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Role of Network and Platform Functions Virtualization in Future Telco Networks

Eugen Mikóczy [1], Pavol Podhradský [2]
[1] Slovak Telekom, Bajkalská 28, Bratislava, Slovakia
[2] Faculty of Electrical Engineering and Information Technology of Slovak University of Technology, Ilkovičova 3, Bratislava
eugen.mikoczy@telekom.sk, pavol.podhradsky@stuba.sk

Abstract – **In the paper we will specify and try to answer some of the most urgent questions related to Software Defined Networking (SDN) and Network Function Virtualization (NFV) technologies these days. The SDN is changing the present networks and it also defines the concept how Future Networks will be designed. So therefore we provide an overview about key initiatives, technologies and protocols in our paper. Definitely, the NFV on other hand supports integrated service providers to better utilize and control their cloudified infrastructure to deploy much faster fully virtualized platforms, networks and services. Both of these technologies can be combined and extended by new operation methodologies that can significantly change way of designing, development, testing, deployment and operation approaches. This can significantly improve efficiency in comparison of the traditional Telecommunication environments. There are still many open problems in this area, but our paper presents the potential architecture of the Future Network based on SDN/NFV technologies. We provide a vision how open technologies can enable education and experimenting about SDN/NFV and at the same time to use them to build distributed virtual open laboratories.**

Keywords – **Future network, SDN, NFV,**

I. INTRODUCTION

The paper presents a crucial issues of service providers and analyzes actual trends related to SDN/NFV and what it means for designing of Future Networks (FN). We start in next section with presentation background and basic terms related to Next Generation Networks (NGN) and Next Generation of Internet (NGI) and with comparison of different approaches of architecture evolution or revolution towards Future Networks. As it is introduced in the abstract we will also focus on main issues listed usually when collecting requirements and intentions of service providers while discussing Future Networks (FN). We stress on what in the reality means SDN the decoupling of the control from data plane for redesign of Telecommunication core packet networks. Followed by section about NFV as well as infrastructure and service platforms are re-define by virtualization. We all know that NFV and SDN are changing the Telecommunication industry. The role of the standardization and/or open (source) ecosystems and universities they can use SDN & NFV for education it is evaluated as well. In final part of the paper we will elaborated one use case from ongoing R&D project for setup distributed open laboratory for testing mentioned technologies for education and experimenting.

II. OVERVIEW OF BACKGROUND FOR NGN, NGI, FUTURE NETWORKS

The aim of this section is to discuss and compare two approaches to Future Networks (FN) evolutionary and revolutionary ones [1]. We can understand Next Generation Networks (NGN) as an architecture when classical old generations of digital exchanges based on TDM technologies are phase out by operators and migrate to full All-IP networks using IMS based NGN architectures specified by ETSI or ITU-T NGN.

Next Generation Internet (NGI) also known as Future Generation Internet (FGI) or Future Internet has been proposed based on the research of Internet architecture and identification of limitation of actual architectures and protocols. This new concept is also known as Future Generation Internet (FGI) or Future Internet what is a new approach to deliver new services upon ―Internet 2 or ―Beyond IP. These networks can be designed in an evolutionary way or in revolutionary clean slate approach on ―green field. FGI has been driven by the philosophical thought that we would design the internet differently, if we could redesign the internet from scratch today. In an MIT Technology review [2]: in The Internet is Broken (2005) David D. Clark said: “We are at an inflection point, a revolution point” “The Net’s basic flaws cost firms billions, impede innovation, and threaten national security. It’s time for a clean-slate approach.” On other hand Telecommunication standardization bodies after concluding NGN specification (e.g. ETSI NGN TISPAN release 3) focus on defining how the Future Network should be designed. ITU-T Focus Group for Future Networks specified FN as follows [3]: “Future Network (FN): A future network is a network which is able to provide revolutionary services, capabilities, and facilities that are hard to provide using existing network technologies”. As well major service providers have been discussing key issues and expectations for Future Networks as part of ETSI architecture evolution and industry whitepaper for Network Function Virtualization [4] there for ETSI ISG expert group focusing specially to NFV was setup.

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III. KEY REQUIREMENTS FOR FUTURE NETWORKS

We can split key challenges and requirements on following 5 main groups:

- Provide advance multimedia services and enriched user experience
- Assure Anywhere, Anytime connectivity, mobility and security
- Enable flexible architecture and fast innovations, open ecosystem
- Reduction of complexity, independence of services from infrastructure and faster time to market
- Cost reduction and improve operation effectiveness

A. Advance multimedia services and enriched user experience

Initially FN shall bring new services much faster to customers and with improved user experience so there are several requirements that can be applied to any Future proof Multimedia Architecture and Services [5]:

- Rich set of multimedia services accessibility from anywhere, anytime
- User friendly interface and multi-device/screen support
- Service personalization on user/group/community level
- Any to any interaction & communication (U2U, U2S, S2U, UinC)
- Advance search (SD&S) and user/service/content/context metadata with personalized recommendations
- Support for QoS and QoE, adaptive service/media delivery
- Interconnections/mobility, advanced content delivery networks
- Support for new media and scalable formats (for HD, 3D, VR)

B. Anywhere connectivity, mobility and security

One of the key expectation of users that their services will be accessible from anywhere and always-on so it is expected independently from access networks or device they are using. Future network should fully support mobility and connectivity of users, devices or even things (in case of Internet of Things). Improved security is listed within priorities of all Future Networks initiatives that contain network, information security but also resilience, reliability as well improvements in authentication, privacy and trust topics.

C. Flexible architecture and enable effective innovations, open ecosystem

Flexible architecture means well designed modular architecture that can be easily adapted, extended and modified without impacting end customer. Especially well define open standards with modules connected with open interfaces can enable developers independently extend features and capabilities in one module minimizing impact on others. We see that open source communities and initiatives can expose new innovative technologies and we will provide some examples in next sections. Ultimate goal is not just innovation for themselves but also extend accessibility to these new technologies and open experimenting to anyone that can bring us new ideas and new use case not even elaborated yet as well potentially improve time to market from such new idea to real products.

D. Reduction of complexity, independence of services from infrastructure and faster time to market

We face a huge complexity and usually services are highly tight to infrastructure and network in Telecommunication environment. On other hand Internet as network has limited intelligence in network pushing complexity on application layer moving that to application servers and software based service platforms. Expectation here is to make services fully independent from infrastructure itself or networking elements. So anyone can develop new services without deep engineering skills about telco platform or network. Again the goal is to open future networks for innovation and enable faster time to market for new services changing from months to days or even hours. Additionally innovation in the network and infrastructure can have independent lifecycle from services and services can be easily portable cross distributed architecture.

E. Cost reduction and improve operation effectiveness

Last but not least improvements are expected in operation effectiveness and cost reduction for development but also deployment and operation. We expect high level of automation and infrastructure elasticity. Elasticity means that infrastructure can scale in/out depending on load and efficiently used resources and energy. Resilience of solution is not based on pure redundancy of elements and HW but can be leverage on infrastructure elasticity and automatic recovery. Manageability and orchestration are also precondition that together with automation of deployment and operation can improve efficiency. We assume that these changes in technologies will also require different skill set from people that will these solution design/develop and operate.

IV. SOFTWARE DEFINED NETWORKING

Several research teams analyze drawbacks of initial 70's design of TCP/IP and Internet architecture that is evolving over last 40 years. Already early 90's has been within IETF identify potential aspect for improvements [6]:

- Routing and Addressing limitations
- Support for Multi-Protocol Architecture
- Improve Security of Architecture
- E2E Traffic Control and State
- Ready for Advanced Applications

Generally the actual traditional packet network architecture consist on nodes that integrate in each node features, packet control logic and packet forwarding hardware. In most of

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routers (or any networking equipment for that matter) there is specialized hardware for fast switching of data between interfaces - Data Forwarding plane. The forwarding is managed by rules created by processor running operating system, routing algorithms, address translation, and other higher functions - this is the Control plane. But traditional packet network as shown on Fig.1 combines data forwarding and control plane in each node.

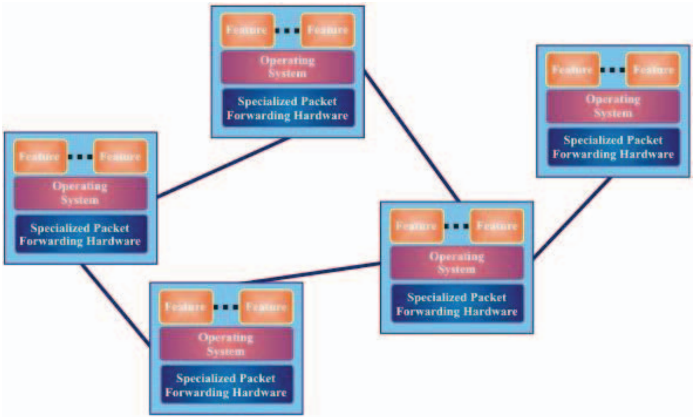

Figure 1. Traditional packet network architecture [7]

That limits introduction of new features and with complex protocol that address specific purpose needs to make IP layer bottleneck and introduces complexity of control mechanisms, protocol translation/interworking and limits innovation in IP networks. Extreme growing number of connected devices also can limit future addressing space and usability/scalability of existing routing protocols for large complex networks, as well as further innovation because new features have be distributed to all routing nodes.

The SDN defines separation of the control and data forwarding plane in network as depicted in Fig. 2. By the implementing of the separated control plane by the software for general purpose computer (called Network OS) from forwarding plane on network equipment, it is possible to centralize routing and switching decisions, as well as configuration of all network devices.

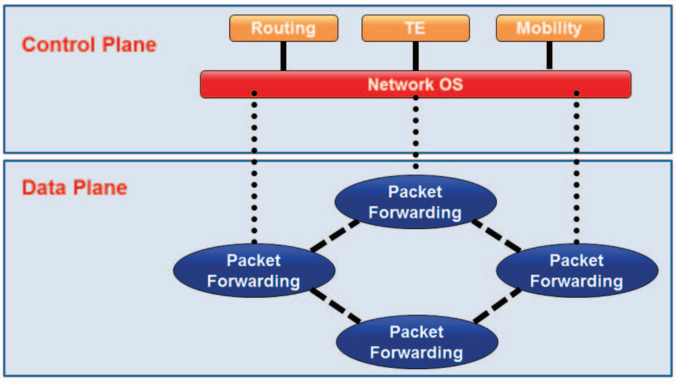

Figure 2. Basic SDN architecture [7]

SDN based network can enable:

- **Simpler architecture:** Separation of control from routing data plane, Potentially integrated control plane of IP & Transport networks
- **Resilience and Automation:** Self-healing mechanisms, scale in/out, higher level of automation, E2E network visibility
- **Time to market:** Faster delivery of new service, hosting network functions in infrastructure cloud

OpenFlow is an open standard originally developed at universities and currently maintained by Open Network Foundation (ONF) [8] – a non-profit consortium with mission to commercialize and promote OpenFlow based SDN. ONF succeeded spectacularly, with OpenFlow being the most popular protocol used for communication between control plane and data forwarding plane – becoming the de facto standard. The OpenFlow specifications describe:

- the southbound protocol between OF controller and OF switches
- the operation of the OF switch

The concept of SDN controller that control SDN node have been realized also with several open source projects for example Open Daylight (ODL)[9] and Open Contrail [10]. Open Networking Lab (ON.Lab) initiates an open source project called Open Network Operating System (ONOS) that designed as SDN network operating system for service provider networks. It is architected [11] to provide high availability, scalability, performance and rich northbound and southbound abstractions. NETCONF is a network management protocol that provides mechanisms to remotely install, manipulate, and delete the configuration of network devices.

V. NETWORK FUNCTION VIRTUALIZATION

These days the operators usually run network/service platforms and IT systems in separate datacenters and often on dedicated hardware. So, that there is trend of „Cloudification", re-platforming and move of application to Infrastructure cloud based on commodity x86 hardware with Virtualization and cloud orchestration that helps share and better utilize the same cloud infrastructure for multiple network and IT applications (in [12] is example of Slovak Telekom virtualized Infrastructure Cloud architecture in Fig. 3).

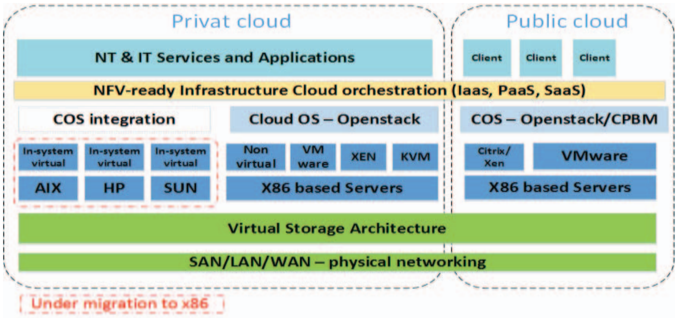

Figure 3. Hybrid Infrastructure Cloud architecture [12]

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In October 2012 the white paper that presented the first draft of NFV was published [4] driven mainly by service providers expectations. European Telecommunications Standards Institute (ETSI) set out the various requirements which are placed on the technology and described the benefits that come with NFV technology and this technology should bring. Network Functions Virtualization Industry Specification Group (ETSI NFV ISG [13]) has been created to cover all tasks related to newly emerged technology.

The architecture of NFV technology was designed [14], [15] based on the following components:

- NFVI (NFV Infrastructure) [16] - provides virtual resources needed to support the implementation of virtualized network functions - commercial COTS hardware components for acceleration, layer of software that virtualizes and abstracts the underlying hardware.
- VNF (Virtualized Network Functions) [15] - software implementation of network functions that is able to run by NFVI and may be accompanied by EMS - Element Management System, which manages the VNF. VNF is an entity corresponding to today's network node, which is expected to be delivered as pure software independent of the hardware.
- NFV MANO (Management and Orchestration) [17]- covers orchestration and lifecycle management of physical and / or software tools that support the virtualization and infrastructure lifecycle management VNFs. NFV MANO focuses on virtualization management tasks, which is necessary for NFV framework. It also collaborates with external NFV OSS / BSS and enables integration NFV to existing networks.

We provide our vision of NFV based architecture [18] where Infrastructure cloud is used as NFVI running virtualized network functional and service platform on top (Fig.4) together with SDN controller running as one NF and control virtual networking.

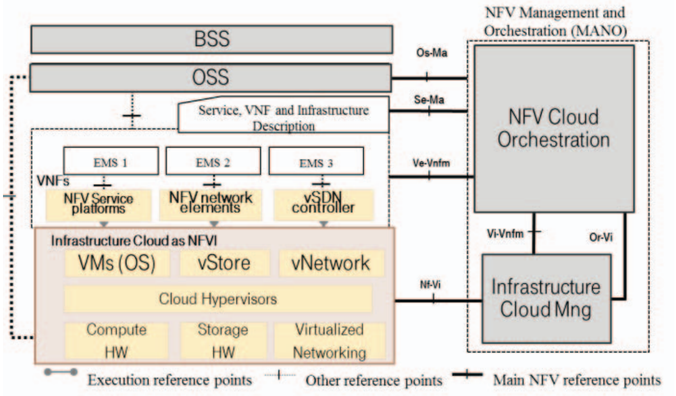
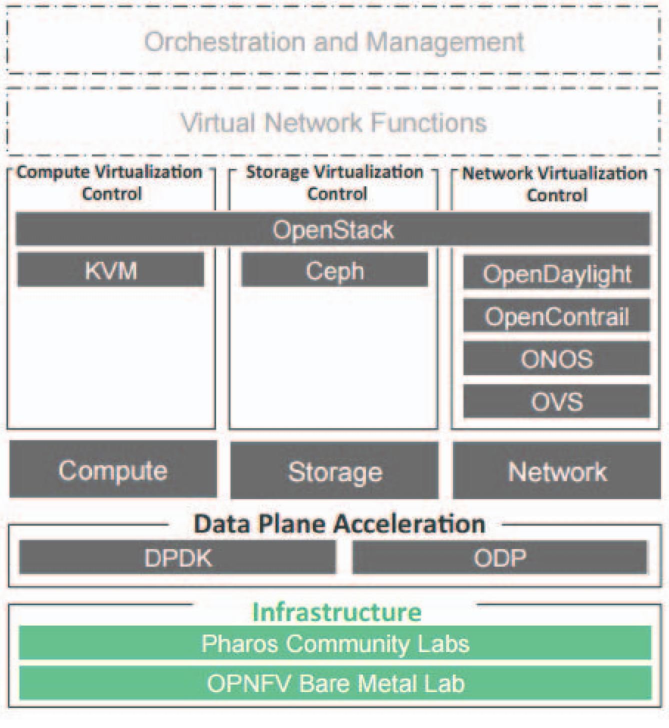


Figure 4. NFV architecture that combine Infrastructure Cloud for NFV with virtualized networking with SDN [18]

The next step and main differences between "just" virtualization of existing platforms and "Real NFV" is but also provide integration between NFVI and VNFs as well that both components are orchestrate and under control of MANO. Because just when Virtualized functions support automatic deployment, scaling, restore, automation of processes and fully utilize concept of MANO this bring real advances of NFV concept. These concepts are changing our design, development, testing, deployment, operation approaches that can significantly improve efficiency in comparison of the traditional Telecommunication environment and pure virtualization. We understand that traditional IT systems of BSS/OSS have to be changed to fully support NFV. The other important question is what these crucial changes implicate to IT adaptations of Business Support Systems (BSS) and Operation Support Systems (OSS). As way how product in BSS is designed and order management adapted to support real-time provisioning as well adapted mediation and billing. Main change in IT integration will be definitely on OSS side because fulfillment with MANO definitely change as well assurance and troubleticketing.

One of new initiative Open NFV (OPNFV) [19] declares to develop carrier-grade, integrated, open source platform to accelerate the introduction of new NFV products and services. OPNFV utilizes some existing technologies (Fig. 5) like Open Stack as Cloud OS with pre-integration of OpenStack modules with Compute (using KVM virtualization), Storage (using CEPH) and Virtualize Networoking using SDN controllers (ODL, OpenContrail, ONOS) and SDN nodes (OpenVirtualSwitch - OVS).



Figue 5. OPNFV architecture and open spurce components [19]

Additionally OPNFV also provides development, integration, testing and deployment tools (for Continuous Integration / Continuous Deployment). ETSI NFV ISG also recetly announced Open Source MANO project (OSM)[20].

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VI. TELCO TARGET ARCHITECTURE UTILIZING SDN/NFV

The combination of SDN for the virtual networking integrated with OpenStack Neutron and virtualized SDN controller (vSDNc) can be utilize in NFVI. Additionally NFV can deliver selected network and service functions.

Following changes and steps are therefore required [21]:

1. Virtualize existing Service Platforms
2. Introduce Infrastructure Cloud
3. Consolidate Virtual Storage
4. Move from physical to virtual DCs networking
5. Utilize Cloud orchestration and add MANO
6. Introduce selected NFV service platforms
7. Migrate NFV network services including SDN controller
8. Perform OSS/BSS adaptations required for Real-Time OSS and MANO integration
9. Introduce virtual CPEs as one of VNF
10. SDN enabled in IP and transport control

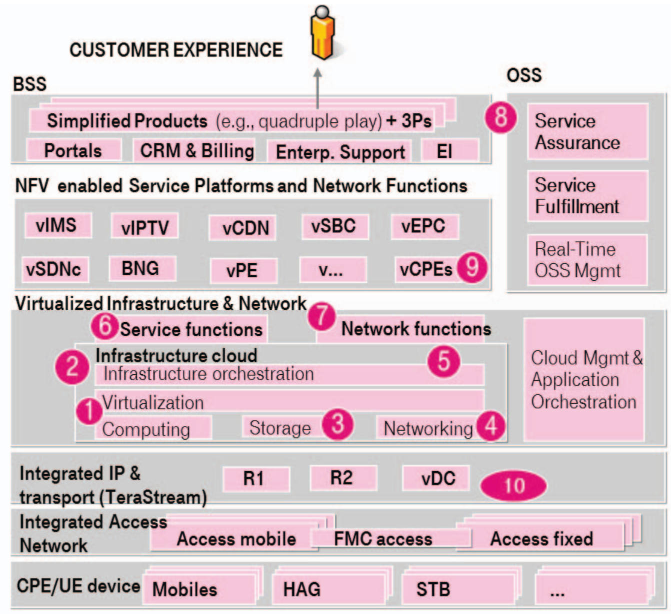

Figure 6. Potential Future Telco architecture using SDN/NFV

VII. SDN/NFV OPEN LAB FOR EDUCATION AND EXPERIMENTS

The NEWTON project architecture is primary focus on the distributed e-learning infrastructure and Fab/Virtualized laboratories cross Europe. As on the NEWTON should run also virtual courses and experiments expected to be performed to provide education about SDN/NFV we also evaluate potential using open source SDN/NFV project to provide distributed Virtualized Network Function infrastructure that host communication services (e.g. using WebRTC), virtualized e-learning management systems (vLMS), multimedia streaming (MM Streaming) as well enable flexible cloud management and orchestration with automation tools to setup laboratory environment for specific experiments on Fab, or Virtual Labs (example conceptual architecture on Fig.7).

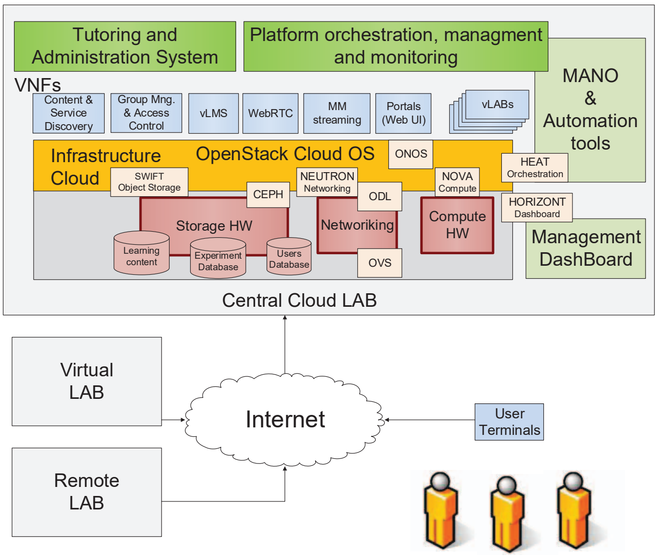

Figure 7. Conceptual Architecture for Distributed Virtualized Open Laboratory for Education and Experimentation

The key part of Infrastructure cloud is using of Open Stack as Cloud Operation System (Cloud OS) with its modules integrated with proper other components (Swift to storage, Neutron for Networking and also with ODL, Nova towards Compute HW, Heat for orchestration with MANO, Horizont for integration with Management dashboard). Generally Infrastructure control utilized also architecture from OPNFV. Databases required for user managements, content metadata and experiments metadata. Experiment metadata also contain information required by Heat and automation tools and tools supporting Continuous Integration (e.g. Jenkins, Puppet, Chef, Gerrit, Artifact, Jira) to change lab environment flexibly depending of experiments or exercises that plan to run locally or remotely.

VIII. CONCLUSION

In the paper we provided an overview about main trends related to SDN/NFV and how related technologies can be utilize for the Future Networks architecture. These technologies can address several issues listed in section 2 but definitely there will remain the most of them to be addressed by standardization and industry. We analyzed key technologies and industry initiatives that enable as to design innovative conceptual architecture for Distributed Virtualized Open Laboratory for Education and Experimentation as part of several national or international projects running on STU together with European partners. We believe that open source initiatives and building laboratory out of them can allows students and researcher experiment and flexibly create and deploy SDN/NFV experiments and setup of lab easier and faster to use it for education and research.

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We used in paper material collected in various projects and presentation presented by authors on several conferences and events like ETSI Future Network Technologies Workshop [22], TM Forum Live [18], Broadband Forum [21] as well lectures about SDN/NFV at STU and e-book [23]. This paper presents some of the results and acquired experience from the following projects: H2020 project NEWTON, No. 688503, ERASMUS+ project TECHpedia, No. 2014-1-CZ01-KA202-002074, VEGA project INOMET, No. 1/0800/16 and APVV project MUFLON, No. APVV-0258-12.

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