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Elastic Everything - What of the Developing World?

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Abstract: Telecommunications along with cloud computing are in the process of a transformation towards a Cloud Integrated Network (CIN)[1] triggered by an elastic network in the form of two disruptive technologies Software Defined Networking (SDN) and Network Function Virtualisation (NFV). This project is considering how key infrastructure development at national level and changed Local SPs (LSP) network architectures and business models can deliver the CIN within the constraints of a developing country. A potential set of solutions will be developed through experimental simulations and system models to demonstrate how the CIN can be delivered by rural SPs in a developing nation. While the project is in its early stages, work at the Ugandan Internet eXchange Point (IXP) virtualising services, adding an Akamai Content Delivery Node (CDN) has demonstrated an increased demand and has necessitated a corresponding upgrade the core switches. An OpenStack orchestration laboratory has been built for experimentation with NFV orchestration and Virtual Infrastructure Manager (VIM) functions. A similar testbed will consider Open Source MANO (OSM) and the Open Network Automation Platform (ONAP) Projects. The project will develop potential architectures for the delivery of the CIN to the rural customers of LSPs as well as consider the need for eXchangelets in the future.

Keywords: SDN, NFV, OpenStack, CIN.

1. Introduction

1.1 Cloud Computing, Management and Automation

The move by the IT sector traditional owner-owned infrastructure, software and systems to cloud computing [2] has forced industry to consider management of servers. As a result a number of cloud orchestration tools have been developed for cloud automation. Such tools offer end-to-end process management by controlling and coordinating lower level processes to deliver a completed resource or service. One of the most well-known and used tools is the OpenStack Cloud OS that has been developed to control pools of compute, storage and network resources on standardised hardware.

1.2 Networking

Networking as a key component of infrastructure has not had such revolutionary change because powerful vendors have controlled the industry with proprietary, specialist hardware. There has been increasing speeds, added features but in general vendors have maintained both control and data forwarding planes within their networking platforms. These devices have relied on protocols like Border Gateway Protocol (BGP) originally proposed as far back as 1989 [3] to communicate. Traditional networks with abstraction layering have levels of header encapsulation that impact negatively on the Maximum Transfer Unit (MTU) size, thereby reducing the effective capacity of the packets. SDN and NFV are two potentially disruptive technologies that can change networking. In fact SDN has already taken hold in Data Centre applications supplanting traditional switching and routing technologies.

1.3 Implications for Africa, the Case of Uganda

Can Africa benefit from these changes? Certainly large cities on the edge of the continent with access to the undersea cables that connect it to Internet nodes in Europe and the Middle East can, but what about rural areas, cities and countries without proximity to the sea. Take Uganda for example where Internet access in Kampala is dependent upon a fibre cable 1,150 km long to Mombassa and rural parts of the country dependent upon distribution from the National Data Transmission Backbone Infrastructure [4] which links Kampala to major towns in the regions. However even this has a defect in terms of bandwidth and redundancy and requires investment in Dense Wave Division Multiplexer (DWDM) technology [5].

While it has been suggested that SDN and NFV can provide solutions for African network operators with low coverage yet high capacity demands [6] and there is evidence of work in the field at the Communications Research Group at the University of Cape Town [7] [8] it tends to focus on smarter cities [9] [10].

While in Europe, North America and Asia optical networks are being installed and the speed of deployment is gathering pace. This upgrading of access infrastructure in terms of both speed, low latency and reliability makes for a natural migration to SDN and NFV technologies from the Data Centre to business and consumer premises.

Sub-Saharan Africa by comparison has not had this fibre revolution and taking a country like Uganda with over 40 million people, approximately 91% of these rural dwellers and women having an average of 6.9 children (global average: 2.7) [11]. The country is in the early stages of a population explosion, estimated to be 65 million by 2030 and expected to pass the 100 million by 2050. Internet access in the country today is almost exclusively provided by wireless, even within the capital Kampala and such services are provided to a small percentage of the population. Therefore the conditions that are ideal for SDN and NFV do not exist.

SDN and NFV roll-outs will enable more efficient and new services in the developed markets. How can SPs in the less developed markets react? Can SDN and NFV technologies be adopted by rural SPs and what changes will be essential to ensure that developing countries with mainly rural populations are not left behind?

2. Objectives

This project will:

1. consider how national level, key infrastructure development can enable National Service Providers (NSP) and LSPs evolve to meet the demands of the future CIN.
2. appraise how the LSP can use these technologies to deliver the CIN within the constraints of a developing country.
3. develop a set of potential solutions, such as experimental simulations and system models that use the SDN and NFV technologies to deliver the CIN of the future within the constraints of a developing nation.

3. Methodology

This research work will take the form of an IXP feasibility study, a learning laboratory, a simulation and the development of a systems model. While SDN evolved because of an obvious need in Data Centres and NFV is evolving because large SPs want to virtualise the products they deliver to customers. What is not clear is if and how these technologies can be applied to improved Internet services and ultimately the delivery of the CIN in developing countries.

3.1 Part A – Internet eXchange Point

Part A of this research involves working with the development of the Uganda IXP. This involves the virtualisation of services and enhancements to facilitate the incorporation of CDN to bring content nearer to the ultimate end customer. An assessment of the benefits of the eXchange and an evaluation of its potential to form part of the solution suite in developing countries. A secondary question to be considered is if the development of micro eXchanges around the country will become necessary to cater for the latency and packet loss intolerant applications of the future.

This work will be ongoing through the project and will provide primarily qualitative; "lessons learned" output. Can such a centralised entity provide technical and economic benefit to the delivery of services in developing countries?

3.2 Part B – Mastery of SDN and NFV

This second part to the project involves the building of a learning laboratory at netLabs!UG in Kampala, Uganda to develop scenarios using developing orchestration tools like OpenStack and the relatively infant Open Source NFV OSM and ONAP projects, emulation and distributed emulation tools like Mininet and MaxiNet, controllers like Open Daylight (ODL) and Open Network Operating System (ONOS) while exploring methods of applying solutions using Virtual Machines (VM) and emerging container (CT) technologies.

A secondary element to this part will be the development of a training module that can be delivered at undergraduate or postgraduate level for students to evangelise these technologies.

3.3 Part C – Simulation and System Model for the Future LSP

Part C will be informed by the outputs of the earlier parts. This will involve the building of an experimental simulation and system model of a future LSP using cloud orchestration, SDN and NFV technologies. This system model can further be used at netLabs!UG for further academic work beyond the scope of this project.

Avenues that have not been considered for SDN/NFV to discover how the technology can bring added value to rural areas of developing nations will be explored and documented.

4. Technology Description

4.1 Software Defined Networking

The SDN architecture separates network control and forwarding functions, migrating control to a centralised policy server [12]. Control plane policy rules manage the data plane devices via the OpenFlow protocol [13] while services in the application plane can adjust the policy rules using a REpresentational State Transfer (REST) style web architecture. This allows for Create, Read, Update and Delete (CRUD) operations over a North Bound Interface (NBI) in the form of RESTful Application Programmable Interface (API) using Hypertext Transfer Protocol (HTTP) methods; GET, PUT, POST and DELETE [14].

While there are many SDN Controllers, the Linux Foundation host the main two, the ODL project has emerged as a leader [15] with the ONOS project [166] providing a more Service Provider (SP) focused cluster based solution to handle the demands of scale associated with SPs. As SDN evolves it has become apparent that new NBI mechanisms are required to meet the diverse applications that will call on the SDN Controller [17]. SDN has facilitated the redesign of the data centre by offering more control of simplified switches reducing CAPital EXpenditure (CAPEX) while giving more control of the overall network. OpenStack through its Neutron service Modular Layer 2 (ML2) plugin [18] can act as an SDN network service orchestrator when integrated with an SDN Controller like ODL.

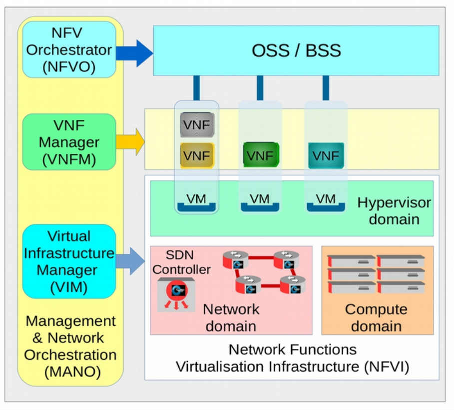

Illustration 1: NFV Ecosystem

4.2 Software Defined WAN

Software Defined WAN (SD-WAN) is a particular implementation of SDN principles. An SDN Controller monitors a number of links to end hosts. Some links are over the Internet via Virtual Private Networks (VPN) while others are via other SPs network services like Metro Ethernet or Multi-Protocol Label Switching (MPLS) circuits. The SDN controller matches the Service Level Agreement (SLA) parameters with the available circuits and dynamically delivers traffic over the most cost effective path.

4.3 Network Function Virtualisation

Tier 1 SPs could see the impact of virtualisation and cloud computing had on compute as well as the potential of SDN for networking. They considered the potential for functions to migrate to virtual Provider Edge (vPE) infrastructure within their own network, virtual Customer Edge (vCE) infrastructure on their customers network or on their own supplied virtual Customer Premise Equipment (vCPE) on the customer's premises would reduce OPerational EXpenditure (OPEX) and CAPEX, allow for faster, scalable and elastic service delivery and potentially offer a mechanism for new services. This lead to the creation of the NFV project at European Telecommunications Standards Institute (ETSI) [19].

While NFV has evolutionary challenges like interoperability with legacy systems and can future virtualised functions perform like specialised, function specific hardware? the perceived benefits have made such a compelling case for migration that pioneer SPs like Verizon have already built internal architectures describing how the technologies will be used in their networks [20] demonstrating that without doubt they will form the core of services to be offered well into the future.

Illustration 1 demonstrates the overall NFV ecosystem [21]. The underlying infrastructure collectively is called the Network Function Virtualisation Infrastructure (NFVI) and it consists of three domains, Compute, Network and Hypervisor/Virtualisation. The network domain consists of islands of switches with SDN Controllers or a traditional switched/routed network. The compute domain is the hardware and storage necessary to support the upper layers. The final domain is the hypervisor/virtualisation domain which contains the virtualisation hypervisors and VMs built using existing hypervisors like Kernel-based Virtual Machine (KVM), Xen, VMWare or container technology like Docker.

NFVI domains are managed by a VIM. A Virtual Network Function Manager (VNFM) controls the build of Virtual Network Functions (VNF) on the VMs and the NFV Orchestrator (NFVO) co-ordinates, authorises, releases and engages resources independently of any specific VIM. It also provides an overall management of VNF instances sharing resources of the NFVI through the Operations Support Systems (OSS) / Business Support System (BSS) allowing for the rapid deployment and scalability of services. This reduces administrator workloads by removing manual tasks. It also offers APIs and other extension tools to integrate with existing environments.

4.4 Open platform NFV

The Linux Foundation established a collaborative project called Open Platform NFV (OPNFV) in October 2014 [22] to provide a platform for the deployment of NFV solutions. OPNFV focuses on the NFVI and VIM which means a focus on the building of interfaces between existing projects like OpenStack, KVM, Xen, LinuX Containers (LXC), Open vSwitch (OvS), Linux bridge, Data Plane Development Kit (DPDK), Open Dataplane (ODP) and the GNU/Linux kernel. Working with existing elements to create a functional reference platform will be a major win for the technology and certainly contribute to the goals of phase 2 of the ETSI NFV.

4.5 Management and Network Orchestration in NFV

There are a number of projects considering the problem of MANO. OpenStack introduced a project called Tacker that provides an early implementation of a generic VNFM and NFVO based on the ETSI architectural framework that can be used to deploy VNFs on remote customer networks as a vCE, on a SP provided vCPE or on the SP's own vPE infrastructure. This will form an important cog in the OPNFV architecture. Two other projects were launched in 2016, Telefónica's early work has been hosted by ETSI as a the OSM project and a second project driven initially by the Chinese companies China Mobile and Huawei, hosted by the Linux Foundation originally called Open Orchestrator Project (OPEN-O) but after a merger in February 2017 with the AT&T Enhanced Control, Orchestration, Management and Policy (ECOMP) project created the ONAP Project.

4.6 Functional Example; the Forwarding Graph

Taking an example of a telephone call that must be switched by a SIP Proxy function, it is necessary for the traffic to be viewed first by the firewall, and then sent to a load balancer to distribute the workload to one of multiple SIP Proxy VNF which prevents overloading of any one. Finally the output traffic from the SIP Proxy is redirected as necessary. As is demonstrated in Illustration 2 the SDN Controller controls the flow of traffic via the OvS, directing the traffic initially to the firewall, then directing the output of the firewall for this flow to the SIP Proxy and then directing the output of the SIP Proxy to the firewall again prior to directing that flow to the output. This Forwarding Graph (FG) forms a logical network service chain.

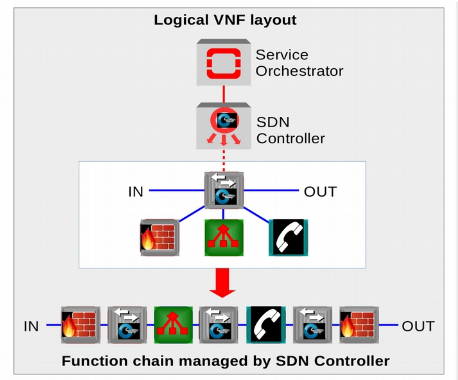

Illustration 2: Service chain

With such FGs it will be possible to automate how virtual network connections can be dynamically established to handle traffic flows for connected services, like the phone call just described and just as easily destroyed once their function is complete, for example the telephone call hang-up. It will be equally possible to dynamically assign relevant resources to the flow like bandwidth, encryption and Quality of Service (QoS).

5. Developments

While OpenStack is now a mature cloud platform, the framework promotes the development of new services, like Tacker just described. This makes it ideal for the rapid development and prototyping that is ongoing particularly around NFV. The Colorado release of OPNFV is considered a lab ready starting point for the evolution of NFV use cases and services and a means for testing integration with upstream projects. Much of the work carried out by the OPNFV projects involve collaboration with upstream projects and such collaboration between projects is a feature of modern cloud and networking and co-ordination is essential to their combined success. OSM and ONAP are at the very early stages and it will be interesting to see the niche each of these MANO projects occupies in the future.

This project aims to consider these technologies with a view to exploring how they can be leveraged to provide services to LSPs providing solutions to rural communities. For such LSPs to survive, significant change will be required in their current business model, they must transform to use the bandwidth services of existing larger LSPs while filling gaps in their coverage where that proves necessary, thereby offering a complete service to rural customers. As the elastic network evolves then this aggregator LSP will be well placed to use SDN technology to dynamically select the bandwidth that meets the customer SLA and is the cheapest at that time.

Another consideration is the Global Service Provider (GSP), can they use NFV infrastructure like vCE to deliver their services on the LSPs network to their customers? Can smaller LSPs in rural developing countries offer such services?

6. Results

This project is in its early stages. Work has begun on the upgrade of the Uganda IXP. A comparison between OpenStack with the Kernel Virtual Machine (KVM) hypervisor and Proxmox Virtual Environment (VE) was made and it was decided to select Proxmox VE for the IXP implementation as it proves simpler to implement and maintain in an environment where the hypervisor is for internal use only. A distributed Proxmox VE Hypervisor platform has been installed and the major services like the router servers, IXP Manager, statistics server have been virtualised using VMs or CTs as was considered most appropriate to each service role.

An Akamai CDN has been installed and has already shown to be a major positive impact with a threefold increase in average traffic levels from 300 Mb/s to a point where it regularly peaks at 2.5 Gb/s today. Such has been the increased demand, it has required upgrading the core switches and migrating major eXchange members to 10 Gb/s ports. This positive result has been the catalyst to initiate the process of adding a Google Global Cache (GGC) to further enhance the offering and bring Google content closer to the Ugandan user.

Work on the second part of the project has also begun with the building of an OpenStack orchestration laboratory to allow for experimentation with Tacker NFV orchestration and the use of OpenStack as a VIM. Work to date has involved mastering OpenStack and the building of YAML Ain’t Markup Language (YAML) Heat Orchestration Templates (HOT), this has been documented [23].

7. Business Benefits

Future business is connected business, access to the Internet today and the CIN of tomorrow is critical to the future of all business and without access it will become much more difficult to sustain business outside major cities. In the case of developing countries with secondary access to sea cables as is the case in Uganda, could see business move to neighbouring countries like Kenya and Tanzania who have primary access to the cables.

While this work will not solve the major infrastructure deficit which is the responsibility of government in countries with secondary access, it will look at potential network architectures for LSPs. Such architectures will leverage SDN and NFV techniques to build the complete coverage solution, using a blend of partner and own network elements to give the appearance and effect of a single network where dynamic bandwidth allocation meets customer SLAs and considers the delivery of services by GSP customers on their networks.

8. Conclusions

The elastic vision for compute and storage has evolved as a pay per use model and such a change has arrived for networking. The combination of elastic compute, elastic storage and now elastic network has laid the foundations for elastic functions in the form of NFV.

This project is in its early stages. From part A the early conclusions are demonstrated by the increased traffic through the IXP when a CDN is attached. The traffic that would have left Uganda to access Akamai server is now facilitated by the cache and is evidenced as lower latency for the end customer. Further increased traffic throughput should be observed with the addition of a Google GGC. Additionally, the completion of the virtualisation project will give the IXP greater flexibility to accommodate further caching and therefore improved services for the SPs and their customers.

Developing countries risk a widening gap as developed countries evolve to the CIN over dense fibre networks even to rural areas. As technologies are software based and open source in nature they offer a more feasible solution for low income countries. The question to be considered in this project is how an SDN and NFV can be used to provide better services in developing nations where the underlying infrastructure is not as developed.

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