Design and Implementation of IPv4 and IPv6 Provisioning Technologies for VPC Architecture

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***Abstract*—IETF has formally announced IPv6 to be the next standard of Internet Protocol to conquer IPv4 address exhaustion problem. At the same time, the newly risen technologies like Internet of Things (IoT) and AI are mostly built in a cloud native way and deployed in the cloud such as VPC (Virtual Private Cloud). Therefore, in order to support these technologies, VPC are supposed to provide IPv6 Internet connectivity. However, Internet Protocol transfer from IPv4 to IPv6 should deal with the complicated VPC networking architecture and ensure that Internet Protocol must be changed on the fly without the impact on the existing IPv4 services in VPC. To solve these challenges, in this paper the dual IP stack provisioning and resource management technologies for the VPC architecture is designed and implemented to fulfill the near-zero downtime VPC Internet Protocol transfer from the IPv4-only to IPv4/IPv6 dual stack and finally until IPv6-only networking.**

Keywords—IPv4, IPv6, Provisioning, Virtual Private Cloud (VPC), Cloud, IP Pool, Resource, Physical Network Functions (PNF), Virtual Network Function (VNF), Virtualization Infrastructure Management (VIM), Network Functions Virtualization (NFV)

I. Introduction

To solve the IPv4 exhaustion issue, IETF announced IPv6 formally become the next standard of Internet Protocol in 2017. Therefore, in recent, the organizations of government and communication service provider (CSP) over worldwide start to develop IPv6 networking technologies. In 2018, after the largest CSP in Taiwan, Chunghwa Telecom [1], proactively released the mobile network service and broadband network service to support IPv6. IPv6 capability in Taiwan made a success from the rank 65 to rank 4 in the world according to APNIC statistics [2][3]. The ubiquitous capability of IPv6 will quickly applied to the future technologies including IOT applications, smart city, smart home, AI and health care. The future technologies mentioned mostly rely on the features and services of Cloud Native or Virtual Private Cloud (VPC) infrastructure [4]. According to Open Digital Architecture (ODA) proposed by TM forum, the business requirements of modern digital system should take the advantage of exploiting the flexibility of cloud [5]. Hence that makes it important to provide IPv4/IPv6 co-existed connectivity for VPC.

However, there are challenges to develop IPv4/IPv6 co-existed networking in VPC. First, it is difficult to manage IPv4 and IPv6 IP resources due to huge differences between IP format and IP allocation mechanism. Second, one service in VPC is usually composed by many different sub-services, so the management and allocation of resources across VNF, PNF, VIM elements are complicated. Third, because of the high dependency between the elements in VPC. It is challenging to manipulate the IPv6 services on the fly without any impact on current IPv4 services.

In this paper, IPv4 and IPv6 provisioning technologies are proposed in a BSS/OSS system called Cloud BOSS and which is designed and implemented to fulfill the IPv4/IPv6 co-existed networking in VPC. This provisioning technologies include the design of an IP pooling management method which divides the IP resources into different IP pools according to the particular usage purpose. Besides, considering the principles of the IPv6 design, this provisioning technologies adopt the auto-configuration method to generate IP address automatically. Finally, this provisioning technologies are able to coordinate the complicated IPv4/IPv6 co-existed service-level dependency efficiently and change it into resource-level management to provision the heterogeneous elements precisely in VPC.

II. Related Work

Developments in IPv6 technologies have started for years, but IPv6 researches in cloud are still in the beginning. This paper focuses on proposing provisioning technologies in VPC to support IPv6. In 2013, Chunghwa Telecom proposed the hosted private cloud solution in order to provide customers a high available, secure, reliable and flexible on-demand cloud services [6][7]. In the proposed solution, a BSS/OSS system, called Cloud BOSS, integrates and manages all the heterogeneous cloud resources to provide the VPC service. More detailed implementation and capability of Cloud BOSS is described in [8][9]. In 2016, Service Chain Orchestration (SCO) was published [10], Cloud BOSS uses SCO to manage and operate NFV technologies. In this paper, based on these researches, a brand new IPv4 and IPv6 provision technologies is proposed in Cloud BOSS to leverage the both IPv4 and IPv6 networking and monitoring services for VPC. According to the TM forum Open Digital Architecture (ODA) released in 2018, the standard describes the requirements and the design principles of modern digital BSS/OSS, which helps the transformation of CSPs industries to seek Blue Ocean services like digitalize manufacturing, transport, health and city management. IPv4 and IPv6 provisioning technologies in Cloud BOSS follows ODA design principles. The definition of ODA functional architecture is showed in Fig. 1. and stated below.

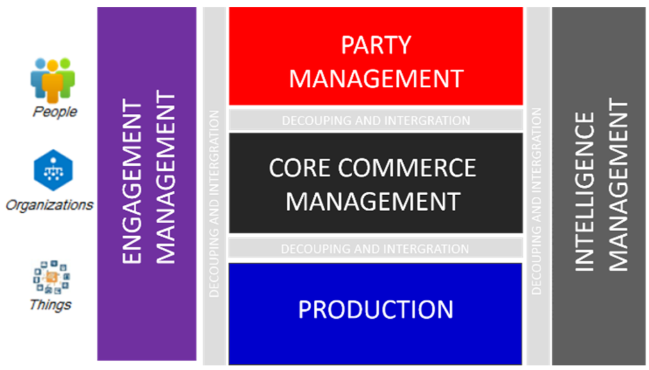

Fig. 1. TM forum Open Digital Architecture(ODA)

ENGAGEMENT MANAGEMENT (EGM): Management for a single coherent customer experience.

PARTY MANAGEMENT (PM): Supporting complex business models.

CORE COMMERCE MANAGEMENT (CCM): Supporting third party and marketplace offers and service composition and orchestration.

PRODUCTION: Abstracting the complexity of infrastructure.

INTELEGENCE MANAGEMENT (IM): Support systems of insight, AI, Machine.

III. PROPOSED PROVSIONING SCHEME

A. *IPv4 and IPv6 co-existed Architecture and Services in VPCs*

In order to provide a complete IPv4/IPv6 co-existed architecture in VPC, nearly all of the elements rubricated in Fig .2. need to be equipped with the dual IPv4 and IPv6 functions. From the view point of elements outside VPC that is outer the blue dotted circle region in Fig. 2., the PNF elements including the security use IPS Protector and DDoS Protector, Internet and Intranet Gateway and Insight Server are pre-configured and enabled with the IPv4 and IPv6 capability. In contrast, at the view point of elements inside VPC, all VMs and VNF elements inside VPC can be applied on demand as services like VPC platform, Subnet Services, Routing service, Firewall service, Server Load Balancer and so on. Then these services will be provisioned dynamically to provide a private and secure cloud for the user. That is to say when user creates the new VPC platform whether a user enables the IPv6 functions or not, Cloud BOSS provisions the IPv6 functionalities ready for the elements like FW-VNF and VR-VNF fixed through the whole life time of VPC platform. The rest of IPv6 elements can be created as user's will like IPv6 subnet, IPv6 SLB-VNF and user VM with IPv6 network interfaces.

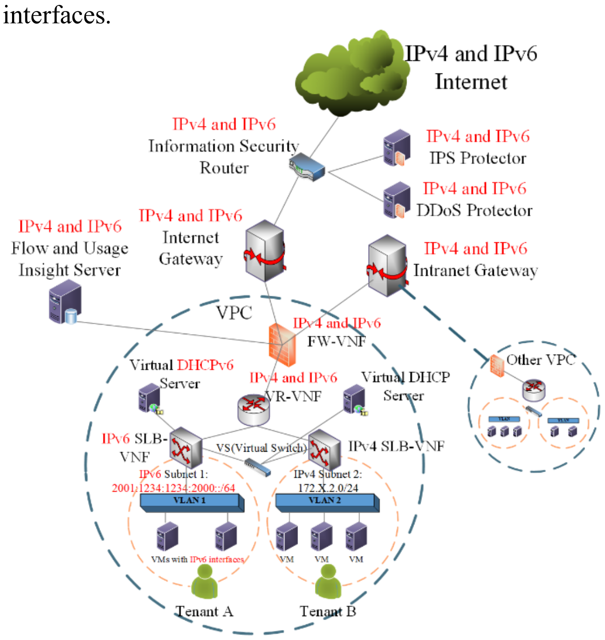

Fig. 2. IPv4 and IPv6 co-existed Architecture and Services in VPC

B. *IPv4 and IPv6 Provisioning Components of Cloud BOSS Alignment to ODA Architecture*

In Fig. 3. Cloud BOSS IPv4 and IPv6 provisioning technologies propose eight components which can be aligned to three related management areas of the ODA, i.e., Core Commerce Management, Production Management and Intelligence Management. The eight components are delivered as the following.

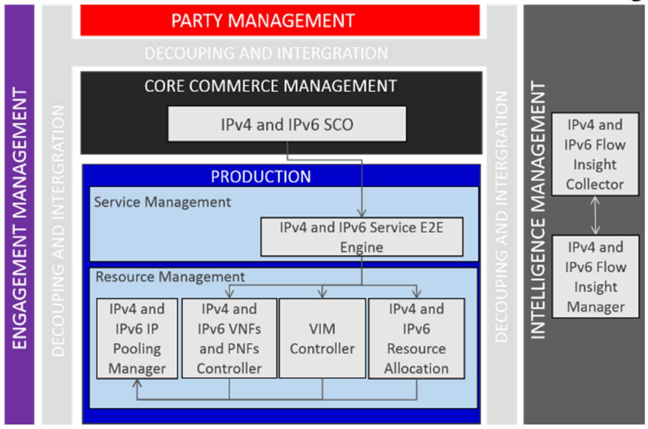

Fig. 3. IPv4 and IPv6 provisioning components of Cloud BOSS Alignment to ODA Architecture

IPv4 and IPv6 Service Chain Orchestration (SCO): SCO manages the life cycle of a service chain which consists of multiple sub-service.

IPv4 and IPv6 Flow Insight Collector (FIC): FIC samples the IPv4 and IPv6 flow data and collects OS performance information of the user VM prior to send to IPv4 and IPv6 Flow Insight Manger

IPv4 and IPv6 Flow Insight Manager (FIM): FIM corroborates with FIC to handle the collected date and display the data to the user and store it.

IPv4 and IPv6 Service E2E Engine (SEE): SEE controls IPv4 or IPv6 service provision steps from end-to-end. In each step SEE is capable of coordinating the resource allocation and communicating with VIM, PNFs, VNFs Controller to configure.

VIM Controller: VIM Controller manages the resource status and manage the life cycle of user's VM, VNF elements, virtual switch and other virtualized node.

IPv4 and IPv6 PNFs and VNFs Controller (PVC): PVC is able to access the PNFs and VNFs networking elements to configure and release settings.

IPv4 and IPv6 IP Pooling Manager (IPM): IPM administers the IPv4 and IPv6 resources distribution according to the particular usage purpose and manages the IP resource status. In the next context, the IP Pooling plan and data model design is further discussed.

C. *IPv4 and IPv6 IP Pooling Plan and Data Model Design*

Fig. 4. states the usage purpose for each IP pool. For the reason of having an effective and efficient IP resources management in VPC, IPM classifies the IPv4 and IPv6 IP

resources into IP pools according to particular usage purpose.

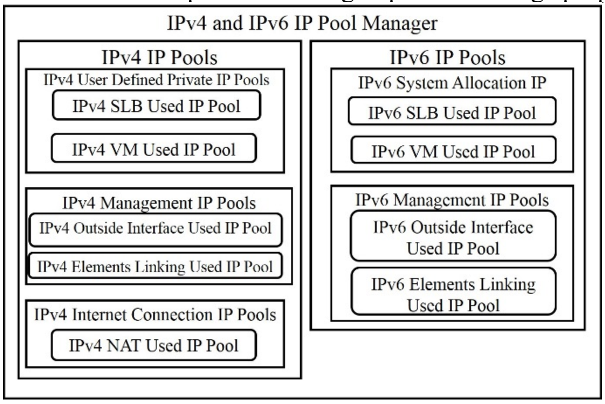

Fig. 4. IPv4 and IPv6 IP Pools by usage purpose

IPv4 SLB Used IP Pool: Belongs to private subnet and is used for SLB service. When user needs to assign a IP address for IPv4 SLB Virtual IP (VIP) which will be allocated from this IP pool.

IPv4 VM Used IP Pool: Belongs to private subnet and is used for VM service. When user needs to assign a IPv4 address for VM IPv4 network interface which will be allocated from this IP pool.

IPv4 Outside Interface Used IP Pool: Belongs to public subnet and is used for Internet service. When user needs to assign a IPv4 address for outside interface of Virtual Firewall or Virtual Router which will be allocated from this IP pool.

IPv4 Elements Linking Used IP Pool: Belongs to private subnet and is used for management. When Cloud BOSS needs to assign a IPv4 address for connection between network elements in VPC which will be allocated from this IP pool.

IPv4 NAT Used IP Pool: Belongs to public subnet and is used for NAT service. When user needs to assign a NAT used IP for user VM to connect to Internet which will be allocated from this IP pool.

IPv6 SLB Used IP Pool: Belongs to public subnet and is used for SLB service. When user needs to assign a IP address for IPv6 SLB VIP which will be allocated from this IP pool.

IPv6 VM Used IP Pool: Belongs to public subnet and is used for VM service. When user needs to assign a IPv6 address for user VM interface, which will be automatically generated by SLAAC and Modified EUI-64 algorithm and allocated from this IP pool.

IPv6 Outside Interface Used IP Pool: Belongs to public subnet and is used for Internet service. When user needs to assign a IPv6 address for outside interface of Virtual Firewall or Virtual Router which will be allocated from this IP pool.

IPv6 Elements Linking Used IP Pool: Belongs to public subnet and is used for management. When Cloud BOSS needs to assign a IPv6 address for connection between network elements in VPC which will be allocated from this IP pool. IP Resource Allocation Scheme

Resource Allocation (RA) component designs a general strategy on IP establishment and allocation in order to maintain the consistence of IP allocation logic and the convenience of configuration on networking elements. But due to the diversity of IPv4 and IPv6 protocol, there are still many details need to handle. TABLE II. displays the difference on IP establishment and allocation in IPv4 and IPv6.

TABLE I. IPv4 AND IPv6 IP POOL AND IP ADDRESS MANAGEMENT METHODS

Management methods		IPv4	IPv6
IP Establishment	*IP pool*	Dynamic	Pre-establish
	IP address	Pre-establish	Dynamic
IP Allocation	*IP address record*	Update status before provision	Add/delete after provision

IV. THE *PRACTICE* USE CASE

A. *Case Study: Apply for a new IPv6 Server Load Balancer (SLB) for VMs*

When the workload of user's VM becomes overloading because of the increasing IPv6 requests, user is recommended for applying a IPv6 Server Load Balancer to add more VMs in VPC for load balancing the workloads of VMs.

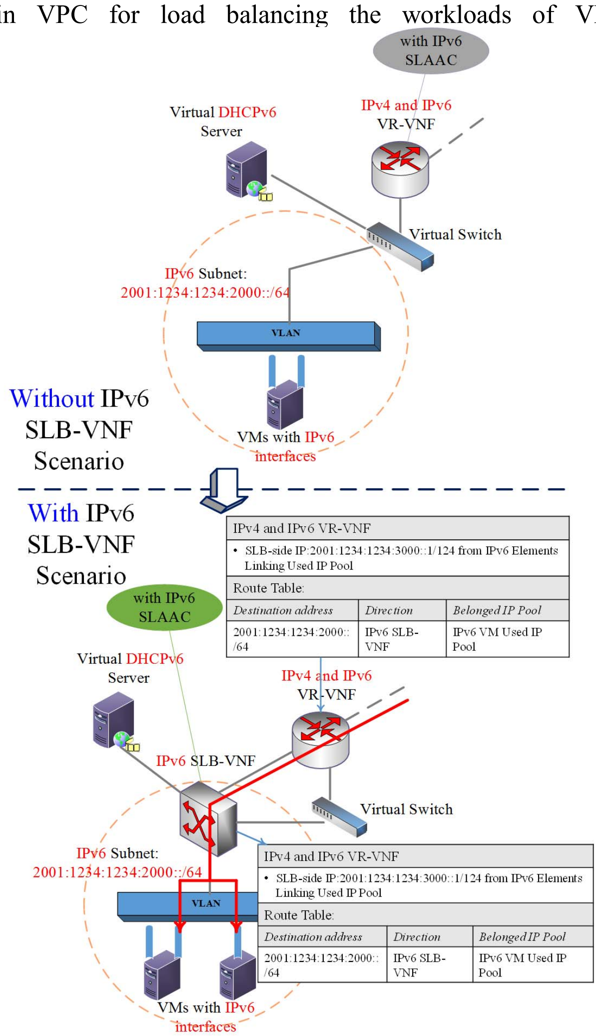

Fig. 5. IPv6 Server Load Balancer establishment use case in VPC

IPv6 SLB-VNF will establish dynamically after applied. With a look at Fig. 5., in the upper side part, there is use scenario without SLB. SLAAC function enables at VR-VNF and Virtual DHCPv6 Server is connected to Virtual Switch for the purpose of the auto-configuration on the user's VM network interface. In contrast, in the down side part in Fig. 5., IPv6 SLB-VNF establishment is supposed to finish provisioning steps like the linking and routing between IPv6 SLB-VNF and VR-VNF, SLAAC setting over SLB-VNF, as well as Virtual DHCPv6 Server movement.

Prior to the provisioning steps start, Resource Allocation (RA) component in Cloud BOSS manages the IP resource allocation at first. For the further explanation how the provisioning steps work, we lists the address example of IP Pools below.

IPv6 SLB Used IP Pool: Available IP in 2001:1234:1234:2000:FFFF::/80

IPv6 VM Used IP Pool: Available IP in 2001:1234:1234:2000::/64 except in 2001:1234:1234:3000:FFFF::1/80

IPv6 Outside Interface Used IP Pool: Available IP 2001:1234:1234:1000::/64

IPv6 Elements Linking Used IP Pool: 2001:1234:1234:3000::1 to 2001:1234:1234:3000::16

RA allocates the north-side interface of SLB-VNF from IPv6 Elements Linking Used IP Pool which is used to connect to VR-VNF. South-side interface of SLB-VNF is allocated from IPv6 VM Used IP Pool. Real IP (RIP) of SLB-VNF allows user to choose from VM interface IP addresses which to be load balanced. VIP allocation strategy is a special design based on the feature of Modified EUI-64 algorithm. Modified EUI-64 algorithm calculates Host ID from MAC address. Because Organizational Unit Identifier (OUI) partial address contained in MAC address is reserved by IEEE, RA can create an extra IPv6 IP pool 2001:1234:1234:2000:FFFF::/80 for IPv6 SLB Used IP Pool from IPv6 subnet 2001:1234:1234:2000::/64 address space.

IPv6 SLB establishment consists of the following provisioning steps.

Step 1: Cloud BOSS configures the SLB-VNF South-Side interface IP: 2001:1234:1234:3000::2/124 which is chosen from IPv6 Elements Linking Used IP Pool.

Step 2 : Cloud BOSS configures route table on SLB-VNF to set the default route policy 0::/0 which is pointed to VR-VNF direction.

Step 3: Cloud BOSS configures the VR-VNF SLB-link interface IP: 2001:1234:1234:3000::1/124 which is chosen from IPv6 Elements Linking Used IP Pool.

Step 4: Cloud BOSS configures route table on VR-VNF to set IPv6 VM Used IP Pool: 2001:1234:1234:2000::/64 routing policy which is pointed to SLB-VNF.

Step 5: Cloud BOSS configures the SLB-VNF South-Side interface IP: 2001:1234:1234:2000::1/64 which is the gateway IP from IPv6 SLB Used IP Pool.

Step 6: Cloud BOSS enables SLAAC setting over SLB-VNF.

Step 7: Cloud BOSS enables Virtual DHCPv6 server and links it to SLB-VNF.

Step 8: Cloud BOSS configures the SLB-VNF VIP: 2001:1234:1234:2000:FFFF::1/80 which is chosen from IPv6 SLB Used IP Pool.

Step 9: User chooses RIP from the VM interface IP which to be load balancing. Then Cloud BOSS assembles the load balance policy and configures to SLB-VNF.

After the completion of the above provisioning steps, IPv6 SLB-VNF finish the establishment procedure. packet is forwarded to IPv6 SLB-VNF and reassigned its destination according to the balancing method configured in SLB-VNF. Finally, it is carried to VS and received by the appropriate virtual machine.

V. Conclusion

IPv6 cloud development is not only to solve the IPv4 address exhaustion issue but also to build up the foundation for the foreseeable new technologies like IoT, AI and so on. In this paper, we presented the IPv4 and IPv6 provisioning technologies to provide Cloud BOSS the capability to manage IPv4/IPv6 coexisted network resources and orchestrate the physical and virtualized mixed cloud architecture effectively. The practice use cases discussed in chapter IV. show that IPv4 and IPv6 services in VPC will provisioned precisely and efficiently even in such complicated IPv4 and IPv6 co-existed environment. Therefore, based on this reliable provisioning technologies, applications deployed on IPv4 VPC could transfer to IPv6-only VPC seamless without impact during the transition period. In 2018, the increasing of IPv6 capable rate of Taiwan is rank 1 in the world, by this significance confidence, IPv6 development in cloud services would be prosperous growth as well in the near future.

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