Appraisal on Cloud Computing and Network Functions Virtualization

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Summary
With an end goal to move the computing and networking industries from the present manual arrangement to automated solutions that are coordinated with the rest of the infrastructure, there have been a few developing technologies in the past couple of years, among them are cloud computing and network functions virtualization (NFV). "Comprehensively, every one of these solutions are intended to make computing and networking more automated and adaptable to help cloud and virtualized environment. These technologies are software-driven plans that guarantee to change service and application conveyance techniques, so as to increase network agility. In this article, a review of the two standards, featuring their key highlights and their relationship was presented; to give a comprehension of the two ideal models and how they explain diverse subsets of the large-scale issue of system versatility.
Key words:
cloud, cloud computing, network functions, network functions virtualization

1. Introduction

Cloud computing as characterized by the United States Government's National Institute of Standards and Technology (NIST), is a computing model for facilitating universal, advantageous, on-demand network access to a common pool of configurable computing assets (e.g., networks, servers, storage, applications, and services) that can be made accessible quickly and discharged with negligible administration exertion or service provider interaction (Peter & Timothy, 2011)."
Cloud computing was additionally characterized as a cyber-infrastructure, that is an accumulation of computing resources that builds profitability, quality and consistency by capturing shared trait among application needs and encourages the effective sharing of equipment and services (Mladen, 2008).
The meaning of cloud computing is said to be "cloudy" as various specialists and scientists alike in the industry has defined it in different ways. The author of Oracle, Larry Ellison says "cloud computing has been defined to include everything that is done already... without the understand of what would be done differently in the light of cloud computing" (Dan, 2008). The founder of the Free Software Foundation and creator of the operating system GNU, Richard Stallman says "it's stupidity. It's worse than stupidity: it's a marketing hype campaign" (Bobbie, 2008).

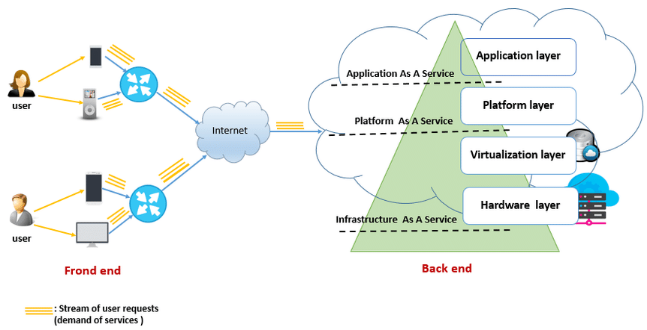

Fig. 1 Cloud Computing Architecture Source: (Google.com, 2018)

1.1 Brief History of Cloud Computing

The term cloud computing is genuinely new since its rise in the computing scene, yet its concepts are not new. As they were duplicated from other computing standards, for example utility computing, grid computing, service-oriented architecture among others (Lizhe & Gregor, 2008). It tends to be said that cloud computing has been in existence in various forms and can be followed back to the mid-sixties in the period of timesharing and utility computing. The seventies saw the approach of mainframe computers. The Eighties saw the coming of personal computers, while the nineties saw the dot-com bubble and the approach of grid computing. In this manner, prompting virtualization innovation, and in this way cloud computing (Ratnadeep, 2009).
In 1999, cloud computing was first endeavored when Marc Andreesen established the LoudCloud organization. Offering services which are presently alluded to as Software as a Service (SaaS) utilizing an Infrastructure as a Service model (IaaS). Along these lines, making it the first organization to offer cloud computing services (Sheff, 2003). "In 2000 Microsoft propelled web services as SaaS offering, in 2001 International Business Machine (IBM) followed suite with the arrival of its Autonomic Computing Manifesto (Jeffrey & David, 2003) and in 2007

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coordinated effort among IBM and Google propelled research in cloud computing (Steve, 2007).

2. Cloud Deployment Model

There are four cloud deployment models according to National Institute of Standards and Technology (NIST), and are highlighted by (Peter & Timothy, 2011) (Sanjoli & Jasmeet, 2013) namely: -

i. Private (Personal) cloud
This is operated exclusively for an organization. It gives a more secure platform to representatives and clients of an organization." It might exist on or off organization's premise and management could be outsourced or not or a combination of both. E.g. eBay.

ii. Public (General) cloud
"This is made accessible to the overall population or a large industry group and is owned by an organization offering cloud services. Resources are progressively allotted on a per-user basis through web applications. For instance: Drop Box, SkyDrive and Google drive.

iii. Hybrid (Mixed) cloud
This could be a composition of at least two or more cloud bounded together, in some cases a blend of the Public cloud and Private cloud; by standardized or proprietary technology that empower data and application portability. E.g. Amazon, Google, Windows Azure.

iv. Community (Domain-Specific) cloud
This is shared by different organisations or institutions that have a common concern or interest, for example, compliance considerations, security requirements. Community clouds are an intermediary between private and public clouds." This sort of cloud might be overseen by the organization or by a third party and might be situated on-premises or off-premises.

2.1 Cloud Computing Service Models

There are three service models provided by cloud computing. "These models are based on NIST definition of cloud computing and are as follows:

i. Cloud Software as a Service (SaaS)
This offers the consumer the capacity to utilize the provider's applications running on a cloud infrastructure. The applications are available through the Internet by means of the client's device. E.g., Web-based email, Gmail, Yahoo, cooperate email (Sanjoli & Jasmeet, 2013).

ii. Cloud Platform as a Service (PaaS)
This offers developers the capacity to configuration, fabricate, test and deploy onto the cloud provider's infrastructure; applications made utilizing programming languages and tools supported by the provider. E.g. Microsoft Azure, Java, Google App Engine (Pratiyush, Vikas, & Manish, 2013).

iii. Cloud Infrastructure as a Service (IaaS)
This offers consumers the capacity to process, store, utilize networks, and other fundamental computing resources on-demand. Likewise, to deploy and run arbitrary software, which can incorporate operating systems. E.g. Rackspace and Amazon S3."

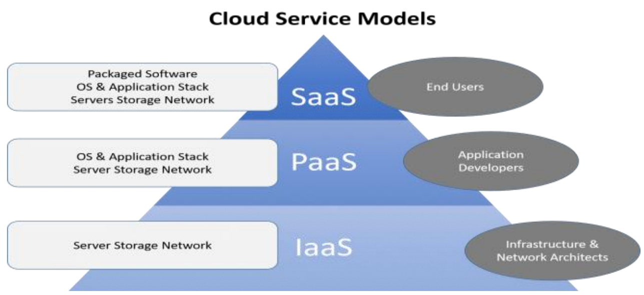

Fig. 2 Cloud Computing Service Models Source: (Google.com, 2018)

3. Characteristics of Cloud Computing

Cloud computing from other computing paradigms can be distinguished by a number of characteristics; categorized into essential characteristics and common characteristic as identified by NIST. (Peter & Timothy, 2011) highlighted the essential characteristics as follows:

i. **On-demand self-service –** This enables the clients to utilize cloud computing services and resources whenever.
ii. **Broad network access –** Due to the widespread nature of Cloud Computing, it gives high limit availability where expansive measure of data can be transmitted.
iii. **Resource pooling –** This enables numerous clients to share a pool of resources, for example, hardware, database and basic infrastructure.
iv. **Rapid elasticity –** It is anything but difficult to scale up or down the resources whenever; in this way, allowing automatic monitoring.
v. **Measured services –** "Resource use by clients can be monitored, controlled and reported, giving straightforwardness to all parties included.

3.1 Advantages of Cloud Computing

There are a number of benefits offered by Cloud computing, these includes the potential for (Nein, 2009):

- **i.** Cost reduction
- **ii.** Increased flexibility
- **iii.** Access anywhere
- **iv.** Easy to implement
- **v.** Service quality
- **vi.** Delegate non-critical application
- **vii.** Always the latest software
- **viii.** Sharing and group collaboration

3.2 Challenges of Cloud Computing

There are a number of challenges faced by cloud computing, and are as follows:

- **i. Security:** The fast selection of cloud computing has been obstructed by various security concerns appeared by clients (Sultan & Zheng, 2013)." These security issues incorporate, availability, integrity, confidentiality, data access, data segregation, privacy, recovery, accountability, multi-tenancy issues and so on. Cloud computing security issues can be alleviated by various means, for example, cryptography, utilization of numerous cloud providers, standardization of APIs, enhancing virtual machines support and legal support (Bhushan & Rajesh, 2012).
- **ii. Availability of Service:** Using just a single Cloud Computing Service Provider (CCSP), may result in a downside if or when a shutdown happens making the service inaccessible. CCSP guarantees to give unbounded versatility, yet because of the quick increment in clients such guarantee isn't satisfied (Sultan & Zheng, 2013).
- **iii. Third Party Dependence:** Customers have no influence over their own information, as information is lost in the hands of the cloud computing service provider.

4. Network Functions Virtualization

Network Functions Virtualization (NFV) is another approach to configuration, deploy, and manage networking services by decoupling the physical network equipment from the functions that keeps running on them, which replace hardware centric, dedicated network devices with software running on general-purpose CPUs or virtual machines, working on standard servers.

The term NFV was initially proposed by more than twenty of the world's biggest Telecom Operators, for example, AT&T, British Telecom and so on. According to European Telecommunication Standard Institute (ETSI), the concept of NFV is perceived as a network architecture which changes the method for building and operating networks by utilizing standard IT virtualization technologies and uniting proprietary hardware-based network functions into standard business devices (e.g., x86 architecture machines) (ETSI, 2014).

Network Functions Virtualization means to change the way, the network administrators architect networks, by advancing standard IT virtualization technology to consolidate many network equipment types onto industry standard high-volume servers, switches and storage, which could be situated in Data centres, Network Nodes and at client premises." These virtual appliances can be instantiated on-demand without the installation of new hardware.

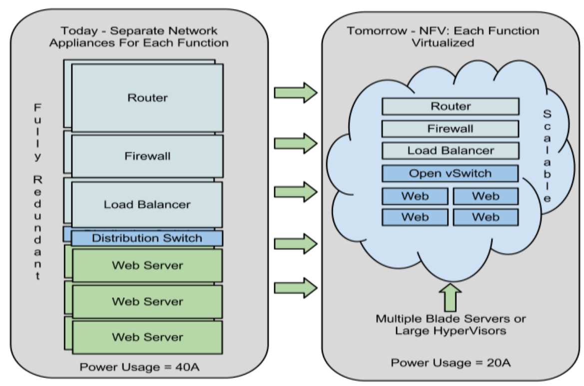

Fig. 3 Network Functions Virtualization Overview Source: (Google.com, 2018)

4.1 Brief History of Network Functions Virtualization

The concept and collaborative work on NFV were conceived in October 2012 when some of the world's leading Telecommunication Service Providers mutually composed a white paper calling for industrial and research action (Guerzoni, 2012). In November 2012 seven of these operators (AT&T, BT, Deutsche Telekom, Orange, Telecom Italia, Telefonica and Verizon) chose the European Telecommunications Standards Institute (ETSI) to be the home of the Industry Specification Group for NFV. Presently, over two years after the fact, a vast network of specialists is working seriously to build up the required principles for NFV and additionally sharing their encounters of its improvement and early implementation (ETSI, 2015). ETSI has effectively finished Phase 1 of its work with the publication of 11 ETSI Group Specifications." These specifications expand on the first release of ETSI documents published in October 2013 and incorporate an infrastructure overview, updated architectural framework, and descriptions of the compute, hypervisor and network domains of the infrastructure. They likewise cover Management and Orchestration (MANO), security and trust, resilience and service quality metrics (Sophia, 2015).

"Regarding the second stage work of NFV, it is an upgrade and improvement of the first stage work of NFV. Since the architectural work isn't considered in this stage, the NFV architectural framework and the MANO framework remain nearly the equivalent. Also, the ETSI NFV ISG has satisfied the greater part of its underlying responsibility for the second stage to create the initial set of normative documents, which incorporate the necessities for interfaces distinguished in the NFV architecture framework, the interface specifications and their information models (ETSI, 2017). With the end goal to approve the second stage work regarding the management on service descriptors and software images, another work is announced, that is, NFV Plugtests (first version) which aims at confirming early interoperability between various implementations and main components inside the NFV architecture (ETSI, 2017). Right now, the third stage is advancing on track for conveying a big set of specifications all through the following years, among which, three new highlights ought to be seen, that is,

i. the definition of cloud-native VNFs which can fully exploit advantages of cloud computing;
ii. the support for Platform as a Service (PaaS) model which can be used to assist VNFs following cloud-native design principles; and
iii. the support for NFV MANO services across multiple administrative domains (Bo, Xingwei, Keqin, Sajal, & Min, 2018).

4.2 Component of Network Function Virtualization Architecture

The NFV Architecture, according to ETSI, compose of three key elements: Network Function Virtualization Infrastructure (NFVI) layer, NFV Management and Orchestration (NFV MANO) layer, and Virtual Network Function (VNF) layer.

i. NFV Infrastructure (NFVI) layer

NFVI gives essential services to satisfying the targets of NFV. By deploying a set of general-purpose network devices in distributed locations, NFVI can fulfill different service requirements, for example, latency and locality, and reduce the network cost on capital expenses and operational expenses." In view of the general-purpose hardware, NFVI additionally gives a virtualization environment for VNF deployment and execution. NFVI can be additionally partitioned into three particular layers, that is, physical infrastructure, virtualization layer and virtual infrastructure (ESTI, 2014) (Bo, Xingwei, Keqin, Sajal, & Min, 2018).

ii. NFV Management and Orchestration (NFV MANO) layer

The essential obligations of NFV MANO are to deal with the whole virtualized setting inside the framework of NFV; which incorporates virtualization component, hardware resource orchestration, life cycle management of VNF instances, interface management between modules, and so on. "Every one of the obligations are classified into three sections as per ETSI, to be specific, Virtualized Infrastructure Manager (VIM), NFV Orchestrator (NFVO) and VNF Manager (VNFM). In particular, the NFVO is mostly in charge of orchestrating NFVI resources and managing the life cycle of VNFs. In order to provide a network service, different VNFs are orchestrated and chained according to the determination of NFVO. The VNFM is in charge of managing different VNF instances. In any case, one VNF instance is related with one single VNFM, while one VNFM might be doled out to manage different VNF instances. Most VNFMs are intended to suit any sort of VNF and also the management work including VNF instantiation, updating, searching, extension and termination. The VIM manages and controls NFVI resources, for example, network, compute and storage. Additionally, VIM can likewise be tweaked to deal with no less than one particular kind of NFVI resource (e.g., network-only, compute-only or storage-only) by presenting the interfaces to the corresponding resource controllers (ETSI I. S., 2014) (Bo, Xingwei, Keqin, Sajal, & Min, 2018).

iii. Virtual Network Function (VNF) layer

The VNF layer assumes an imperative job in the entire NFV structure. NFV is proposed to abstract the basic Physical Network Functions (PNFs) and finally implement them in the form of software (i.e., VNF). VNFs can give the network functionalities initially provided by proprietary network devices, and are required to be executed on the Commercial-Off-The-Shelf hardware. Moreover, each VNF is made out of different VNF Components (VNFCs) which are overseen by the corresponding Element Managers, that makes up the Element Management System. Physical Network Functions (PNF) provide network functions in physical system, while VNFs assume a similar job in virtual network environment. In such manner, the work used to be done by PNFs can now be replaced by initializing corresponding VNFs. Also, chaining numerous VNFs locating in various places of the network can make up a service chain. In view of the practical requirements of enterprises, the VNF locations can be dynamically chosen (Bo, Xingwei, Keqin, Sajal, & Min, 2018).

4.3 NFV Design Considerations

A number of key considerations are to be met before NFV will be an acceptable solution for telecommunication service provider." These considerations are as follows (Rashid, et al., 2015):

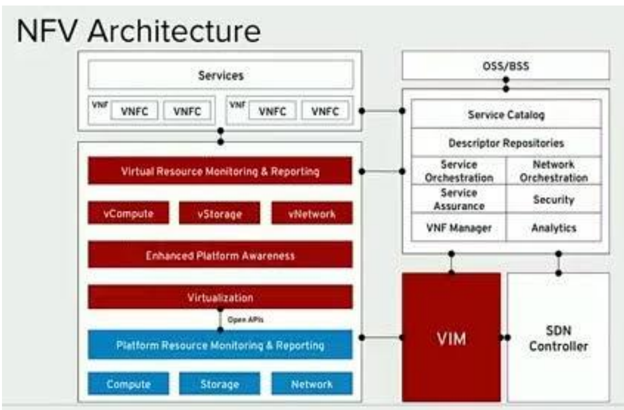

Fig. 4 Network Functions Virtualization Architecture Source: (Google.com, 2018)

- **i. Network Architecture and Performance :** To be worthy, NFV architectures ought to have the capacity to accomplish performance similar to that got from functions running on dedicated hardware." This necessitates every potential bottleneck at all layers of the stack are evaluated and mitigated.
- **ii. Security and Resilience :** The dynamic nature of NFV requests that security innovations, strategies, procedures and practices are installed in its genetic fabric.
- **iii. Reliability and Availability :** In the IT domain, blackouts enduring seconds are tolerable and a client normally initiates retries. "In telecommunications, there is a fundamental service expectation that blackouts will be below the recognizable level (i.e. milliseconds), and service recovery is performed naturally.
- **iv. Support for Heterogeneity :** The primary purpose of NFV depends on breaking the hindrances that outcome from proprietary hardware-based service provision. It is hence unnecessary to refer that transparency and heterogeneity will be at the center of NFV's prosperity.
- **v. Legacy Support :** Backward compatibility will dependably be an issue of high worry for any new innovation. NFV isn't an exemption. The help for both physical and virtual NFs is critical for operators making the progress to NFV as they may need to manage legacy physical assets alongside virtualized functions for some time.
- **vi. Network Scalability and Automation :** In order to accomplish the full advantages of NFV, a scalable and responsive networking solution is essential. In this manner, while meeting the above design considerations, NFV should be acceptably adaptable to have the capacity to help a great many subscribers." Be that as it may, NFV will only scale if all of the functions can be automated. Along these lines, automation of procedures is of central significance to the accomplishment of NFV (Guerzoni, 2012).

4.4 Advantages of Network Function Virtualization

There are a number of advantages offered by NFV, these includes (Sandeep & Prabhu, 2017):

- i. It decreases the cost of equipment and power consumption by merging equipment.
- ii. It allows the abstraction of the underlying hardware, and enables elasticity, scalability and automation, decreasing the time to market for new services.
- iii. It improves quick preparation for new innovation made in network operation.
- iv. More efficiency and easy integration, decreasing the cost of growth.
- v. Services are provided quickly based on demands in scaled up/down.
- vi. It decreases energy consumption of servers and storages.
- vii. "It enables a wide variety of eco-systems and encouraging openness.

4.5 Disadvantages of Network Function Virtualization

There are a number of disadvantages offered by NFV, these includes (Kishore, 2016):

- i. Having to coexist in a cloud-integrated hybrid environment with physical devices.
- ii. Unlike conventional IT environments, NFV requires managing IT in the abstract."
- iii. NFV environments are more dynamic than traditional ones, which might require scaling up with additional features to cope.
- iv. NFV also demands a process realignment so that traditional and virtual infrastructure can be managed simultaneously.

5. Discussions

The association between network function virtualization and cloud computing isn't so far separated. As these two technologies share a typical bond: they are both intended to increase efficiencies and decrease costs, empowering operators to move their infrastructure to enterprise class cloud computing servers. Along these lines, making their network more coordinated, adaptable and responsive. Cloud computing has just been a thundering achievement in most industries, and universally the telecommunication operators are rapidly understanding the value of NFV. It enables the operators to harness the true power of virtual computing by porting their network hardware to the cloud, and operating it remotely.

Organizations can enhance the networking resources effectiveness through network functions virtualization; be that as it may, they can't dispose of provisioning. An operator is still required to provision the virtual machines for the clients. Cloud computing expels the requirement for manual provisioning. "It offers another path for IT service conveyance by giving a client interface to automated, self-service catalogs of standard services, and by utilizing autoscaling to react to increment or decrement in clients' demand.

This decreases the reliance on high cost dedicated and proprietary computing hardware and enables the network to be kept running from shared virtual machines. This cuts down the expense of procuring and deploying hardware, and thusly the capital expenses for the telecom operators descends essentially.

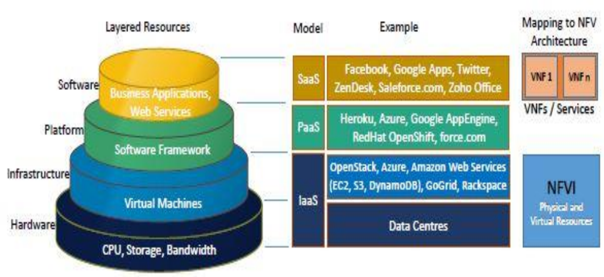

Fig. 5 Comparison between Cloud Computing and Network Functions Virtualization Source: (Google.com, 2018)

6. Conclusion

In this article, we displayed an outline of cloud computing and network functions virtualization technology, illustrated by their service models and design considerations respectively, and synopsis of other key highlights. Cloud computing separates the functionality in computing resources and recreates it in virtual form. While, NFV removes the functionality in networking resources and imitates it in the virtual form. It is imagined that NFV alongside cloud computing, will turn into a basic empowering technology to fundamentally change the manner in which network operators' engineer and adapt their networks." These technologies are being created quickly and are expected to become more robust, sophisticated and affordable in the future. Several major hardware and software organizations are devoting their time and energy to develop the extent of these technologies further. Obviously, all players in the telecommunication industry need to take a gander at these truly, comprehend, and use the preferences and efficiencies that they can get from these.

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