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Investigating Software-Defined Network and Networks-Function Virtualization for Emergent Network-oriented Services

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ABSTRACT - A workgroup was created in the year 2013 to particularly explore on how SDN, or Software-Defined Network, could be practically implemented, taking into consideration not just technical, but also the social and economic impacts. The founding technologies required to support the possible implementation of SDN are yet evolving, which provides a huge scope to study the performance of these systems, to be deemed viable, practically. Networks-Function Virtualization, or NFV, and SDN, are expected to be the pillars of this emergent 5G Networks Technology, which would actually prove to be a stronger blend among Computer Networks, the Cloud and also IT provisioning services, with the aim of increasing performance, while reducing cost. This paper aims to provide an insight into these innovative concepts of SDN and NFV, which could surely revolutionize the way in which Networking and IT Services are being offered.

KEYWORDS -Software-Defined Networks, Networks-Function Virtualization, Logically-centralized Controllers, SDN, NFV, LCC, Cloud Computing, 5G

I. INTRODUCTION

The proper design and deployment of emergent paradigms such as SDN, or Software-Defined Network [1], and NFV, or Networks-Function Virtualization [2] can provide significant assistance to enhancing network performance, with enhanced efficiency being attainable at lesser costs. This could be achieved only if the rate of innovation in the context of Networks design and services becomes better; i.e., simpler and faster. Moreover, this would be possible only with a conscious effort from the side of both the Network Operators (NOs) and the Service Providers (SPs) to attempt and reduce the extent of cost involved for optimal provisioning of network functions and services. Currently, the domains of Computer Networks, I.T. Services and Cloud Computing are being managed separately and their planned integration would surely have a huge impact on the entire Industry, as this merger would enable dynamic provisioning of I.T. services, and that too, at much reduced costs. Explicitly speaking, SDN, by definition, is mainly concerned with the abstraction of the Control (software) realm, from the Data (hardware) realm. In essence, this would separate logical tasks, for example packet forwarding, from the physical tasks, such as switching. As a result, control logic, and also the states, could be migrated to more logically-centralized controllers (LCCs). Another technology which could further augment the performance of such LCCs is that of NFV, or Networks-Function Virtualization. This concept mainly implies virtualization of usual Network functions and services, so that they can be implemented on common-purpose hardware. As a result, network components could be placed dynamically, with their functions and services being distributed to different locations in their network infrastructure.

II. SDN ARCHITECTURE

According to the Open Networking Foundation (ONF) [1] [3], SDN can be defined as a network in which where the software-oriented (control) and the hardware-oriented (data-forwarding) planes would be dissociated. This is so that the physical infrastructure of the Network could be separated from the business applications and functions [3]. Such a

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proposed architecture for SDN has been described in Figure 1. Thus, in an SDN, as expected, decision-making would be separated regarding the data flow and switching. Consequently, the flows would be monitored by an SDN controller, which would thereby interact with these SDN switches, using the OpenFlow protocol given by ONF. These protocol-based processes usually concern the flow of data, as well as the communicating ports and their respective queues. On the other hand, the higher-level applications, and their associated functions, have not been defined by the ONF. That is, they could in fact be designed by other agents. Since SDN is still evolving, there is immense scope for this design to be refined. There is a wide possibility for the addition of several features, including control, mobility, and resource provisioning, including even virtual resources.

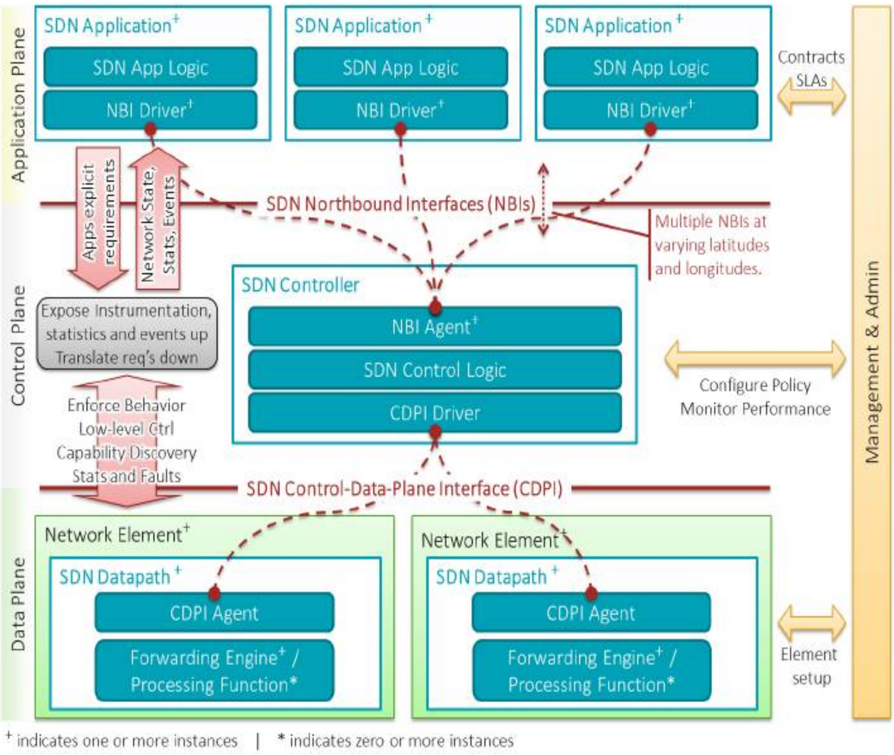

Figure 1 – SDN architectural model
(Source: [3])

This evolution aims to counter the usual issues of performance, scalability, strength, as well as compatibility, by supporting multiple vendors, since it is an essential pre-requisite that the different domain controllers of SDN must be able to co-exist for it to be successfully implemented. This would, however, be largely impacted by the level of functionality provided. **Networks-Function Virtualization**, or NFV, goes hand-in-hand with the above described concept of SDN, as it focuses on virtualization of the associated network functions, usually being performed by Data Centers, to be able to support the dynamic demands of the SDN. These usually include typical virtualization tasks, such as cloning, migration and dynamic allocation of these virtual resources, as well as the related functions. Virtualization provides users with several benefits, as it ensures better utilization of resources, both physical and virtual. Additionally, it also provides better state encapsulation. Further, NFV would also guarantee optimal performance, by the co-location of separate instances of prevalent network functions, even if actually it exists on the same hardware. This collaboration of the NO and the SP could, in fact, optimally create, activate, and also allocate the resources virtually, thus customizing operations, based on the desired pre-requisites.

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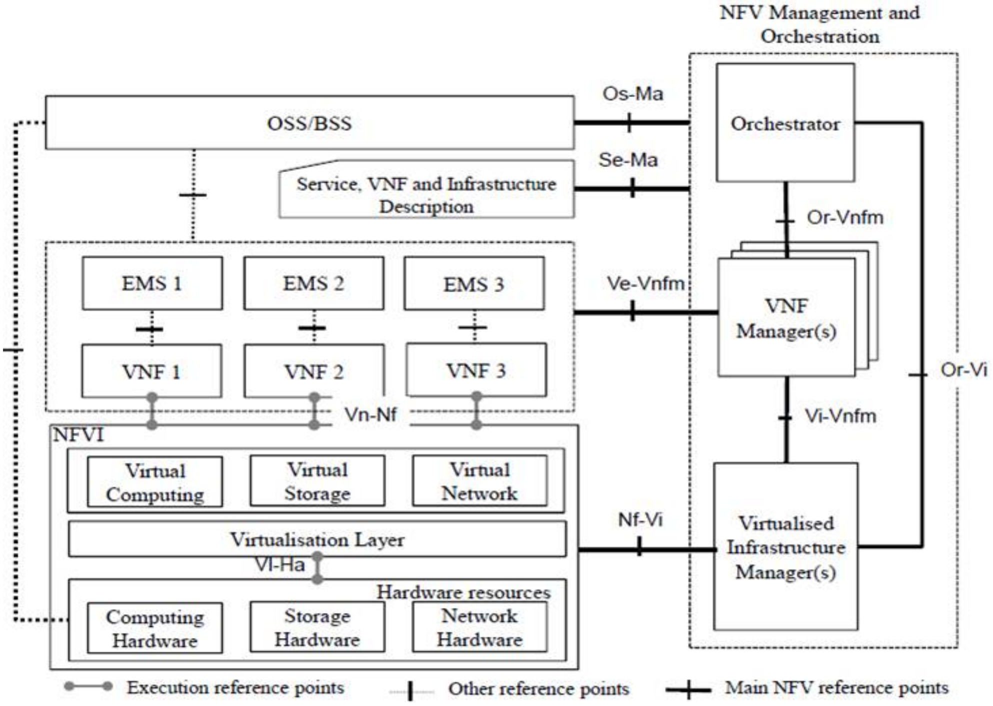

Figure 2 – Functional model for NFV – An Example (Source: ETSI).

It is however not essential to implement SDN to virtualize the network functions, or vice-versa. We can thus say that even though they may not be directly dependent, SDN and NFV are benefitted mutually. Figure 2 describes the functional architecture, as has been provided by ETSI.

III. SDN AND NFV – TECHNICAL EVALUATION

Generally, SDN could be considered to be a paradigm that aims to overcome the congestion experienced by the current layers and protocols stacks. Bar Geva argues in [4] that, the TCP/IP layering structure, in the future, may be just one of several ways to implement a highly-flexible software-defined networking environment. Many evolutionary application scenarios are possible, in case of Computer Networks, regardless of whether wired, or wireless. For instance, it could be possible that SDN actually provides a pertinent solution for the efficient and scalable implementation of network control functions in a scenario comprising heterogeneous, densely situated, wireless networks [5]. In fact, SDN, along with NFV, could also provide a more flexible yet efficient implementation of the LTE-Evolved Packet-Core, or LEPC, network by having its primary functions distributed among the virtualized and cloud-based environment, existing over an SDN-based transport structure [6]. Further, SDN may also help to make certain key functions available, such as load-balancing among diverse wireless technologies, along with admission and flow control across different 5G mobile networks [7]. Switch mobility needs to be enabled, while also making it tougher to attack such spread networks, as pointed out by Namal in [8]. This could be implemented by providing an enhanced Transport layer, which is based on IP-oriented mobility techniques to enable communications among the controller to the nodes. Another major issue in front of SDN is that of optimizing the allocation of resources, and their usage, with the help of NFV. The amalgamation of SDN controllers across diverse domains could be actualized by the east-west binding of compatible interfaces, by the use of either Service Oriented Architecture (SOA), or Inter-Platform Signaling (IPS) to distribute the tasks related to flow processing.

An important aspect to consider is the guarantee of Quality of Service (QoS) for whatever services are being provided by the SDN. Taking maximum advantage of network-programming capabilities provided by SDN, specific advances have been made in addressing the issues related to enforcement and scrutiny of QoS factors. One such implementation is OpenFlow [9], which has led to visible performance enhancement in the network equipments where it had been implemented. It would thus be feasible to devise a smart platform which is able to detect the rules as well as the required interactions, while also resolving the imminent irregularities, something like a debugger for the applications that are being developed for the OpenFlow platform. SDN can also be regarded as an important enabler for various emergent Networking models. The EFI, or European Future Internet, initiative [10] had suggested the up-scaling of cloud services, over existing network infrastructures. SDN would thus be essentially required for the setup of interaction services among such diverse clouds. Further, it is also the prime technology which could provide the much-needed support architecture to facilitate inter-Data Center (DC) communication, over multiple paths, which would, in turn, be built upon the emergent protocols and standards. Lastly, SDN is also expected to simplify the implementation of ICN, or Information Centered Networking in existing IP networks. This would be achieved by effectively disassociating the information which is needed for forwarding, from the respective object names.

Virtualization, particularly NFV, is a vital technology that is coupled to this imminent interest in SDN. The ability of network functions, and services, to be virtualized, along with the application of SDN principles is a real benefit. This is also the rationale behind this hyper-connectivity among disparate telecommunication scenarios, in which the control or processing logic usually resides at the edges of the network, finally being scaled up to transcend into a fully-connected Internet-of-Everything[11]. Such an extent of the virtualization of networks, regardless of the scale at which it operates, surely needs to be managed well. Design issues and technical approaches, with regards to the abstraction, control, virtualization as well as optimization of distinct Transport networks with different technologies, using both packet-switched, and also circuit-switched mechanisms has been discussed in [12]. A plug-in interface-based architecture can be used for the other crucial aspect required for virtualization of the SDN functions. That is, for the internal structure of the node. Lastly, the proposed visualization of a future-oriented emergent network would be moving marginally ahead, as still a major part of the device intelligence is located at the network edge itself.

However, the start can be considered to be a significant step forward as it is proposed that the inter-mingling of SDN and NFV would provide some kind of a de-centralized communication framework for all its users, also incorporating all possible Network equipments at their edges (including all kinds of hyper-connected devices, like smart phones, smart cars, drones, robots, etc.). These solutions could in fact offer considerable processing and storage capacities to actually utilize and execute the services and functions that have been virtualized.

IV. CONCLUSION AND FUTURE ENHANCEMENTS

Technology, as well as socio-economic factors are expected to get improved, correspondingly with a reduction in the cost, with the proposed evolution of networks aiming at the provision of a highly dynamic and flexible collaboration of resources that have been virtualized, also connected through virtual links that are possibly setup and worn down, dynamically, on-demand, to service the various client applications. SDN, in combination with NFV, is expected to show the initial path for this revolution. Generally, in the near future, digitization would become essential for a major segment of the business entities; i.e., large industries, as well as the SMEs (Small and Medium Enterprises). Those, in turn, would begin to rely more largely on the software as well. This change is certain, mainly because of the constant evolution of the underlying technologies, also effecting sizable decrease in costs. This reduction in operational costs has been possible only due to simplification of hardware, better software, and of course, the managerial characteristics that guide the emergent economic paradigms. We can thus find a general consent on the idea that the success of such models would largely depend on whether the solutions proposed for implementation of SDN and NFV would be actually based upon FOSS (Free and open source software) solutions.

The investigation been carried out here is quite complex as it considers not just the extent to which performance needs to be managed, but also the effective coordination of the activities associated with the virtualization of network functions. Moreover, many have argued that this proposed implementation should first take place at the network edges, to contain the level of investment necessary. This is also considered to be a cost-efficient solution, as it would be possible to scale up the architecture quite naturally, with the use of virtual nodes, which would surely generate corresponding increase in revenue. The combination of SDN, and NFV, would therefore augment evolution of not just the End-User devices, CPEs, or Customer Premise Equipments and Terminals, but even provide the consideration for aggregation of network edge nodes. Similar trends can be observed in other industries too. Thus, this SDN-NFV

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collaboration can be considered to facilitate even other novel environments that are capable of enhancing performance, efficiently, by stretching beyond dogmatic Telecommunication and IT frameworks. Such a revolution is truly inevitable, largely due to continuous evolution and optimization of hardware technology, which provides the much needed boost to encourage unconventional economic paradigms. This would, in fact, shift focus in Networks from just its hardware components to its software aspects, in turn facilitating supportive situations for an informational economy to blossom. This would, of course, require diversified business rules, specialized job-roles, skilled workers as well as appropriate capabilities as compared to what prevailed in the economy of the past 20th century that was largely dependent on factory-worker formats, as was the need in Manufacturing, and the associated manual work. In contrast, socio-economic, and cultural values in such an Informational economy would place stress on more creative aspects such as Intelligence, Creativity, Information, and Knowledge, to be able to cope up to the dynamic, ever-changing, socio-economic environments. Further, constant up-gradation of latest skills, dynamic thinking and cognition are essential to tune up to this rapid rate of transformation.

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