5G)"

[17] Omran Ayoub, Francesco Musumeci, Massimo Tornatore, Achille Pattavina, "Techno-Economic Evaluation of CDN Deployments in Metropolitan Area Networks", International Conference on Networking and Network Applications (NaNA), 2017