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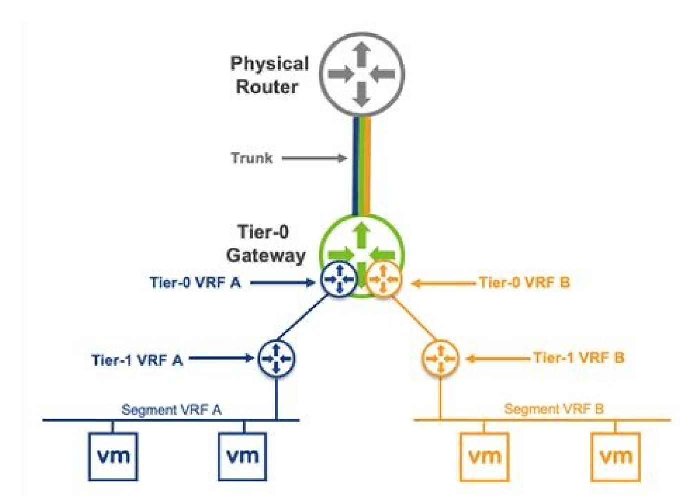

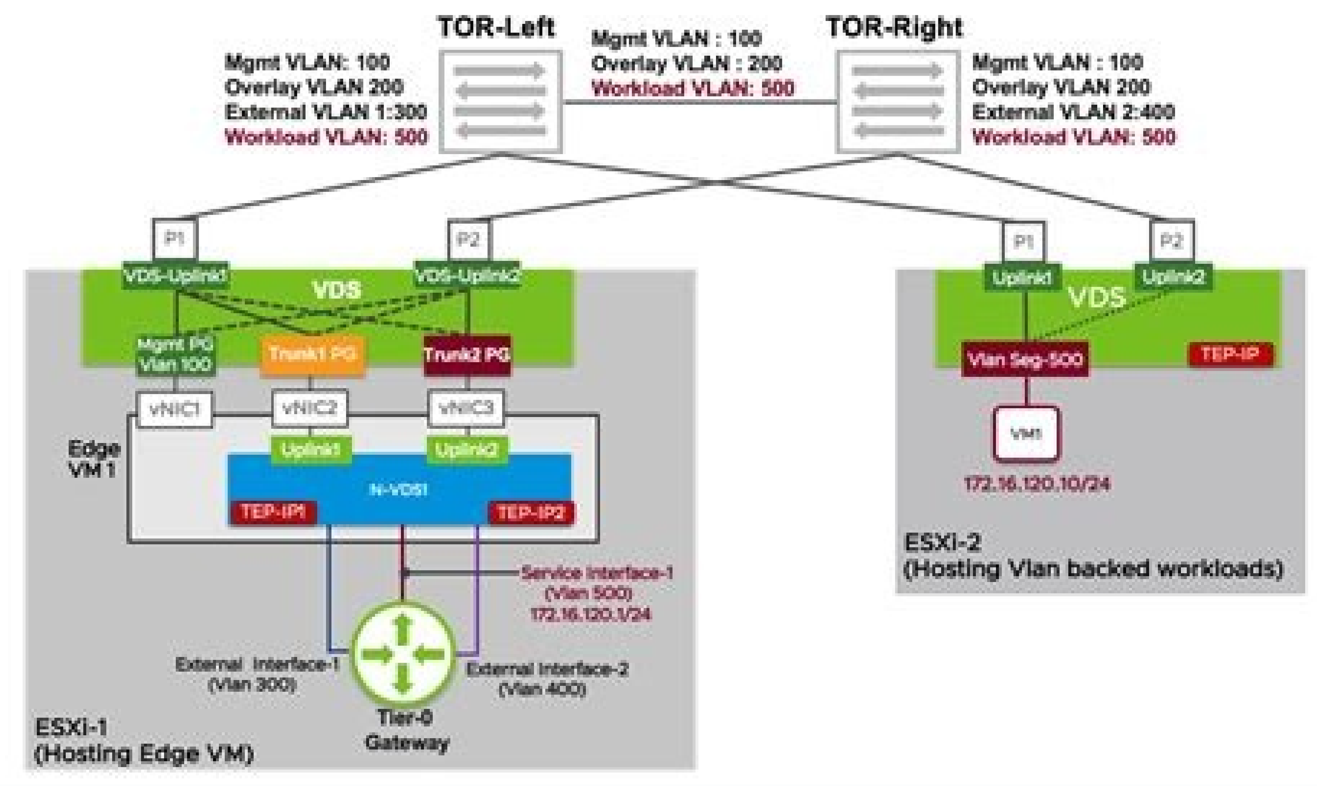

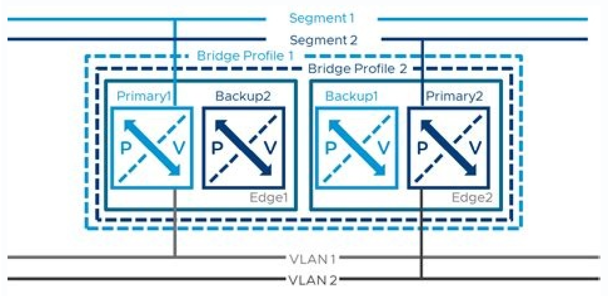

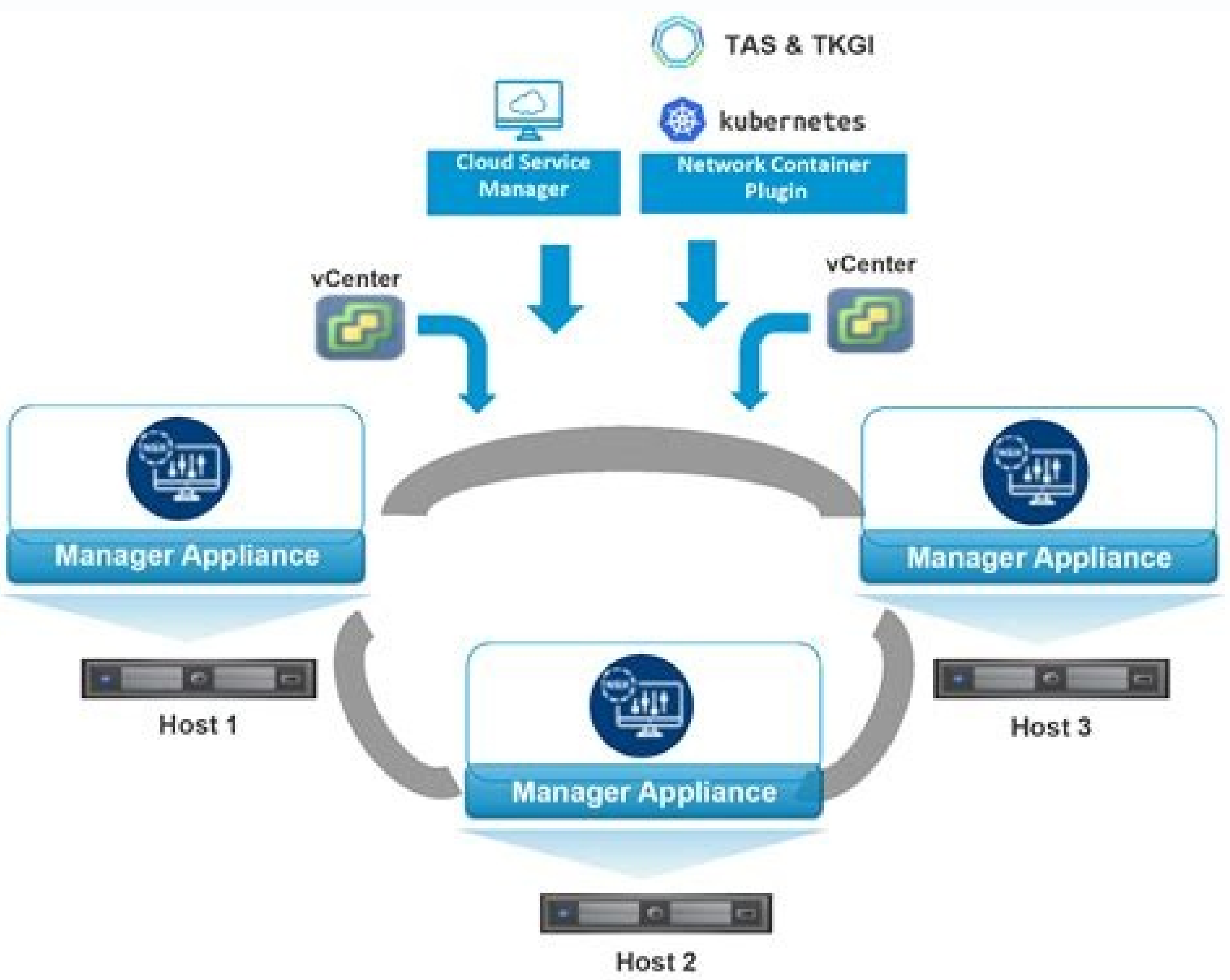

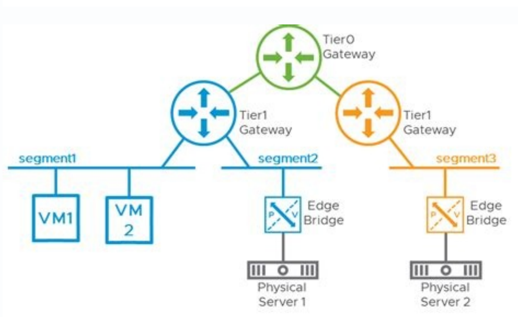

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This document provides guidance and best practices for designing environments that leverage the capabilities of VMware NSX-T®. It is targeted at virtualization and network architects interested in deploying NSX Data Center solutions. 1.1 How to Use This Document and Provide Feedback This document is organized into several chapters. Chapter 2 to 6 explain the architectural building blocks of NSX-T as a full stack solution, providing a detail functioning of NSX-T components, features and scope. They also describe components and functionality utilized for security use cases. These chapters lay the groundwork to help understand and implement the design guidance described in the design chapter. The design chapter (Chapter 7) examines detailed use cases of network virtualization and recommendations of either best practices or leading practices based on the type of use case or design form factor. It offers guidance for a variety of factors including physical infrastructure considerations, compute node requirements, and variably sized environments from small to enterprise scale. This version of design guide we have updated our chapter on performance. This chapter was introduced by a popular request from our loyal customer base in version 2.0 of this document and aims at clarifying the myths vs facts on NSX-T based SDN. This document does not cover installation, and operational monitoring and troubleshooting. For further details, review the complete NSX-T installation and administration guides. A list of additional resources, specific API examples and guidance are included at the end of this document under multiple appendixes. Finally starting with this design guide, readers are encouraged to send a feedback to NSXDesignFeedback_AT_groups_vmware_com (convert to email format). 1.2 Networking and Security Today In the digital transformation era, organizations are increasingly building custom applications to drive core business and gain competitive advantages. The speed with which development teams deliver new applications and capabilities directly impacts the organization's success and bottom line. This exerts increasing pressure on organizations to innovate quickly and makes developers central to this critical mission. As a result, the way developers create apps, and the way IT provides services for those apps, are evolving. Application Proliferation With applications quickly emerging as the new business model, developers are under immense pressure to deliver apps in a record time. This increasing need to deliver more apps in a less time can drive developers to use public clouds or open source technologies. These solutions allow them to write and provision apps in a fraction of the time required with traditional methods. Heterogeneity Application proliferation has given rise to heterogeneous environments, with application workloads being run inside VMs, containers, clouds, and bare metal servers. IT departments must maintain governance, security, and visibility for application workloads regardless of whether they reside on premises, in public clouds, or in clouds managed by third-parties. Cloud-centric Architectures Cloud-centric architectures and approaches to building and managing applications are increasingly common because of their efficient development environments and fast delivery of applications. These cloud architectures can put pressure on networking and security infrastructure to integrate with private and public clouds. Logical networking and security must be highly extensible to adapt and keep pace with ongoing change. Against this backdrop of increasing application needs, greater heterogeneity, and the complexity of environments, IT must still protect applications and data while addressing the reality of an attack surface that is continuously expanding. 1.3 NSX-T Architecture Value and Scope VMware NSX-T is designed to address application frameworks and architectures that have heterogeneous endpoints and technology stacks. In addition to vSphere, these environments may include other hypervisors, containers, bare metal operating systems, and public clouds. NSX-T allows IT and development teams to choose the technologies best suited for their particular applications. NSX-T is also designed for management, operations, and consumption by development organizations in addition to IT. Figure 1-1: NSX-T Anywhere Architecture The NSX-T architecture is designed around four fundamental attributes. Figure 1-1: NSX-T Anywhere Architecture depicts the universality of those attributes that spans from any site, to any cloud, and to any endpoint device. This enables greater decoupling, not just at the infrastructure level (e.g., hardware, hypervisor), but also at the public cloud (e.g., AWS, Azure) and container level (e.g., K8, Pivotal); all while maintaining the four key attributes of platform implemented across the domains. NSX-T architectural value and characteristics of NSX-T architecture include: Policy and Consistency: Allows policy definition once and realizable end state via RESTful API, addressing requirements of today's automated environments. NSX-T maintains unique and multiple inventories and controls to enumerate desired outcomes across diverse domains. Networking and Connectivity: Allows consistent logical switching and distributed routing with multiple vSphere and KVM nodes, without being tied to compute manager/domain. The connectivity is further extended across containers and clouds via domain specific implementation while still providing connectivity across heterogeneous endpoints. Security and Services: Allows a unified security policy model as with networking connectivity. This enables implementation of services such as load balancer, Edge (Gateway) Firewall, Distributed Firewall, and Network Address Translation cross multiple compute domains. Providing consistent security between VMs and container workloads is essential to assuring the integrity of the overall framework set forth by security operations. Visibility: Allows consistent monitoring, metric collection, and flow tracing via a common toolset across compute domains. Visibility is essential for operationalizing mixed workloads – VM and container-centric –typically both have drastically different tools for completing similar tasks. These attributes enable the heterogeneity, app-alignment, and extensibility required to support diverse requirements. Additionally, NSX-T supports DPDK libraries that offer line-rate stateful services. Heterogeneity In order to meet the needs of heterogeneous environments, a fundamental requirement of NSX-T is to be compute-manager agnostic. As this approach mandates support for multi-hypervisor and/or multi-workloads, a single NSX manager's manageability domain can span multiple vCenters. When designing the management plane, control plane, and data plane components of NSX-T, special considerations were taken to enable flexibility, scalability, and performance. The management plane was designed to be independent of any compute manager, including vSphere. The VMware NSX-T® Manager™ is fully independent; management of the NSX based network functions are accesses directly – either programmatically or through the GUI. The control plane architecture is separated into two components – a centralized cluster and an endpoint-specific local component. This separation allows the control plane to scale as the localized implementation – both data plane implementation and security enforcement – is more efficient and allows for heterogeneous environments. The data plane was designed to be normalized across various environments. NSX-T introduces a host switch that normalizes connectivity among various compute domains, including multiple VMware vCenter® instances, KVM, containers, and other off premises or cloud implementations. This switch is referred as N-VDS. The functionality of the N-VDS switch was fully implemented in the ESXi VDS 7.0, which allows ESXi customers to take advantage of full NSX-T functionality without having to change VDS. Regardless of implementation, data plane connectivity is normalized across all platforms, allowing for a consistent experience. App-aligned NSX-T was built with the application as the key construct. Regardless of whether the app was built in a traditional monolithic model or developed in a newer microservices application framework, NSX-T treats networking and security consistently. This consistency extends across containers and multi-hypervisors on premises, then further into the public cloud. This functionality is first available for Amazon Web Services (AWS), Microsoft Azure and will extend to other clouds as well on premises connectivity solutions. In turn enabling developers to focus on the platform that provides the most benefit while providing IT operational consistency across networking and security platforms. Containers and Cloud Native Application Integrations with NSX-T In an age where a new application is directly tied to business gains, delays in application deployment translates to lost revenue or business opportunity. The current era of digital transformation challenges IT in addressing directives to normalize security of applications and data, increase speed of delivery, and improve application availability. IT administrators realize that a new approach must be taken to support business needs and meet timelines. Architecturally solving the problem by specifically defining connectivity, security, and policy as a part of application lifecycle is essential. Programmatic and automatic creation of network and switching segments based on application driven infrastructure is the only way to meet the requirements of these newer architectures. NSX-T is designed to address the needs of these emerging application frameworks and architectures with heterogeneous endpoints and technology stacks. NSX allows IT and development teams to choose the technologies best suited for their particular applications or use case without compromising consistent security and operations. NSX provides a common framework to manage and increase visibility of environments that contain everything from physical servers to VMs and containers. As developers embrace newer technologies like containers and the percentage of workloads running in public clouds increases, network virtualization must expand to offer a full range of networking and security services (e.g., LB, NAT, DFW, etc.) native in these environments. NSX Container solutions provide networking, security, visibility, and Load Balancing services for container-based applications based on Kubernetes (Openshift and Tanzu) as well as managed Kubernetes offerings running in the public cloud (Amazon's Elastic Kubernetes Service – EKS, Amazon Kubernetes Service – AKS, and Google Kubernetes Engine GKE). The NSX Portfolio also consists of solutions like "NSX Container Networking with Project Antrea" and Tanzu Service Mesh which help extend NSX to IaaS and CaaS platforms like Managed Public Clouds or Far Edge Scenarios where there is no underlying NSX dataplane. Figure 1-2: Programmatic Integration with Various PaaS and CaaS The NSX-T Container Plug-in (NCP) is built to provide direct integration with a number of environments where container-based applications could reside. The NSX Container Plugin leverages the Container Network Interface (CNI) to interface with the container and allows NSX-T to orchestrate networking, policy and load balancing for containers. Container orchestrators, such as Kubernetes (i.e., k8s) are ideal for NSX-T integration. Solutions that contain enterprise distributions of k8s, notably Tanzu and RedHat Open Shift support solutions with NSX-T. Additionally, NSX-T supports integration with PaaS solutions like Pivotal Cloud Foundry. Please refer Reference Design Guide for PAS and PKS with VMware NSX-T Data Center for detail guidance. Multi-Cloud Architecture and NSX-T When extended to workloads in public cloud, NSX-T provides a single pane of glass for networking and security policy management across private and multiple public clouds. NSX-T also provides full topology control over switching and routing in overlay mode and abstracts the limitations of underlying cloud provider networks. From the visibility perspective, it provides a view into public cloud inventory such as VMs (e.g., instances) and networks (e.g., VPCs, VNETs). Since the same NSX-T deployment is managing workloads in public cloud, the entire infrastructure can be consistently operated on day two. Figure 1-3: Multi-cloud Architecture with NSX-T The Cloud Service Manager provides inventory view across multiple clouds, multiple Public Cloud Accounts, and Multiple VPCs/VNETs across multiple regions. The NSX-T Manager deployed in Datacenter provides policy consistency across multiple cloud deployments, including a mix of public and private clouds. The Public Cloud Gateway provides a localized NSX control plane in each Public Cloud and can be shared between multiple VPCs/VNETs. Starting with NSX-T 2.5 release, NSX Cloud supports two modes of operations - The Native Cloud Enforced Mode and NSX Enforced Mode. When using the Native Cloud Enforced mode, NSX Policies are translated to Native Cloud Constructs such as Security Groups (in AWS) or combination of Network Security Group/Application Security Groups (in Azure). In NSX Enforced Mode (which was the only mode available in NSX-T 2.4 and prior), the NSX policies are enforced using NSX Tools which is deployed in each Cloud instance. Mix mode deployment is possible, and the mode is chosen at a VPC/VNET level. In other words, a single pair of Public Cloud Gateways can manage few VPCs in NSX Enforced mode and others in Native Cloud Enforced mode. This provides customers with greatest choice of deployment mode while reducing the footprint in Public Cloud, thus saving operational costs while maximizing cross-cloud consistency. Additionally, NSX-T 2.5 onward, native cloud service endpoints (RDS, ELB, Azure LB, etc.) are discovered automatically and can be used in NSX-T DFW policy. Customer does not need to find the endpoint IPs manually while creating these policies. Architecturally, the Public Cloud Gateway is responsible for discovery of cloud VMs/service endpoints as well as the realization of policies in both modes of operation. In Native Cloud Enforced Mode, NSX Provides common management plane for configuring rich micro-segmentation policies across multiple public clouds. When using NSX Enforced Mode, the Public Cloud Gateway also provides services such as VPN, NAT and Edge Firewall, similar to an on-premises NSX-T Edge. NSX Enforced mode further allows each cloud based VM instance additional distributed data plane benefits including logical switching, logical routing and monitoring features such as syslog, port-mirroring, IPFIX, etc -all the while allowing customers to follow cloud providers best practices for designing network topologies. For further information on how NSX-T is benefiting in cloud workload visit NSXCLOUD and explore. Extensible The key architectural tenets of heterogeneity and app-alignment are inherently properties of extensibility, but full extensibility requires more. Extensibility also means the ability to support multi-tenant and domain environments along with integration into the DevOps workflow. NSX-T reproduces the complete set of networking services (e.g., switching, routing, firewalling, load balancing, QoS) in software. These services can be programmatically assembled in arbitrary combinations to produce unique, isolated virtual networks in a matter of seconds. NSX-T works by implementing three separate but integrated planes: management, control, and data. The three planes are implemented as sets of processes, modules, and agents residing on two types of nodes: manager appliance and transport. Figure 2-1: NSX-T Architecture and Components 2.1 Management Plane and Control Plane 2.1.1 Management Plane The management plane provides an entry point to the system for API as well NSX-T graphical user interface. It is responsible for maintaining user configuration, handling user queries, and performing operational tasks on all management, control, and data plane nodes. The NSX-T Manager implements the management plane for the NSX-T ecosystem. It provides an aggregated system view and is the centralized network management component of NSX-T. NSX-T Manager provides the following functionality: ● Serves as a unique entry point for user configuration via RESTful API (CMP, automation) or NSX-T user interface. ● Responsible for storing desired configuration in its database. The NSX-T Manager stores the final configuration request by the user for the system. This configuration will be pushed by the NSX-T Manager to the control plane to become a realized configuration (i.e., a configuration effective in the data plane). ● Retrieves the desired configuration in addition to system information (e.g., statistics). ● Provides ubiquitous connectivity, consistent enforcement of security and operational visibility via object management and inventory collection and for multiple compute domains – up to 16 vCenters, container orchestrators (TAS/TKGI & OpenShift) and clouds (AWS and Azure) Data plane components or transport node run a management plane agent (MPA) that connects them to the NSX-T Manager. 2.1.2 Control Plane The control plane computes the runtime state of the system based on configuration from the management plane. It is also responsible for disseminating topology information reported by the data plane elements and pushing stateless configuration to forwarding engines. NSX-T splits the control plane into two parts: ● Central Control Plane (CCP) – The CCP is implemented as a cluster of virtual machines called CCP nodes. The cluster form factor provides both redundancy and scalability of resources. The CCP is logically separated from all data plane traffic, meaning any failure in the control plane does not affect existing data plane operations. User traffic does not pass through the CCP Cluster. ● Local Control Plane (LCP) – The LCP runs on transport nodes. It is adjacent to the data plane it controls and is connected to the CCP. The LCP is responsible for programing the forwarding entries and firewall rules of the data plane. 2.1.3 NSX Manager Appliance Instances of the NSX Manager and NSX Controller are bundled in a virtual machine called the NSX Manager Appliance. In the releases prior to 2.4, there were separate appliances based on the roles, one management appliance and 3 controller appliances, so total four appliances to be deployed and managed for NSX. Starting 2.4, the NSX manager, NSX policy manager and NSX controller elements will co-exist within a common VM. Three unique NSX appliance VMs are required for cluster availability. NSX-T relies on a cluster of three such NSX Manager Appliances for scaling out and for redundancy. This three-node cluster relies on a majority of the appliances in the cluster to be available and as such, attention should be paid to placement of these appliances for availability The NSX-T Manager stores all of its information in an in-memory database immediately which is synchronized across the cluster and written to disk, configuration or read operations can be performed on any appliance. The performance requirements of the NSX Manager Appliance's disk is significantly reduced as most operations occur in memory. The benefits with this converged manager appliance include less management overhead with reduced appliances to manage. And a potential reduction in the total amount of resources (CPU, memory and disk). With the converged manager appliance, one only need to consider the appliance sizing once. Figure 2-2: NSX Manager and Controller Consolidation Each appliance has a dedicated IP address and its manager process can be accessed directly or through a load balancer. Optionally, the three appliances can be configured to maintain a virtual IP address which will be serviced by one appliance selected among the three. The design consideration of NSX-T Manager appliance is further discussed at the beginning of the beginning of the chapter 7. 2.2 Data Plane The data plane performs stateless forwarding or transformation of packets based on tables populated by the control plane. It reports topology information to the control plane and maintains packet level statistics. [illegible] represented by a dedicated Logical Port, as shown in the diagram below: Figure 3-20: Primary Edge Bridge forwarding traffic between segment and VLAN When associating a segment to a Bridge Profile, the user can specify the VLAN ID for the VLAN traffic as well as the physical port that will be used on the Edge for sending/receiving this VLAN traffic. At the time of the creation of the Bridge Profile, the user can also select the failover mode. In the preemptive mode, the Bridge on the primary Edge will always become the active bridge forwarding traffic between overlay and VLAN as soon as it is available, usurping the function from an active backup. In the non-preemptive mode, the Bridge on the primary Edge will remain standby should it become available when the Bridge on the backup Edge is already active. 3.3.1.4 Edge Bridge Firewall The traffic leaving and entering a segment via a Bridge is subject to the Bridge Firewall. Rules are defined on a per-segment basis and are defined for the Bridge as a whole, i.e. they apply to the active Bridge instance, irrespective of the Edge on which it is running. Figure 3-21: Edge Bridge Firewall The firewall rules can leverage existing NSX-T grouping constructs, and there is currently a single firewall section available for those rules. 3.3.1.5 Seamless integration with NSX-T gateways This part requires understanding of Tier-0 and Tier-1 gateway and refer to the Logical Routing chapter for further understanding about Tier-0 and Tier-1 gateways. Routing and bridging seamlessly integrate. Distributed routing is available to segments extended to VLAN by a Bridge. The following diagram is a logical representation of a possible configuration leveraging T0 and T1 gateways along with Edge Bridges. Figure 3-22: Integration with routing In this above example, VM1, VM2, Physical Servers 1 and 2 have IP connectivity. Remarkably, through the Edge Bridges, Tier-1 or Tier-0 gateways can act as default gateways for physical devices. Note also that the distributed nature of NSX-T routing is not affected by the introduction of an Edge Bridge. ARP requests from physical workload for the IP address of an NSX router acting as a default gateway will be answered by the local distributed router on the Edge where the Bridge is active. The logical routing capability in the NSX-T platform provides the ability to interconnect both virtual and physical workloads deployed in different logical L2 networks. NSX-T enables the creation of network elements like segments (Layer 2 broadcast domains) and gateways (routers) in software as logical constructs and embeds them in the hypervisor layer, abstracted from the underlying physical hardware. Since these network elements are logical entities, multiple gateways can be created in an automated and agile fashion. The previous chapter showed how to create segments; this chapter focuses on how gateways provide connectivity between different logical L2 networks. Figure 4-1: Logical and Physical View of Routing Services shows both logical and physical view of a routed topology connecting segments/logical switches on multiple hypervisors. Virtual machines "Web1" and "Web2" are connected to "overlay Segment 1" while "App1" and "App2" are connected to "overlay Segment 2". Figure 4-1: Logical and Physical View of Routing Services In a data center, traffic is categorized as East-West (E-W) or North-South (N-S) based on the origin and destination of the flow. When virtual or physical workloads in a data center communicate with the devices external to the data center (e.g., WAN, Internet), the traffic is referred to as North-South traffic. The traffic between workloads confined within the data center is referred to as East-West traffic. In modern data centers, more than 70% of the traffic is East-West. For a multi-tiered application where the web tier needs to talk to the app tier and the app tier needs to talk to the database tier and, these different tiers sit in different subnets. Every time a routing decision is made, the packet is sent to a physical router. Traditionally, a centralized router would provide routing for these different tiers. With VMs that are hosted on same the ESXi or KVM hypervisor, traffic will leave the hypervisor multiple times to go to the centralized router for a routing decision, then return to the same hypervisor; this is not optimal. NSX-T is uniquely positioned to solve these challenges as it can bring networking closest to the workload. Configuring a Gateway via NSX-T Manager instantiates a local distributed gateway on each hypervisor. For the VMs hosted (e.g., "Web 1", "App 1") on the same hypervisor, the E-W traffic does not need to leave the hypervisor for routing. 4.1 Single Tier Routing NSX-T Gateway provides optimized distributed routing as well as centralized routing and services like NAT, AVI Load balancer, DHCP server etc. A single tier routing topology implies that a Gateway is connected to segments southbound providing E-W routing and is also connected to physical infrastructure to provide N-S connectivity. This gateway is referred to as Tier-0 Gateway. Tier-0 Gateway consists of two components: distributed routing component (DR) and centralized services routing component (SR). 4.1.1 Distributed Router (DR) A DR is essentially a router with logical interfaces (LIFs) connected to multiple subnets. It runs as a kernel module and is distributed in hypervisors across all transport nodes, including Edge nodes. The traditional data plane functionality of routing and ARP lookups is performed by the logical interfaces connecting to the different segments. Each LIF has a vMAC address and an IP address being the default IP gateway for its connected segment. The IP address is unique per LIF and remains the same everywhere the segment exists. The vMAC associated with each LIF remains constant in each hypervisor, allowing the default gateway IP and MAC addresses to remain the same during vMotion. The left side of Figure 4-2: E-W Routing with Workloads on the Same Hypervisor shows a logical topology with two segments, "Web Segment" with a default gateway of 172.16.10.1/24 and "App Segment" with a default gateway of 172.16.20.1/24 are attached to Tier-0 Gateway. In the physical topology view on the right, VMs are shown on two hypervisors, "HV1" and "HV2". A distributed routing (DR) component for this Tier-0 Gateway is instantiated as a kernel module and will act as a local gateway or first hop router for the workloads connected to the segments. Please note that the DR is not a VM and the DR on both hypervisors has the same IP addresses. Figure 4-2: E-W Routing with Workloads on the Same Hypervisor East-West Routing - Distributed Routing with Workloads on the Same Hypervisor In this example, "Web1" VM is connected to "Web Segment" and "App1" is connected to "App-Segment" and both VMs are hosted on the same hypervisor. Since "Web1" and "App1" are both hosted on hypervisor "HV1", routing between them happens on the DR located on that same hypervisor. Figure 4-3: Packet Flow between two VMs on Same Hypervisor presents the logical packet flow between two VMs on the same hypervisor. Figure 4-3: Packet Flow between two VMs on Same Hypervisor "Web1" (172.16.10.11) sends a packet to "App1" (172.16.20.11). The packet is sent to the default gateway interface (172.16.10.1) for "Web1" located on the local DR. The DR on "HV1" performs a routing lookup which determines that the destination subnet 172.16.20.0/24 is a directly connected subnet on "LIF2". A lookup is performed in the "LIF2" ARP table to determine the MAC address associated with the IP address for "App1". If the ARP entry does not exist, the controller is queried. If there is no response from controller, an ARP request is flooded to learn the MAC address of "App1". Once the MAC address of "App1" is learned, the L2 lookup is performed in the local MAC table to determine how to reach "App1" and the packet is delivered to the App1 VM. The return packet from "App1" follows the same process and routing would happen again on the local DR. In this example, neither the initial packet from "Web1" to "App1" nor the return packet from "App1" to "Web1" left the hypervisor. East-West Routing - Distributed Routing with Workloads on Different Hypervisor In this example, the target workload "App2" differs as it rests on a hypervisor named "HV2". If "Web1" needs to communicate with "App2", the traffic would have to leave the hypervisor "HV1" as these VMs are hosted on two different hypervisors. Figure 4-4: E-W Packet Flow between two Hypervisors shows a logical view of topology, highlighting the routing decisions taken by the DR on "HV1" and the DR on "HV2". When "Web1" sends traffic to "App2", routing is done by the DR on "HV1". The reverse traffic from "App2" to "Web1" is routed by DR on "HV2". Routing is performed on the hypervisor attached to the source VM. Figure 4-4: E-W Packet Flow between two Hypervisors Figure 4-5: End-to-end E-W Packet Flow shows the corresponding physical topology and packet walk from "Web1" to "App2". Figure 4-5: End-to-end E-W Packet Flow "Web1" (172.16.10.11) sends a packet to "App2" (172.16.20.12). The packet is sent to the default gateway interface (172.16.10.1) for "Web1" located on the local DR. Its L2 header has the source MAC as "MAC1" and destination MAC as the vMAC of the DR. This vMAC will be the same for all LIFs. The routing lookup happens on the HV1 DR, which determines that the destination subnet 172.16.20.0/24 is a directly connected subnet on "LIF2". A lookup is performed in the "LIF2" ARP table to determine the MAC address associated with the IP address for "App2". This destination MAC, "MAC2", is learned via the remote HV2 TEP 20.20.20.20. HV1 TEP encapsulates the original packet and sends it to the HV2 TEP with a source IP address of 10.10.10.10 and destination IP address of 20.20.20.20 for the encapsulating packet. The destination virtual network identifier (VNI) in the Geneve encapsulated packet belongs to "App Segment". HV2 TEP 20.20.20.20 decapsulates the packet, removing the outer header upon reception. It performs an L2 lookup in the local MAC table associated with "LIF2". Packet is delivered to "App2" VM. The return packet from "App2" destined for "Web1" goes through the same process. For the return traffic, the routing lookup happens on the HV2 DR. This represents the normal behavior of the DR, which is to always perform routing on the DR instance running in the kernel of the hypervisor hosting the workload that initiates the communication. After the routing lookup, the packet is encapsulated by the HV2 TEP and sent to the remote HV1 TEP. The HV1 decapsulates the Geneve packet and delivers the encapsulated frame from "App2" to "Web1". 4.1.2 Services Router East-West routing is completely distributed in the hypervisor, with each hypervisor in the transport zone running a DR in its kernel. However, some services of NSX-T are not distributed, due to its locality or stateful nature such as: ● Physical infrastructure connectivity (BGP Routing with Address Families – VRF lite) ● NAT ● DHCP server ● VPN ● Gateway Firewall ● Bridging ● Service Interface ● Metadata Proxy for OpenStack A services router (SR) is instantiated on an edge cluster when a service is enabled that cannot be distributed on a gateway. A centralized pool of capacity is required to run these services in a highly available and scaled-out fashion. The appliances where the centralized services or SR instances are hosted are called Edge nodes. An Edge node is the appliance that provides connectivity to the physical infrastructure. Left side of Figure 4-6: Logical Router Components and Interconnection shows the logical view of a Tier-0 Gateway showing both DR and SR components when connected to a physical router. Right side of Figure 4-6: Logical Router Components and Interconnection shows how the components of Tier-0 Gateway are realized on Compute hypervisor and Edge node. Note that the compute host (i.e. HV1) has just the DR component and the Edge node shown on the right has both the SR and DR components. SR/DR forwarding table merge has been done to address future use-cases. SR and DR functionality remains the same after SR/DR merge in NSX-T 2.4 release, but with this change SR has direct visibility into the overlay segments. Notice that all the overlay segments are attached to the SR as well. Figure 4-6: Logical Router Components and Interconnection A Tier-0 Gateway can have following interfaces: ● External Interface – Interface connecting to the physical infrastructure/router. Static routing and BGP are supported on this interface. This interface was referred to as uplink interface in previous releases. This interface can also be used to extend a VRF (Virtual routing and forwarding instance) from the physical networking fabric into the NSX domain. ● Service Interface: Interface connecting VLAN segments to provide connectivity and services to VLAN backed physical or virtual workloads. Service interface can also be connected to overlay segments for Tier-1 standalone load balancer use-cases explained in Load balancer Chapter 6 . This interface was referred to as centralized service port (CSP) in previous releases. Note that a gateway must have a SR component to realize service interface. NSX-T 3.0 supports static and dynamic routing over this interface. ● Linked Segments – Interface connecting to an overlay segment. This interface was referred to as downlink interface in previous releases. Static routing is supported over that interface ● Intra-Tier Transit Link (Internal link between the DR and SR). A transit overlay segment is auto plumbed between DR and SR and each end gets an IP address assigned in 169.254.0.0/24 subnet by default. This address range is configurable only when creating the Tier-0 gateway. As mentioned previously, connectivity between DR on the compute host and SR on the Edge node is auto plumbed by the system. Both the DR and SR get an IP address assigned in 169.254.0.0/24 subnet by default. The management plane also configures a default route on the DR with the next hop IP address of the SR's intra-tier transit link IP. This allows the DR to take care of E-W routing while the SR provides N-S connectivity. North-South Routing by SR Hosted on Edge Node From a physical topology perspective, workloads are hosted on hypervisors and N-S connectivity is provided by Edge nodes. If a device external to the data center needs to communicate with a virtual workload hosted on one of the hypervisors, the traffic would have to come to the Edge nodes first. This traffic will then be sent on an overlay network to the hypervisor hosting the workload. Figure 4-7: N-S Routing Packet Flow shows the traffic flow from a VM in the data center to an external physical infrastructure. Figure 4-7: N-S Routing Packet Flow Figure 4-8: End-to-end Packet Flow – Application "Web1" to External shows a detailed packet walk from data center VM "Web1" to a device on the L3 physical infrastructure. As discussed in the E-W routing section, routing always happens closest to the source. In this example, eBGP peering has been established between the physical router interface with the IP address 192.168.240.1 and the Tier-0 Gateway SR component hosted on the Edge node with an external interface IP address of 192.168.240.3. Tier-0 Gateway SR has a BGP route for 192.168.100.0/24 prefix with a next hop of 192.168.240.1 and the physical router has a BGP route for 172.16.10.0/24 with a next hop of 192.168.240.3. Figure 4-8: End-to-end Packet Flow – Application "Web1" to External "Web1" (172.16.10.11) sends a packet to 192.168.100.10. The packet is sent to the "Web1" default gateway interface (172.16.10.1) located on the local DR. The packet is received on the local DR. DR doesn't have a specific connected route for 192.168.100.0/24 prefix. The DR has a default route with the next hop as its corresponding SR, which is hosted on the Edge node. The HV1 TEP encapsulates the original packet and sends it to the Edge node TEP with a source IP address of 10.10.10.10 and destination IP address of 30.30.30.30. The Edge node is also a transport node. It will encapsulate/decapsulate the traffic sent to or received from compute hypervisors. The Edge node TEP decapsulates the packet, removing the outer header prior to sending it to the SR. The SR performs a routing lookup and determines that the route 192.168.100.0/24 is learned via external interface with a next hop IP address 192.168.240.1. The packet is sent on the VLAN segment to the physical router and is finally delivered to 192.168.100.10. Observe that routing and ARP lookup happens on the DR hosted on the HV1 hypervisor to determine that the packet must be sent to the SR. On the edge node, the packet is directly sent to the SR after the tunnel encapsulation has been removed. Figure 4-9: End-to-end Packet Flow – External to Application "Web1" follows the packet walk for the reverse traffic from an external device to "Web1". Figure 4-9: End-to-end Packet Flow – External to Application "Web1" An external device (192.168.100.10) sends a packet to "Web1" (172.16.10.11). The packet is routed by the physical router and sent to the external interface of Tier-0 Gateway hosted on Edge node. A single routing lookup happens on the Tier-0 Gateway SR which determines that 172.16.10.0/24 is a directly connected subnet on "LIF1". A lookup is performed in the "LIF1" ARP table to determine the MAC address associated with the IP address for "Web1". This destination MAC "MAC1" is learned via the remote TEP (step2). The load-balancer being a centralized service, it is instantiated on a Tier-1 gateway SR (Service Router). The drawback from this model is that, because the Tier-1 gateway now has a centralized component, East-West traffic for Segments behind different Tier-1 will be pinned to an Edge node in order to get to the SR. This is the case even for traffic that does not need to go through the load-balancer. 6.2.2 One-arm load balancing In one-arm load balancing mode, both client traffic (client traffic to the load-balancer VIP) and server traffic (load-balancer to server) use the same load balancer interface. In that case, LB-SNAT will be used to make sure that the traffic from the servers back to the client indeed go through the load-balancer. There are two variations over this one-arm load-balancing scenario: a case where both clients and servers are on the same subnet and a case where they are on different subnets. For both cases the solution leverages load-balancer source NAT in order to make sure that traffic from a server to its clients is directed to the load-balancer. As a result, the server will not see the real IP address of the clients. Note that the load-balancer can inject an "X-Forwarded-For" header for HTTP/HTTPS traffic in order to work around this issue. 6.2.2.1 Clients and servers on the same subnet In the design below, the clients and servers are on the same Tier-1 gateway downlink. Figure 6-6: One-Arm Load Balancing with Clients and Servers on the same Segment The need for a Tier-1 SR in for the centralized load-balancer service result in East-West traffic for Segments behind different Tier-1 being pinned to an Edge node. This is the same drawback as for the inline model described in the previous part. 6.2.2.2 Load Balancer One-Arm attached to Segment In the design below, the blue Tier-1 gateway does not run any load-balancer service. Instead, the load-balancer has been deployed as a standalone Tier-1 gateway (represented in orange in the diagram), with a single Service Interface. This gateway is acting as an appliance instantiating a load-balancer. This way, several segments below the blue Tier-1 gateway can have their own dedicated load-balancer. Figure 6-7: Load Balancer One-Arm attached to segment overlay This design allows for better horizontal scale, as an individual segment can have its own dedicated load-balancer service appliance(s). This flexibility in the assignment of load-balancing resources comes at the expense of potentially instantiating several additional Tier-1 SRs on several Edge nodes. Because the load-balancer service has its dedicated appliance, in East-West traffic for Segments behind different Tier-1 gateway (the blue Tier-1 gateway in the above diagram) can still be distributed. The diagram above represented a Tier-1 One-Arm attached to overlay segment. Figure 6-8: Load Balancer One-Arm attached to segment VLAN Tier-1 One-Arm LB can also be attached to physical VLAN segments as shown in above figure, and thus offering load balancing service even for applications on VLAN. In this use case, the Tier-1 interface is also using a Service Interface, but this time connected to a segment-VLAN instead of a segment-overlay. 6.3 NSX-T load-balancing technical details This section provides additional details on how the load-balancer components are physically implemented in an NSX-T environment. Even if it's not necessary for implementing the designs described in the previous part, understanding the traffic flow between the components, the high-availability model or the way the monitor service is implemented will help the reader optimize resource usage in their network. 6.3.1 Load-balancer high-availability The load-balancer is a centralized service running on a Tier-1 gateway, meaning that it runs on a Tier-1 gateway Service Router (SR). The load-balancer will thus run on the Edge node of its associated Tier-1 SR, and its redundancy model will follow the Edge high-availability design. Figure 6-9: Load Balancing High-Availability The above diagram represents two Edge nodes hosting three redundant Tier-1 SRs with a load-balancer each. The Edge High Availability (HA) model is based on periodic keep alive messages exchanged between each pair of Edges in an Edge Cluster. This keepalive protects against the loss of an Edge as a whole. In the above diagram, should Edge node 2 go down, the standby green SR on Edge node 1, along with its associated load-balancer, would become active immediately. There is a second messaging protocol between the Edges. This one is event driven (not periodic), and per-application. This means that if a failure of the load-balancer of the red Tier-1 SR on Edge node 1 is detected, this mechanism can trigger a failover of just this red Tier-1 SR from Edge node 1 to Edge node 2, without impacting the other services. The active load balancer service will always synchronize the following information to the standby load balancer: State Synchronization L4 Flow State Source-IP Persistence State Monitor State This way, in case of failover, the standby load balancer (and its associated Tier-1 SR) can immediately take over with minimal traffic interruption. 6.3.2 Load-balancer monitor The pools targeted by the virtual servers configured on a load-balancer have their monitor services running on the same load-balancer. This ensure that the monitor service cannot fail without the load-balancer failing itself (fate sharing). The left part of the following diagram is representing the same example of relation between the different load-balancer components as the one used in part 6.1. The right part of the diagram is providing an example of where those components would be physically located in a real-life scenario. Figure 6-10: NSX-T Load Balancer Monitor Here, LB1 is a load-balancer attached to Tier-1 Gateway 1 and running two virtual servers VS1 and VS2. The SR for Tier-1 Gateway 1 is instantiated on Edge 1. Similarly, load-balancer LB2 is on gateway Tier-1 Gateway 2, running VS3. The monitors Monitor1 and Monitor2 protecting server pools Pool1, Pool2 and Pool3 used by LB1. As a result, both Monitor1 and Monitor2 are implemented on the SR where LB1 reside. Monitor2 is also polling servers used by LB2, thus it is also implemented on the SR where LB2 is running. The Monitor2 example highlights the fact that a monitor service can be instantiated in several physical locations and that a given pool can be monitored from different SRs. 6.3.3 Load-balancer Layer4 or Layer7 load balancing NSX-T LB offers Layer4 (L4) and Layer7 (L7) load balancing. L4 VIP load balances UDP and TCP connections. The client connection is load balanced by the VIP and its connection is terminated by one of the pool members. Figure 6-11: NSX-T L4 VIP L7 VIP load balances HTTP or HTTPS connections. The client connection is terminated by the VIP, and once the client's HTTP or HTTPS request is received then the load balancer establishes another connection to one of the pool members. If needed, some specific load balancing configuration can also be done by L7 VIP, like a selection of specific pool members based on the request. Figure 6-12: NSX-T L7 VIP For L7 VIP HTTPS, NSX-T LB offers 3 modes: HTTPS Off-Load, HTTPS End-to-end SSL, and SSL Passthrough. HTTPS Off-Load decrypts the HTTPS traffic at the VIP and forward the traffic in clear HTTP to the pool members. It is the best balance between security, performance, and LB flexibility: Security: traffic is encrypted on the external side. Performance: web servers don't have to run encryption. LB flexibility: all advanced configuration on HTTP traffic available like URL load balancing. Figure 6-13: NSX-T L7 HTTPS Off-Load VIP HTTPS End-to-End SSL decrypts the HTTPS traffic at the VIP and re-encrypts the traffic in another HTTPS session to the pool members. It is the best security and LB flexibility: Security: traffic is encrypted end to end. Performance: this mode has lower performance with traffic decrypted/encrypted twice. LB flexibility: all advanced configuration on HTTP traffic available like URL load balancing. Figure 6-14: NSX-T L7 HTTPS End-to-End VIP HTTPS SSL Passthrough does not decrypt the HTTPS traffic at the VIP and SSL connection is terminated on the pool members. It is the best security and performance, but with limited LB flexibility: Security: traffic is encrypted end to end. Performance: highest performance since LB does not terminate SSL traffic LB flexibility: advanced configuration based on HTTP traffic is not available. Only advanced configuration based on SSL traffic is available like SSL SNI load balancing. Figure 6-15: NSX-T L7 SSL Passthrough VIP 6.3.4 Load-balancer IPv6 NSX-T LB has many NSX-T network and security services offers its service for IPv4 and IPv6 clients. Figure 6-16: NSX-T LB IPv4 and IPv6 6.3.5 Load-balancer traffic flows Tier-1 gateway looks like a single entity from a logical point of view. However, and as mentioned several times already, when a load-balancer is configured on a Tier-1 gateway, it is physically instantiated on a Tier-1 Gateway Service Router. This part is exploring the scenarios where the logical representation of a Tier-1 gateway, hiding the distinction between SR and DR, can lead to confusion. 6.3.5.1 The in-line model With the in-line model, traffic between the clients and the servers necessarily go through the load balancer. Thanks to this property, there is no need for source LB-SNAT in order to make sure that traffic goes through the load balancer both ways. The following diagram shows both logical and physical representation of a Tier-1 gateway used to host a load-balancer operating in-line. Clearly, traffic from clients must go through the Tier-1 SR where the load-balancer is instantiated in order to reach the server and vice versa: Figure 6-17: In-Line Model: Logical and Expanded View The following diagram represents another scenario that, from a logical standpoint at least, looks like an in-line load-balancer design. However, source LB-SNAT is required in this design, even if the traffic between the clients and the servers cannot apparently avoid the Tier-1 gateway where the load-balancer is instantiated. Figure 6-18: Load Balancing VIP IP@ in Tier-1 Downlink Subnet – Tier-1 Expanded View The following expanded view, where the Tier-1 SR and DR are represented as distinct entities and hosted physically in different location in the network, clarifies the reason why source LB-SNAT is mandatory: Figure 6-19: Load Balancing VIP IP@ in Tier-1 Downlink Subnet – Tier-1 Expanded View Traffic from server to client would be switched directly by the Tier-1 DR without going through the load-balancer on the SR if source LB-SNAT was not configured. This design is not in fact a true in-line deployment of the load-balancer and does require LB-SNAT. 6.3.5.2 One-arm model From a logical standpoint, the VIP of a virtual server belongs to the subnet of the downlink of the Tier-1 gateway associated to the load-balancer. The following diagram represents a load-balancer on a Tier-1 gateway with a downlink to subnet 10.0.0/24. The Tier-1 gateway interface has the IP address 10.0.0.1, and a virtual server with VIP 10.0.0.6 has been configured on the load balancer. Figure 6-20: Load Balancing VIP IP@ in Tier-1 Downlink Subnet – Logical View The diagram below offers a possible physical representation of the same network, where the Tier-1 gateway is broken down between an SR on an Edge Node, and a DR on the host where both client and servers are instantiated (note that, in order to simplify the representation, the DR on the Edge was omitted.) Figure 6-21: Load Balancing VIP IP@ in Tier-1 Downlink Subnet – Tier-1 Expanded View This representation makes it clear that because the VIP is not physically instantiated on the DR, even if it belongs to the subnet of the downlink of the Tier-1 gateway, some additional "plumbing" is needed in order to make sure that traffic destined to the load-balancer reach its destination. Thus, NSX configures proxy-ARP on the DR to answer local request for the VIP and adds a static route for the VIP pointing to the SR (represented in red in the diagram.) 6.3.6 Load-balancing combined with SR services (NAT and Firewall) Since NSX-T 2.4, the load-balancing service can be inserted in a service chain along with NAT and centralized firewall. In case of service chaining, the order is NAT, then central firewall, at last load balancing. Figure 6-22: LB + NAT + FW Services Chaining This section examines the technical details of a typical NSX-T-based enterprise data center design. It looks at the physical infrastructure and requirements and discusses the design considerations for specific components of NSX-T. Central concepts include: ● Connectivity of management and control plane components (NSX-T Manager.) ● Design for connecting the compute hosts with both ESXi and KVM hypervisors. ● Design for the NSX-T Edge and Edge clusters. ● Organization of compute domains and NSX-T resources. ● Review of sample deployment scenarios. 7.1 Physical Infrastructure of the Data Center An important characteristic of NSX-T is its agnostic view of physical device configuration, allowing for great flexibility in adopting a variety of underlay fabrics and topologies. Basic physical network requirements include: ● IP Connectivity – IP connectivity between all components of NSX-T and compute hosts. This includes management interfaces in hosts as well Edge nodes - both bare metal and virtual Edge nodes. ● Jumbo Frame Support – A minimum required MTU is 1600, however MTU of 1700 bytes is recommended to address the full possibility of variety of functions and future proof the environment for an expanding Geneve header. As the recommended MTU for the NSX-T is 9000, the underlay network should support at least this value, excluding overhead. ● The VM MTU – Typical deployment carries 1500 byte MTU for the guest VM. One can increase the MTU up to 8800 (a ballpark number to accommodate bridging and future header expansion) in case for improving the throughput of the VM. However, all non-TCP based traffic (UDP, RTP, ICMP etc.) and traffic that need to traverse firewall or services appliance, DMZ or Internet may not work properly thus it is advised to use caution while changing the VM MTU. However, replication VMs, backups or internal only application can certainly benefit from increasing MTU size on VM. (Note: IP protocol behavior is to drop any packets with the DF bit set upon arriving at a segment with a lower MTU setting). This can cause the connectivity problems. Once above requirements are met, NSX can be deployed in any type of physical topology – core/aggregation/access, leaf-spine, etc. ● On any switch from any physical switch vendor, including legacy switches. ● With any underlying technology. IP connectivity can be achieved over an end-to-end layer 2 network as well as across a fully routed environment. For an optimal design and operation of NSX-T, well known baseline standards are applicable. These standards include: ● Device availability (e.g., host, TOR, rack level) ● TOR bandwidth - both host-to-TOR and TOR uplinks ● Fault and operational domain consistency (e.g., localized peering of Edge node to northbound network, separation of host compute domains etc.) This design guide assumes that best practices are being followed such that (in large environments) development and/or test environments are separated from production environments. This not only minimizes the effect of catastrophic failure in one environment from affecting the other, but also provides a means for upgrading an environment of lesser importance and reduces the risk of downtime. The tradeoffs of failure domain radius and expense are similar to those in legacy infrastructure and beyond the scope of this document. This guide uses the example of a routed leaf-spine architecture. This model is a superset of other network topologies and fabric configurations, so its concepts are also applicable to layer 2 and non-layer 2 spine topologies Figure 7-1: Typical Enterprise Design displays a typical enterprise design using the routed leaf-spine design for its fabric. A layer 3 fabric is beneficial as it is simple to set up with generic routers and it reduces the span of layer 2 domains to a single rack. Figure 7-1: Typical Enterprise Design A layer 2 fabric would also be a valid option, for which there would be no L2/L3 boundary at the TOR switch. Multiple compute racks are configured to host compute hypervisors (e.g., ESXi, KVM) for the application VMs. Compute racks typically have the same structure and the same rack connectivity, allowing for cookie-cutter deployment. Compute clusters are placed horizontally between racks to protect against rack failures or loss of connectivity. Several racks are dedicated to the infrastructure. These racks host: ● Management elements (e.g., vCenter, NSX-T Managers, OpenStack, vRNI, etc.) ● Bare Metal Edge or Edge node VMs ● Clustered elements are spread between racks to be resilient to rack failures The different components involved in NSX-T send different kinds of traffic in the network; these are typically categorized using different VLANs. A hypervisor could send management, storage, and vMotion that would leverage three different VLAN tags. Because this particular physical infrastructure terminates layer 3 at the TOR switch, the span of all VLANs is limited to a single rack. The management VLAN on one rack is not the same broadcast domain as the management VLAN on a different rack as they lack L2 connectivity. In order to simplify the configuration, the same VLAN ID is however typically assigned consistently across rack for each category of traffic. Figure 7-2: Typical Layer 3 Design with Example of VLAN/Subnet details an example of VLAN and IP subnet assignment across racks. Figure 7-2: Typical Layer 3 Design with Example of VLAN/Subnet Upcoming examples will provide more detailed recommendations on the subnet and VLAN assignment based on the NSX-T component specifics. For smaller NSX deployments, these elements may be combined into a reduced number of racks as detailed in the section Multi-Compute Workload Domain Design Consideration.. 7.2 NSX-T Infrastructure Component Connectivity NSX-T Manager Appliances (bundling manager and controller functions) are mandatory NSX-T infrastructure components. Their networking requirement is basic IP connectivity with other NSX-T components over the management network. The details of these communication ports are listed under . NSX-T Manager Appliances are typically deployed on a hypervisor as a standard VLAN backed port group; there is no need for colocation in the same subnet or VLAN. There are no host state dependencies or MTU encapsulation requirements as these components send only management and control plane traffic over the VLAN. Figure 7-3: ESXi Hypervisor in the Management Rack The ESXi management hypervisors are configured with a VDS/VSS with a management port group mapped to a management VLAN. The management port group is configured with two uplinks using physical NICs "P1" and "P2" attached to different top of rack switches. The uplink teaming policy has no impact on NSX-T Manager operation, so it can be based on existing VSS/VDS policy. Figure 7-4: KVM Hypervisors in the Management Rack presents the same NSX-T Manager appliance VMs running on KVM hosts. Figure 7-4: KVM Hypervisors in the Management Rack The KVM management hypervisors are configured on a Linux bridge with two uplinks using physical NICs "P1" and "P2". The traffic is injected into a management VLAN configured in the physical infrastructure. Either active/active or active/standby is fine for the uplink team strategy for NSX-T Manager since both provide redundancy; this example uses simplest connectivity model with active/standby configuration. In a typical deployment, the NSX management components should be deployed on a VLAN. This is the recommended best practice. The target compute cluster only need to have the hypervisor switch – VSS/VDS on ESXi and Linux Bridge on KVM. Deploying NSX management components on the software defined overlay requires elaborate considerations and thus beyond the scope of this document. 7.2.1 NSX-T Manager Node Availability and Hypervisor interaction The NSX-T Manager cluster represents a scale-out distributed system where each of the three NSX-T Manager nodes is assigned a set of roles that define the type of tasks that node can implement. For optimal operation, it is critical to understand the availability requirements of Management cluster. The cluster must have three nodes for normal operation; however, the cluster can operate with reduced capacity in the event of a single node failure. To be fully operational, the cluster requires that a majority of NSX-T Manager Nodes (i.e., two out of three) be available. It is recommended to spread the deployment of the NSX-T Manager Nodes across separate hypervisors to ensure that the failure of a single host does not cause the loss of a majority of the cluster. A failure domain at minimum should address the failure of a single host and may extend to a data store, vSphere cluster, or even cabinet or rack. NSX does not natively enforce this design practice. On a vSphere-based management cluster, deploy the NSX-T Managers in the same vSphere cluster and leverage the native vSphere Distributed Resource Scheduler (DRS) and anti-affinity rules to avoid instantiating more than one NSX-T Manager node on the same ESXi server. For more information on how to create a VM-to-VM anti-affinity rule, refer to the VMware documents on VM-to-VM and VM-to-host rules. For a vSphere-based design, it is recommended to leverage vSphere HA functionality to ensure single NSX-T Manager node can recover during the loss of a hypervisor. Furthermore, NSX-T Manager should be installed on shared storage. vSphere HA requires shared storage so that VMs can be restarted on another host if the original host fails. A similar mechanism is recommended when NSX-T Manager is

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API Usage Example 2- Application Security Policy Lifecycle Management - API & JSON Below example provides the sample API/JSON on how a security admin can leverage declarative API to manage life cycle of security configuration - grouping and micro-segmentation policy, for a given 3-tier application. curl -X PATCH \ \ -H 'authorization: Basic YWRtaW46Vk13YXJlIW1ncjE5OTg=' \ -H 'cache-control: no-cache' \ -H 'content-type: application/json' \ -H 'postman-token: e55c1202-8e10-5cf8-b29d-ec86a57fc57c' \ -d '{ "resource_type": "Infra", "children": [{ "resource_type": "ChildDomain", "marked_for_delete": false, "Domain": { "id": "default", "resource_type": "Domain", "description": "default", "display_name": "default", "children": [{ "resource_type": "ChildGroup", "marked_for_delete": false, "Group": { "resource_type": "Group", "description": "DEV-RED-web-vms", "display_name": "DEV-RED-web-vms", "id": "DEV-RED-web-vms", "expression": [{ "member_type": "VirtualMachine", "value": "DEVREDwebvm", 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"/infra/domains/default/groups/DEV-RED-web-vms"] }] } }] } }] }' Back to Appendix 2. This appendix gives the actual API & JSON request body for the example describe in Failure Domain and in Services Availability Considerations with Edge Node VM. Following steps show an example of how to create a failure domain and how to consume them. POST https:///api/v1/failure-domains/ Copy the following JSON code into the body of the API call. { "display_name": "FD-1" } Add Edge nodes to their failure domains. Change the "failure_domain_id" from system generated default to newly created failure domain using PUT API. Retrieve the UUID of the Edge node. GET https:/// api/v1/transport-nodes/ Add an Edge node to the failure domain created. PUT https:///api/v1/ transport-nodes / Use the following JSON code into the body of the API call. { "resource_type": "FailureDomain", "description": "failure domain of rack1", "display_name": "FD1", "id": "795097bb-fb32-44f1-a074-73445ada5451", "preferred_active_edge_services": "true", "_revision": 0 } Enable "Allocation based on Failure Domain" on the Edge cluster level Retrieve the Edge Cluster configuration by using the following GET API. GET https:///api/v1/edge-clusters/ Copy the output of the body. Enable the feature on Edge cluster level. Modify the following json code into the body of the API call. PUT https:///api/v1/edge-clusters/ "allocation_rules": [FD1], Validate by creating a Tier-1 Gateway A user can also enforce that all active Tier-1 SRs are placed in one failure domain. This configuration is supported for Tier-1 gateway in preemptive mode only. Set preference for a failure domain using "preferred_active_edge_services" PUT https:///api/v1/failure-domains/ { "preferred_active_edge_services ": true } By default, bridge will use the first uplink in N-VDS config. In order to distribute bridge traffic over multiple uplinks user need to map named pinning policy to BridgeEndpoint (VLAN/Segment), with following steps. Step1: Define Transport Zone with Named Pinning Policy. Step2: Define 2 Named teaming Policy in the Edge Uplink Profile, to direct traffic to each of the uplinks. Step 3: Associate "uplink_teaming_policy_name" to the BridgeEndpoints individually as shown below. Currently only API option is available. Following example VLAN 1211 uses uplink-1 associated with TO-TOR-A teaming policy and VLAN 1221 uses uplink-2 associated with TO-TOR-B teaming policy. Similarly, one can associate other BridgeEndpoints to the teaming-policy. An API to place specific bridging instances on an Uplink PUT https://{{nsxmanager}}/api/v1/bridge-endpoints/ with parameter "uplink_teaming_policy_name":"" Please refer Example-1: VLAN 1211 uses uplink-1 associated with TO-TOR-A teaming policy PUT https://{{nsxmanager}}/api/v1/bridge-endpoints/e9f06b71-323e-4190-a3d9-58a3ca4f114f { "vlan": 1211, "vlan_trunk_spec": { "vlan_ranges": [] }, "ha_enable": true, "bridge_endpoint_profile_id": "fa7b6bb1-e947-4b5b-9427-8fb11859a8d5", "vlan_transport_zone_id": "d47ac1fd-5baa-448e-8a86-110a75a0528a", "resource_type": "BridgeEndpoint", "id": "e9f06b71-323e-4190-a3d9-58a3ca4f114f", "display_name": "e9f06b71-323e-4190-a3d9-58a3ca4f114f", "tags": [], "uplink_teaming_policy_name":"TO-TOR-A", "_revision" : 1 } Example-2: VLAN 1221 uses uplink-2 associated with TO-TOR-B teaming policy PUT https://{{nsxmanager}}/api/v1/bridge-endpoints/f17c1d00-3b5b-409f-a33d-54d3ddef3f9a { "vlan": 1221, "vlan_trunk_spec": { "vlan_ranges": [] }, "ha_enable": true, "bridge_endpoint_profile_id": "fa7b6bb1-e947-4b5b-9427-8fb11859a8d5", "vlan_transport_zone_id": "d47ac1fd-5baa-448e-8a86-110a75a0528a", "resource_type": "BridgeEndpoint", "id": "f17c1d00-3b5b-409f-a33d-54d3ddef3f9a", "display_name": "f17c1d00-3b5b-409f-a33d-54d3ddef3f9a", "uplink_teaming_policy_name": "TO-TOR-B", "_revision" : 5 } Peering with Physical Infrastructure Routers This connectivity remains the same. See Deterministic Peering with Physical Routers. Before NSX-T 2.5 - Bare Metal Design with 2 pNICs Figure A5-1 shows an Edge rack connectivity for the simple enterprise design. Figure A5-1: Typical Enterprise Bare Metal Edge Node Rack The bare metal Edges "EN1" and "EN2" are each configured with a management interface attached to "P1" and an "N-VDS 1" with a single uplink, comprised of pNICs "P2" and "P3" configured as a LAG. The interfaces of an individual bare metal Edge communicate only with a default gateway or a routing peer on the directly connected top of rack switch. As a result, the uplink-connected VLANs are local to a given TOR and are not extended on the inter-switch link "ToR-Left" and "ToR-Right". This design utilizes a straight through LAG to a single TOR switch or access device, offering the best traffic distribution possible across the two pNICs dedicated to the NSX-T data plane traffic. The VLAN IDs for the management and overlay interfaces can be unique or common between two ToR, it only has local significance. However, subnet for those interfaces is unique. If common subnet is used for management and overlay, then it requires carrying those VLANs between ToRs and routing north bound to cover the case of the all uplinks of given ToR fails. The VLAN ID and subnet for the external peering connectivity is unique on both ToR and carries common best practices of localized VLAN for routing adjacencies. If the rack contains other compute hosts participating in the same overlay transport zone, it is a common practice to allocate separate VLANs and subnets for infrastructure traffic as well as for overlay VMkernel interfaces, the reason for this rational is that bare metal configuration is localized to a ToR and operational consideration differs significantly, The routing over a straight through LAG is simple and a supported choice. This should not be confused with a typical LAG topology that spans multiple TOR switches. A particular Edge node shares its fate with the TOR switch to which it connects, creating as single point of failure. In the design best practices, multiple Edge nodes are present so that the failure of a single node resulting from a TOR failure is not a high impact event. This is the reason for the recommendation to use multiple TOR switches and multiple Edge nodes with distinct connectivity. This design leverages an unconventional dual attachment of a bare metal Edge to a single ToR switch. The rationale is based on the best strategy for even traffic distribution and overlay redundancy. Services Availability Considerations Bare metal Edge Node An additional design consideration applies to bare metal Edge clusters with more than two Edge nodes. Figure A5-2 shows connectivity of Edge nodes where four Edge nodes belong to single Edge cluster. In this diagram, two Edge nodes are connected to "ToR-Left" and the other two are connected to "ToR-Right". This is the only recommended configuration with two pNICs design. Figure A5-2: One Edge Cluster with 4 Edge Nodes As part of designating Edge node services, both the role (i.e., active or standby) and location must be explicitly defined and for a given deployment of Tier-0 or Tier-1, the services must be deployed in same cluster. Without this specificity, the two Edge nodes chosen could be "EN1" and "EN2", which would result in both active and standby tiers being unreachable in the event of a "ToR-Left" failure. It is highly recommended to deploy two separate Edge clusters when the number of Edge nodes is greater than two, as shown in Figure A5-3. Figure A5-3: Two Edge Clusters with 2 Edge Nodes Each This configuration deploys the tiers in two Edge clusters, allowing maximum availability under a failure condition, placing Tier-0 on "Edge Cluster1" and Tier-1 on "Edge Cluster2". Before NSX-T 2.5 Release - Edge Node VM Design An Edge node can run as a virtual machine on an ESXi hypervisor. This form factor is derived from the same software code base as the bare metal Edge. An N-VDS switch is embedded inside the Edge node VM with four fast path NICs and one management vNIC. The typical enterprise design with two Edge node VMs will leverage 4 vNICs: ● One vNIC dedicated to management traffic ● One vNIC dedicated to overlay traffic ● Two vNICs dedicated to external traffic N-VDS when deployed at the host level offers multiple teaming options, however for N-VDS inside the Edge node VM can only carry one teaming mode. In most cases the teaming option for N-VDS inside the Edge is using only Failover Order Teaming. To develop a deterministic connectivity, it is necessary to have more than one N-VDS per Edge node. Since an Edge node runs on ESXi, it connects to a VDS(though N-VDS in shared compute with Edge or all things N-VDS), providing flexibility in assigning a variety of teaming policies at VDS level. As a result, each NIC will be mapped to a dedicated port group in the ESXi hypervisor, offering maximum flexibility in the assignment of the different kind of traffic to the host's two physical NICs. Figure A5-4 shows an ESXi host with two physical NICs. Edges "VM1" is hosted on this ESXi host leveraging the VDS port groups, each connected to both TOR switches. This configuration remains the same since NSX-T 2.0 release and remains valid for NSX-T 2.5 release as well. However, there have been several enhancements like multi-TEP support for Edge node, named teaming policy etc. because of which this deployment is simplified by using one N-VDS to carry both overlay and external traffic. This is discussed in Single N-VDS Based Configuration - Starting with NSX-T 2.5 release and NSX-T 2.5 Edge node VM connectivity with VDS with 2 pNICs. In Figure A5-4 topology, four port groups have been defined on the VDS to connect the Edge VM; these are named "Mgmt. PG" (VLAN 100), "Transport PG" (VLAN 200), "Ext1 PG" (VLAN 300), and "Ext2 PG" (VLAN 400). While this example uses a VDS, it would be the same if a VSS were selected. Use of a VSS is highly discouraged due to the support and flexibility benefits provided by the VDS. "VDS-Uplink1" on the VDS is mapped to the first pNIC "P1" that connects to the TOR switch on the left and "VDS-Uplink2" is mapped to the remaining pNIC "P2", that connects to the TOR switch on the right. The Figure A5-4 also shows three N-VDS, named as "Overlay N-VDS", "Ext 1 N-VDS", and "Ext 2 N-VDS". Three N-VDS are used in this design to ensure that overlay and external traffic use different vNICs of Edge VM. All three N-VDS use the same teaming policy i.e. Failover order with one active uplink i.e. Uplink1. "Uplink1" on each N-VDS is mapped to use a different vNIC of the Edge VM. "Uplink1" on overlay N-VDS is mapped to use vNIC2 of Edge VM. "Uplink1" on Ext1 N-VDS is mapped to use vNIC3 of Edge VM. "Uplink1" on Ext2 N-VDS is mapped to use vNIC4 of Edge VM. Based on this teaming policy for each N-VDS, overlay traffic will be sent and received on vNIC2 of the Edge VM. External traffic from any VLAN segment defined for "Ext-1 N-VDS" will be sent and received on vNIC3 of the Edge VM. Similarly, external traffic from any VLAN segment defined for "Ext-2 N-VDS" will be sent and received on vNIC4 of the Edge VM. Teaming policy used on the VDS port group level defines how traffic from these different N-VDS on Edge node VM exits from the hypervisor. For instance, "Mgmt. PG" and "Transport PG" are configured to use active uplink as "VDS-Uplink1" and standby uplink as "VDS-Uplink2". "Ext1 PG" (VLAN 300) is mapped to use "VDS-Uplink1". "Ext2 PG" (VLAN 400) is mapped to use "VDS-Uplink2". This configuration ensures that the traffic sent on VLAN 300 always uses "VDS-Uplink1" and is sent to the left TOR switch. Traffic sent on VLAN 400 uses "VDS-Uplink2" and is sent to the TOR switch on the right. Figure A5-4: Edge Node VM installed leveraging VDS port groups on a 2 pNIC host In this example, no VLAN tags are configured in either uplink profile for Edge node or on VLAN backed segments connecting Tier-0 gateway to TOR. Hence, the VDS port groups are configured as VLAN port groups each carrying specific VLAN. NSX-T 2.4 Edge node VM connectivity with VDS on Host with 2 pNICs As discussed above, the Edge VM can be connected to vSS, VDS or N-VDS. The preferred mode of connectivity for Edge node VM is VDS due to its features set and possible interaction with other components like storage (e.g. VSAN). The physical connectivity of the ESXi hypervisor hosting the Edge VM nodes is similar to that for compute hypervisors: two pNIC uplinks, each connected to a different TOR switch. Traffic engineering over the physical uplinks depends on the specific configuration of port groups. Figure A5-6 provides a detail of this configuration with two edge VM nodes. Figure A5-6: 2 pNIC Host with two Edge Node VM Traffic profiles for both Edge node VMs "EN1" and "EN2" are configured as follows: ● Management: "vNIC1" is the management interface for the Edge VM. It is connected to port group "Mgt-PG" with a failover order teaming policy specifying "P1" as the active uplink and "P2" as standby ● Overlay: "vNIC4" is the overlay interface, connected to port group "Transport-PG" with a failover order teaming policy specifying "P1" as active and "P2" as standby. The Failover Order teaming policy allows to build a deterministic traffic pattern of the overlay traffic carried by each Edge VM. The TEP for the Edge node is created on an "N-VDS 1" that has "vNIC4" as its unique uplink. The N-VDS teaming policy consist of both P1 and P2 in its profile with active/standby configuration. ● External: This configuration leverages the best practices of simplifying peering connectivity. The VLANs used for peering are localized to each TOR switch, eliminating the spanning of VLANs (i.e., no STP looped topology) and creating a one-to-one relationship with routing adjacency to the Edge node VM. It is important to ensure sure that traffic destined for a particular TOR switch exits the hypervisor on the appropriate uplink directly connected to that TOR. For this purpose, the design leverages two different port groups: ○ "Ext1-PG" – "P1" in VLAN "External1-VLAN" as its unique active pNIC. ○ "Ext2-PG" – "P2" in VLAN "External2-VLAN" as its unique active pNIC. The Edge node VM will have two N-VDS: ○ "N-VDS 1" with "vNIC2" as unique uplink ○ "N-VDS 2" with "vNIC3" as unique uplink. This configuration ensures that Edge VM traffic sent on "N-VDS 1" can only exit the hypervisor on pNIC "P1" and will be tagged with an "External1-VLAN" tag. Similarly, "N-VDS 2" can only use "P2" and will receive an "External2-VLAN" tag. N-VDS teaming policy is still Failover Order, however for each external PG it differs from each other and that of overlay PG. In this case Ext1-PG profile consist of only P1 and no standby is configured, while Ext2-PG consist of P2 and not standby. Note on VLAN tagging: In this design VLAN tagging must not be used and disabled under uplink profile for the edge. If requirement is to add services interface for VLAN routing or LB then tagging is required in transport VLAN, refer to VLAN TAG Requirements in chapter 4.8.2.2. Figure A5-7 Typical Enterprise Edge Node VM Physical View with External Traffic The connectivity options described above Figure shows two hosts with single edge VM, however one can applies the exact connectivity options depicted in Figure A5-6 with two Edge VM nodes per host. However, with two edge nodes per hosts requires consideration of placement of active/standby services. The active/standby Tier-1 cannot be placed in the same host otherwise it will constitute a single point of failure. This design consideration is discussed further in NSX-T Edge Resources Design section. Dedicated Host for Edge VM Design with 4 pNICs The four pNICs host can offer design choices that meet variety of business and operational need in which multiple N-VDS or combination of N-VDS and VDS can be deployed. The design choices covering compute host with four pNICs is discussed in section 7.3.3. The design choices with four pNICs hosts utilized for collapsed management and edge or collapsed compute and edge are discussed further in section 7.5. This part focuses on dedicated host for Edge node with four pNICs. It offers greater flexibility in terms of separation of traffic and optimal bandwidth allocation per Edge nodes. With four pNICs the bandwidth offered per host for both N-S and overlay is symmetric as shown in Figure A5-7 where there is dedicated overlay pNIC for each Edge VM node. Thus, total bandwidth passing through the host from N-S to overlay is equal. Figure A5-7: Four pNICs Edge Dedicated Host with two Edge nodes The physical connectivity remains exactly same as two pNICs option as described in section 7.4.2.1 except for following: Overlay Traffic is allocated a dedicated pNIC Two types of VDS teaming configuration possible. The first option is depicted in Figure A5-7 in which each Edge node VM gets a dedicated transport PG. Each one is configured with "Failover Order" teaming under VDS. This way the overlay traffic from each Edge VM will always go to designated pNIC. The second option (not shown in figure) uses single transport PG under VDS, in which the teaming type must be "Source ID" under VDS. It saves the configuration overhead but now the Edge node traffic is non-deterministic, thus little harder to know the exact pNIC over which the overlay traffic is going at a given moment. The above design choice is optimal for having multiple Edge nodes per host. In most cases (except host is oversubscribed with other VMs or resources like management, multi-tenant edges etc.), it is not the host CPU but the number of pNICs available at the host determines the number of Edge node per host. One can optimize following design by adopting four Edge VMs per host where the oversubscription is not a concern but building a high-density multi-tenant or services design is important. The four pNICs host design offers compelling possibility on offering variety of combination of services and topology choices. Options of allocation of services either in form of dedicated Edge VM per services or shared within an Edge Node are disused in separate section below as it requires consideration of scale, availability, topological choices and multi-tenancy. Filter Tags Networking Security NSX Document Benchmark Deep Dive Design Guide Experts Talk Solution Architecture Technical Overview Intermediate Advanced Design Deploy Manage Container Networking Multi-Cloud Networking Network Operations Security

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