DECEMBER 2020

VMWARE NSX-T ® REFERENCE DESIGN GUIDE

Software Version 3.0

VMware NSX-T Reference Design Guide

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Intended Audience

This document is targeted toward virtualization and network architects interested in deploying VMware NSX® network virtualization solutions in a variety of on premise solutions covering VMware vSphere® and KVM.

Revision History

Version	Updates	Comments
1.0	None	NSX-T 2.0
2.0	Completely Revised	NSX-T 2.5
3.0	Completely Revised	NSX-T 3.0

1 Introduction

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.

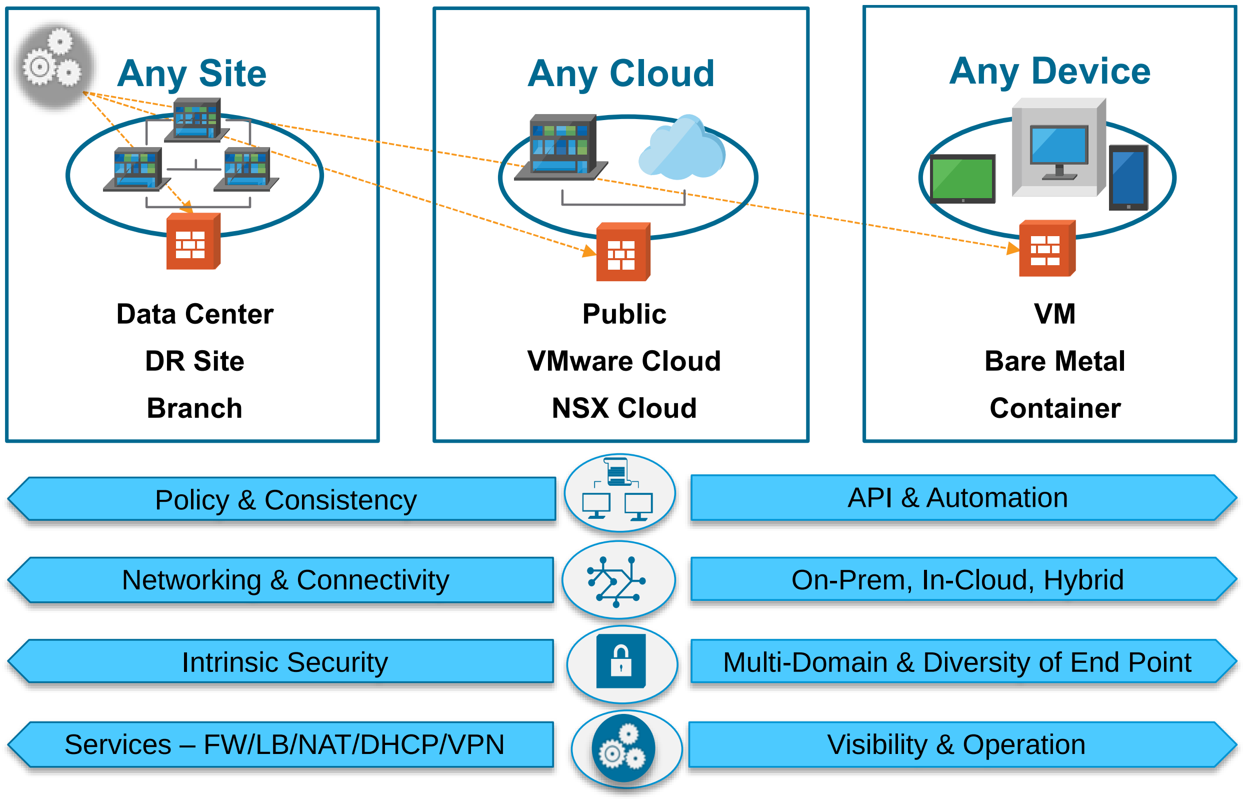


Figure 1-1: NSX-T Anywhere Architecture

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.

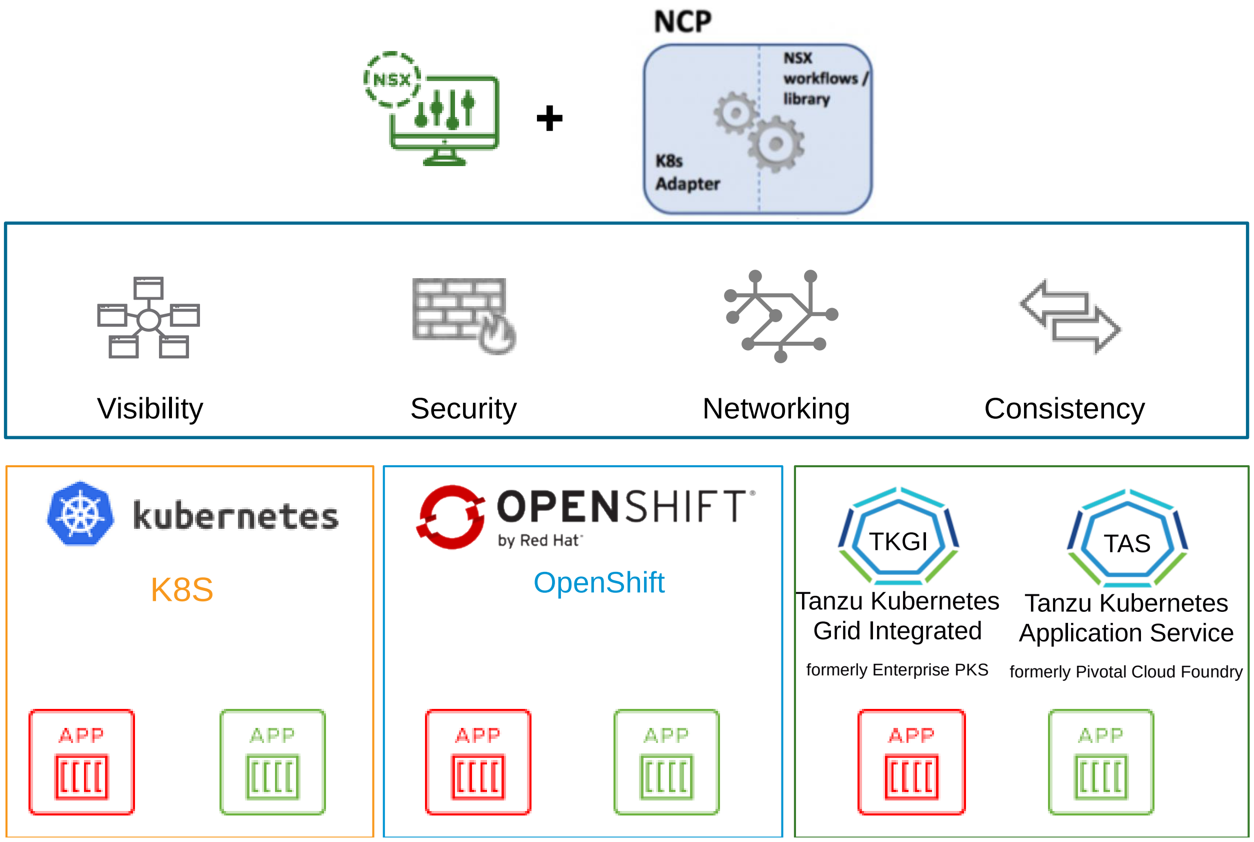


Figure 1-2: Programmatic Integration with Various PaaS and CaaS

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.

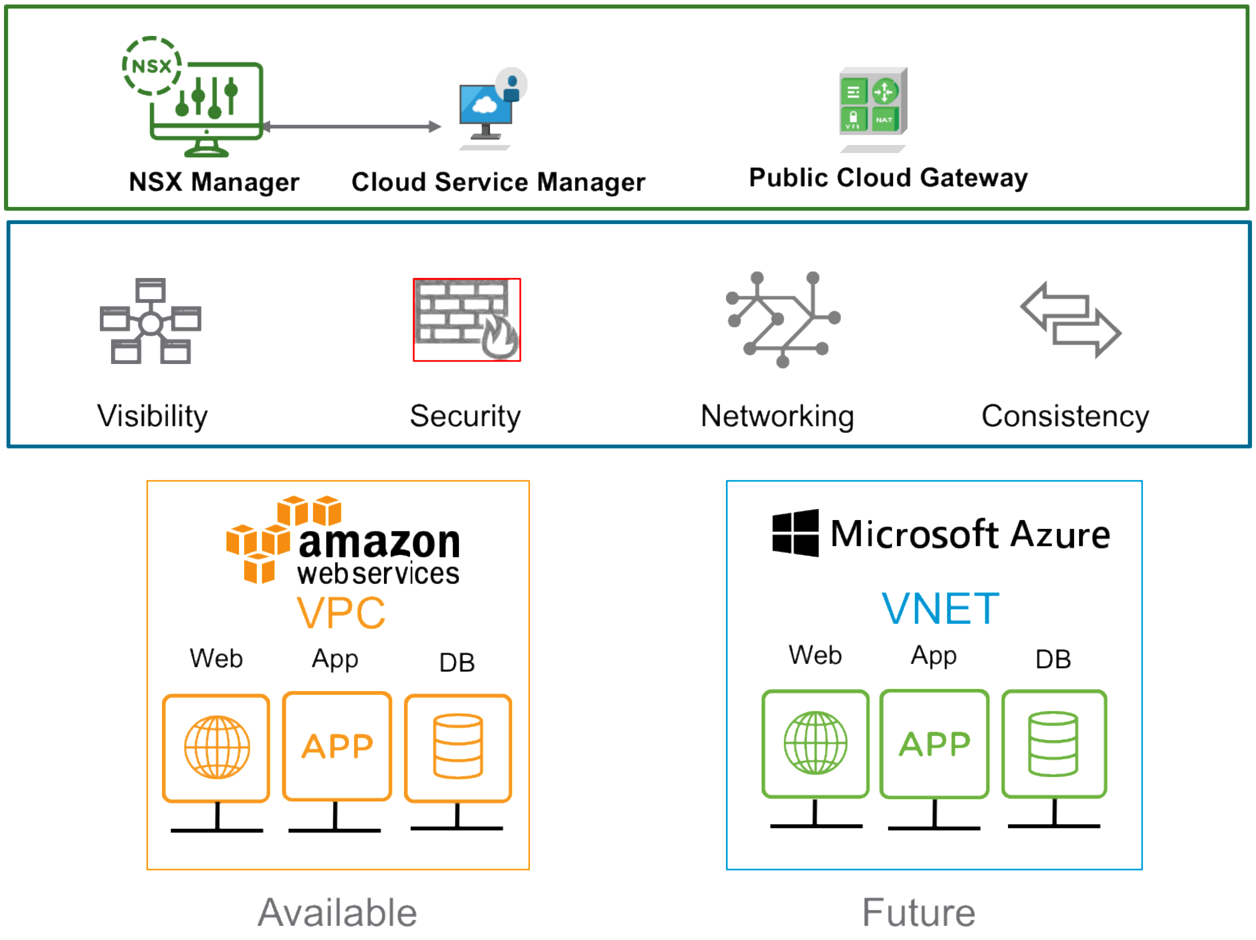


Figure 1-3: Multi-cloud Architecture with NSX-T

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.

2 NSX-T Architecture Components

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.

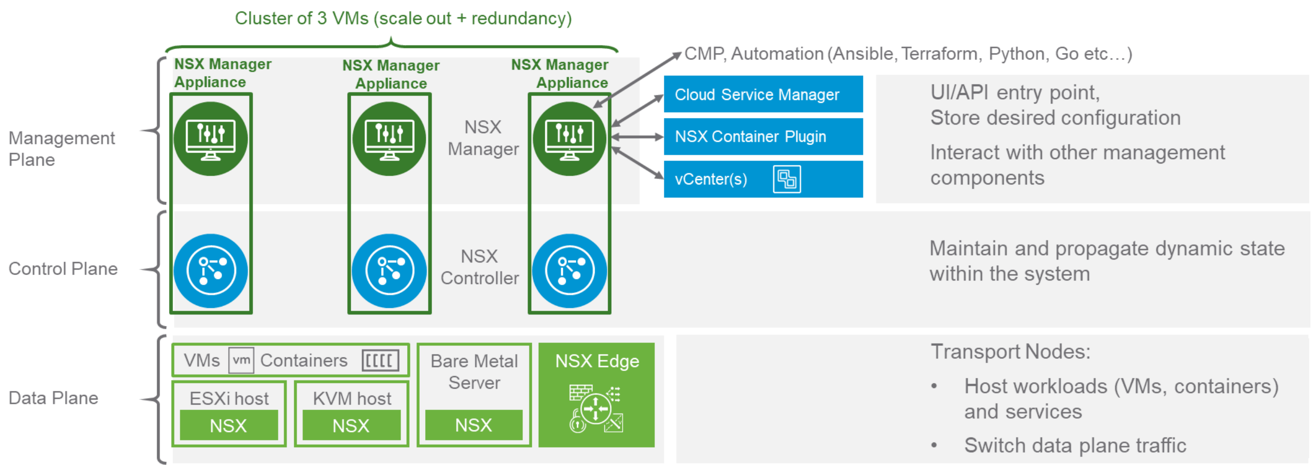

Cluster of 3 VMs (scale out + redundancy)
NSX Manager Appliance
NSX Manager Appliance
NSX Manager Appliance
CMP, Automation (Ansible, Terraform, Python, Go etc…)
Management Plane
NSX Manager
Cloud Service Manager
NSX Container Plugin
vCenter(s)
UI/API entry point, Store desired configuration
Interact with other management components
Control Plane
NSX Controller
Maintain and propagate dynamic state within the system
Data Plane
VMs
Containers
ESXi host
NSX
KVM host
NSX
Bare Metal Server
NSX
NSX Edge
Transport Nodes:
Host workloads (VMs, containers) and services
Switch data plane traffic

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.

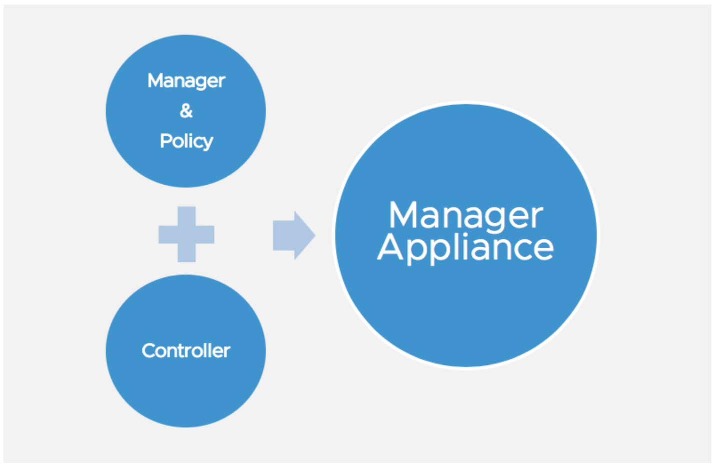


Figure 2-2: NSX Manager and Controller Consolidation

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. The hosts running the local control plane daemons and forwarding engines implementing the NSX-T data plane are called transport nodes. Transport nodes are running an instance of the NSX-T virtual switch called the NSX Virtual Distributed Switch, or N-VDS.
On ESXi platforms, the N-VDS is built on the top of the vSphere Distributed Switch (VDS). In fact, the N-VDS is so close to the VDS that NSX-T 3.0 introduced the capability of installing NSX-T directly on the top of a VDS on ESXi hosts. For all other kinds of transport node, the N-VDS is based on the platform independent Open vSwitch (OVS) and serves as the foundation for the implementation of NSX-T in other environments (e.g., cloud, containers, etc.).
As represented in *Figure 2-1: NSX-T Architecture and Components*, there are two main types of transport nodes in NSX-T:

- **Hypervisor Transport Nodes:** Hypervisor transport nodes are hypervisors prepared and configured for NSX-T. NSX-T provides network services to the virtual machines running on those hypervisors. NSX-T currently supports VMware ESXi™ and KVM hypervisors.
- **Edge Nodes:** VMware NSX-T Edge™ nodes are service appliances dedicated to running centralized network services that cannot be distributed to the hypervisors. They can be instantiated as a bare metal appliance or in virtual machine form factor. They are grouped in one or several clusters, representing a pool of capacity. It is important to remember that an Edge Node does not represent a service itself but just a pool of capacity that one or more services can consume.

2.3 NSX-T Consumption Model

A user can interact with the NSX-T platform through the Graphical User Interface or the REST API framework. Starting with NSX-T 3.0 the GUI & REST API are available as options to interact with the NSX Manager:

1) **Policy Mode**
   - Default UI mode.
   - Previously called the Declarative or Simplified API/Data Model.
   - API accessed via URI which start with /api/policy
2) **Manager Mode**
   - Continuing user interface to address upgrade & Cloud Management Platform (CMP) use case, more info in the next section.
   - Advanced UI/API will be deprecated over time, as we transition all features/use case to Simplified UI/API.
   - API accessed via URI which start with /api

2.3.1 When to use Policy vs Manager UI/API

VMware recommendation is to use NSX-T Policy UI going forward as all the new features are implemented only on Policy UI/API, unless you fall under the following specific use cases: Upgrade, vendor specific container option, or OpenStack Integrations. The following table further highlights the feature transition map to Policy UI/API model.

Policy Mode	**Manager Mode**
Most new deployments should use Policy mode. Federation supports only Policy mode. If you want to use Federation, or might use it in future, use Policy mode.	Deployments which were created using the advanced interface, for example, upgrades from versions before Policy mode was available.
NSX Cloud deployments	Deployments which integrate with other plugins. For example, NSX Container Plug-in, Openstack, and other cloud management platforms.
Networking features available in Policy mode only: ● DNS Services and DNS Zones ● VPN ● Forwarding policies for NSX Cloud	Networking features available in Manager mode only: ● Forwarding up timer
Security features available in Policy mode only: ● Endpoint Protection ● Network Introspection (East-West Service Insertion) ● Context Profiles ○ L7 applications ○ FQDN	Security features available in Manager mode only: ● Bridge Firewall

● New Distributed Firewall and Gateway Firewall Layout ○ Categories ○ Auto service rules ○ Drafts	

It is recommended that whichever mode is used to create objects (Policy or Manager) be the only mode used (if the Manager Mode objects are required, create all objects in Manager mode). Do not alternate use of the modes or there will be unpredictable results. Note that the default mode for the NSX Manager is Policy mode. When working in an installation where all objects are new and created in Policy mode, the Manager mode option will not be visible in the UI. For details on switching between modes, please see the NSX-T documentation.

2.3.2 NSX-T Logical Object Naming Changes

The Manager API/Data model some of the networking and security logical objects names have changed to build a unified object model. The table below provides the before and after naming side by side for those NSX-T Logical objects. This just changes the name for the given NSX-T object, but conceptually and functionally it is the same as before.

	Manager API/UI Object	**Policy API Object**
Networking		
	Logical switch	Segment
	T0 Logical Router	Tier-0 Gateway
	T1 Logical Router	Tier-1 Gateway
	Centralized Service Port	Service Interface
Security	**Manager API/UI Object**	**Policy API Object**
	NSGroup, IP Sets, MAC Sets	Group
	Firewall Section	Security-Policy
	Edge Firewall	Gateway Firewall

2.3.3 NSX-T Policy API Framework

NSX-T Policy API framework provide an outcome driven config option. This allows a single API call to configure multiple NSX networking & security objects for an application deployment. This is more applicable for customers using automation and for CMP plugins. Some of the main benefits of declarative API framework are:

- **Outcome driven**: Reduces the number of configuration steps by allowing a user to describe desired end-goal (the "what"), and letting the system figure out "how" to achieve it. This allows users to utilize user-specified names, not system generated IDs

- **Order Independent:** create/update/delete in any order and always arrive at the same consistent result
- **Prescriptive:** reduces potential for user error with built-in dependency checks
- **Policy Life Cycle Management:** Simpler with single API call. Toggle marked-to-delete flag in the JSON request body to manage life cycle of entire application topology.

The NSX-T API documentation can be accessible directly from the NSX Manager UI, under Policy section within API documentation, or it can be accessed from code.vmware.com.

The following examples walks you through the policy API examples for two of the customer scenarios:

2.3.4 API Usage Example 1- Templatize and Deploy 3-Tier Application Topology

This example provides how Policy API helps user to create the reusable code template for deploying a 3-Tier APP shown in the figure, which includes Networking, Security & Services needed for the application.

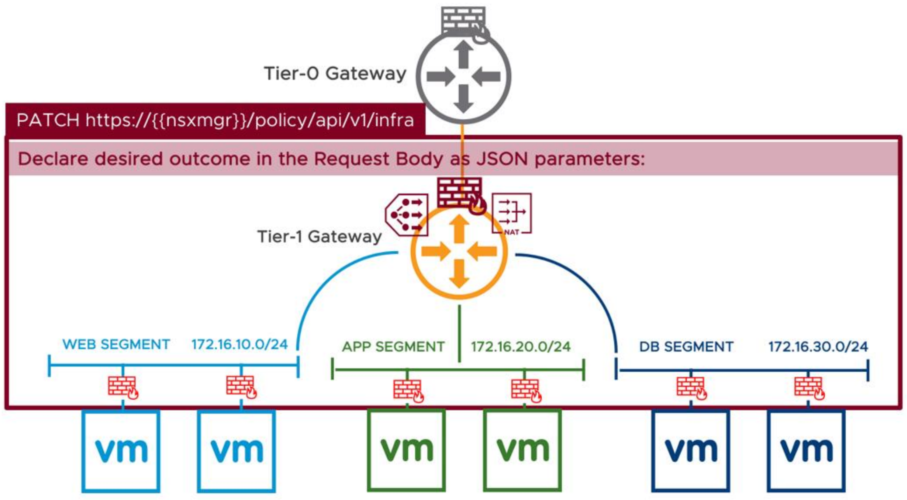

Tier-0 Gateway
PATCH https://{{nsxmgr}}/policy/api/v1/infra
Declare desired outcome in the Request Body as JSON parameters:
Tier-1 Gateway
NAT
WEB SEGMENT
172.16.10.0/24
APP SEGMENT
172.16.20.0/24
DB SEGMENT
172.16.30.0/24
vm

Figure 2-3: NSX-T Policy API - Infra

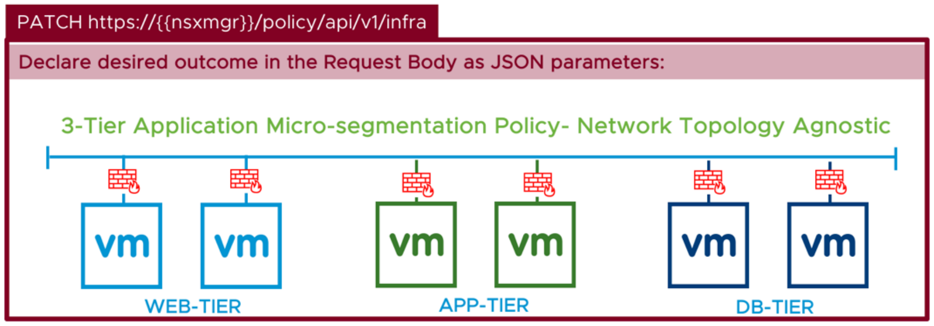
The desired outcome for deploying the application, as shown in the figure above, can be defined using JSON. Once JSON request body is defined to reflect the desired outcome, then API & JSON request body can be leveraged to automate following operational workflows:

- Deploy entire topology with single API and JSON request body.
- The same API/JSON can be further leveraged to templatize and reuse to deploy same application in different environment (PROD, TEST and DEV).
- Handle life cycle management of entire application topology by toggling the "marked_for_delete" flag in the JSON body to true or false.

See details of this at Example 1.

2.3.5 API Usage Example 2- Application Security Policy Lifecycle Management

This example demonstrates how a security admin can leverage declarative API to manage the life cycle of security configuration, grouping, and micro-segmentation policy for a given 3-tier application. The following figure depicts the entire application topology and the desired outcome to provide zero trust security model for an application.


PATCH https://{{nsxmgr}}/policy/api/v1/infra
Declare desired outcome in the Request Body as JSON parameters:
3-Tier Application Micro-segmentation Policy- Network Topology Agnostic
vm
WEB-TIER
APP-TIER
DB-TIER

TO define the desired outcome for defining grouping and micro-segmentation polices using JSON and use single API with JSON request body to automate following operational workflows:

- Deploy white-list security policy with single API and JSON request body.
- The same API/JSON can further leveraged to templatize and reuse to secure same application in different environment (PROD, TEST and DEV).
- Handle life cycle management of entire application topology by toggling the "marked_for_delete" flag in the JSON body to true or false.

The details of both are fully described in Appendix 2, where the API & JSON request body is shown in full details.

3 NSX-T Logical Switching

This chapter details how NSX-T creates virtual Layer 2 networks, called segments, to provide connectivity between its services and the different virtual machines in the environment.

3.1 The NSX Virtual Switch

A transport node is, by definition, a device implementing the NSX-T data plane. The software component running this data plane is a virtual switch, responsible for forwarding traffic between logical and physical ports on the device. The NSX-T virtual switch is called the NSX Virtual Distributed Switch, or N-VDS. On ESXi hosts, the N-VDS implementation is derived from VMware vSphere® Distributed Switch™ (VDS). With any other kind of transport node (KVM hypervisors, Edges, bare metal servers, cloud VMs etc.) the N-VDS implementation is derived from the Open vSwitch (OVS).

NSX-T 3.0 is introducing a new model for its ESXi transport nodes where the NSX software components can be directly installed on the top of an existing VDS. This has several benefits such as using existing model of VDS for non-overlay traffic and avoiding the migration of VMkernel to N-VDS. Representations of the NSX virtual switch in this document will thus be labeled “N-VDS or VDS with NSX” for each scenario where the transport node represented can be an ESXi host. Note that if this new VDS-based model greatly simplifies NSX consumption on the ESXi platform, it has very little if any impact on NSX-based designs: both N-VDS and VDS running NSX provide the same NSX capabilities, only with a different representation in vCenter. Operational details on how to run NSX on VDS are out of scope of this document, but simplification in term of VMkernel interface management that this new model brings will be called out in the design section. We thus recommend deploying NSX on the top of a VDS on ESXi hosts instead of using an N-VDS for greenfield deployments starting with supported ESXi and vSphere versions. The N-VDS is still the only virtual switch available on platforms other than ESXi.

3.1.1 Segments and Transport Zones

In NSX-T, virtual layer 2 domains are called segments. There are two kinds of segments:

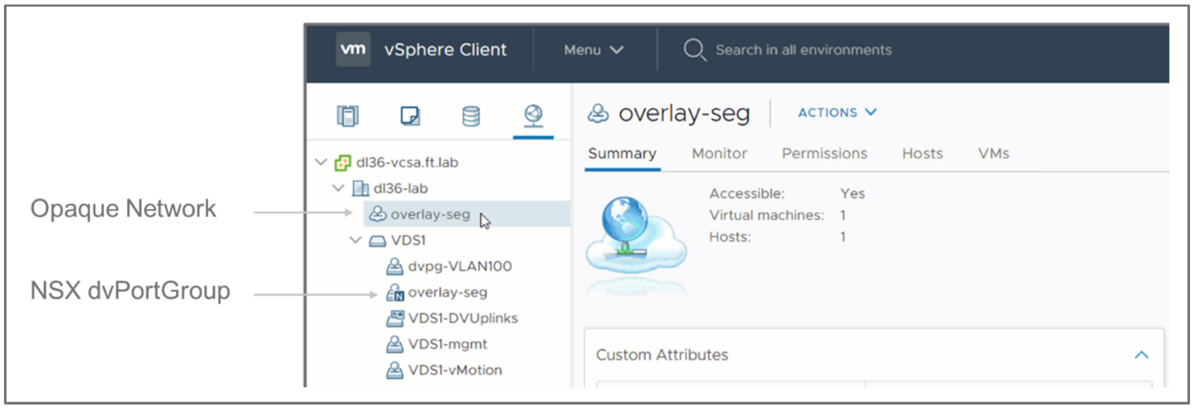
- VLAN backed segments
- Overlay backed segments

A VLAN backed segment is a layer 2 broadcast domain that is implemented as a traditional VLAN in the physical infrastructure. That means that traffic between two VMs on two different hosts but attached to the same VLAN backed segment will be carried over a VLAN between the two hosts in native IEEE encapsulation. The resulting constraint is that an appropriate VLAN needs to be provisioned in the physical infrastructure for those two VMs to communicate at layer 2 over a VLAN backed segment.
On the other hand, two VMs on different hosts and attached to the same overlay backed segment will have their layer 2 traffic carried by tunnel between their hosts. This IP tunnel is instantiated

and maintained by NSX without the need for any segment specific configuration in the physical infrastructure, thus decoupling NSX virtual networking from this physical infrastructure.

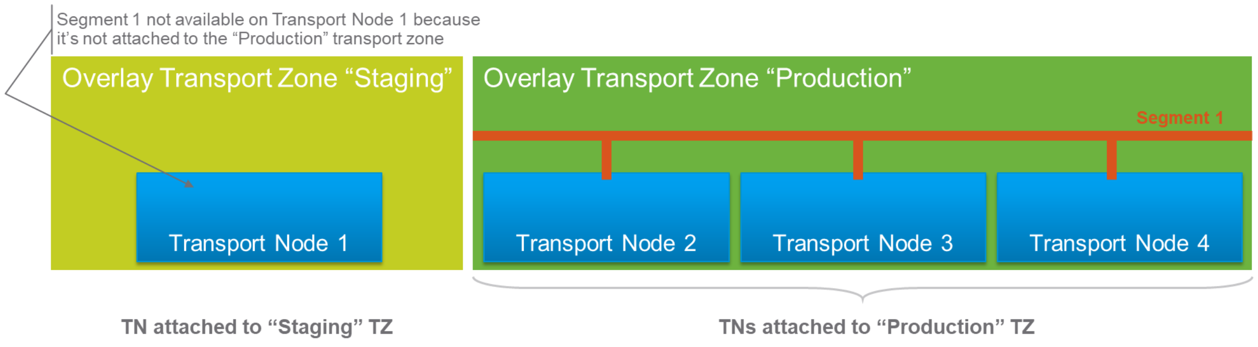
Note: representation of NSX-T segments in vCenter

This design document will only use the term “segment” when referring to the NSX-T virtual Layer broadcast domain. Note however that in the vCenter UI, those segments will appear as “opaque networks” on host configured with an N-VDS, and as NSX dvportgroups on host configured with a VDS. Below is a screenshot representing both possible representation:



Check the following KB article for more information on the impact of this difference in representation: https://kb.vmware.com/s/article/79872

Segments are created as part of an NSX object called a transport zone. There are VLAN transport zones and overlay transport zones. A segment created in a VLAN transport zone will be a VLAN backed segment, while, as you can guess, a segment created in an overlay transport zone will be an overlay backed segment. NSX transport nodes attach to one or more transport zones, and as a result, they gain access to the segments created in those transport zones. Transport zones can thus be seen as objects defining the scope of the virtual network because they provide access to groups of segments to the hosts that attach to them, as illustrated in *Figure 3-1: NSX-T Transport Zone* below:



Segment 1 not available on Transport Node 1 because it’s not attached to the “Production” transport zone
Overlay Transport Zone “Staging”
Overlay Transport Zone “Production”
Segment 1
Transport Node 1
Transport Node 2
Transport Node 3
Transport Node 4
TN attached to “Staging” TZ
TNs attached to “Production” TZ

Figure 3-1: NSX-T Transport Zone

In above diagram, transport node 1 is attached to transport zone “Staging”, while transport nodes 2-4 are attached to transport zone “Production”. If one creates a segment 1 in transport zone “Production”, each transport node in the “Production” transport zone immediately gain access to it. However, this segment 1 does not extend to transport node 1. The span of segment 1 is thus defined by the transport zone “Production” it belongs to.

Few additional points related to transport zones and transport nodes:

- Multiple virtual switches, N-VDS, VDS (with or without NSX) or VSS, can coexist on a ESXi transport node; however, a given pNIC can only be associated with a single virtual switch. This behavior is specific to the VMware virtual switch model, not to NSX.
- An NSX virtual switch (N-VDS or VDS with NSX) can attach to a single overlay transport zone and multiple VLAN transport zones at the same time.
- A transport node can have multiple NSX virtual switches – provided TN has more than 2 pNICs
    - A transport node can thus attach to multiple overlays and VLAN transport zones.
    - All virtual switches can co-exist under the same host except one cannot mix VDS with NSX and N-VDS on the same host.
- A transport zone can only be attached to a single NSX virtual switch on a given transport node. In other words, two NSX virtual switches on the same transport node cannot be attached to the same transport zone.
- Edge transport node-specific points:
    - an edge transport node only has one N-VDS attached to an overlay transport zone.
    - If multiple VLAN segments are backed by the same VLAN ID, only one of those segments will be “realized” (i.e. working effectively).

Please see additional consideration at Running a VDS prepared for NSX on ESXi hosts.

3.1.2 Uplink vs. pNIC

NSX introduces a clean differentiation between the physical uplinks of the host (aka pNICs, or vmnics on ESXi hosts) and the uplinks of the NSX virtual switch. The uplinks of the NSX virtual switch are logical constructs that can be mapped to one or multiple pNICs bundled into a link aggregation group (LAG). *Figure 3-2: N-VDS Uplinks vs. Hypervisor pNICs* illustrates the difference between an uplink and a pNIC:

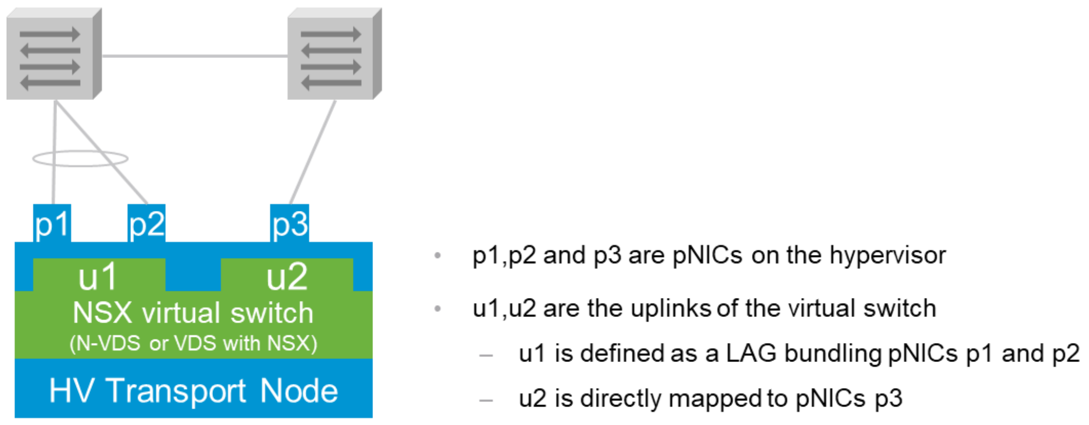

p1
p2
p3
u1
u2
NSX virtual switch
(N-VDS or VDS with NSX)
HV Transport Node
p1,p2 and p3 are pNICs on the hypervisor
u1,u2 are the uplinks of the virtual switch
u1 is defined as a LAG bundling pNICs p1 and p2
u2 is directly mapped to pNICs p3

Figure 3-2: N-VDS Uplinks vs. Hypervisor pNICs

In this example, a single virtual switch with two uplinks is defined on the hypervisor transport node. One of the uplinks is a LAG, bundling physical port p1 and p2, while the other uplink is only backed by a single physical port p3. Both uplinks look the same from the perspective of the virtual switch; there is no functional difference between the two.

Note that the example represented in this picture is by no means a design recommendation, it’s just illustrating the difference between the virtual switch uplinks and the host physical uplinks.

3.1.3 Teaming Policy

The teaming policy defines how the NSX virtual switch uses its uplinks for redundancy and traffic load balancing. There are two main options for teaming policy configuration:

- **Failover Order –** An active uplink is specified along with an optional list of standby uplinks. Should the active uplink fail, the next available uplink in the standby list takes its place immediately.
- **Load Balanced Source Port/Load Balance Source Mac Address –** Traffic is distributed across a specified list of active uplinks.
  - The “Load Balanced Source Port” policy maps a virtual interface to an uplink of the host. Traffic sent by this virtual interface will leave the host through this uplink only, and traffic destined to this virtual interface will necessarily enter the host via this uplink.
  - The “Load Balanced Source Mac Address” goes a little bit further in term of granularity for virtual interfaces that can source traffic from different mac addresses: two frames sent by the same virtual interface could be pinned to different host uplinks based on their source mac address.

The teaming policy only defines how the NSX virtual switch balances traffic across its uplinks. The uplinks can in turn be individual pNICs or LAGs (as seen in the previous section.) Note that a LAG uplink has its own hashing options, however, those hashing options only define how traffic is distributed across the physical members of the LAG uplink, whereas the teaming policy define how traffic is distributed between NSX virtual switch uplinks.

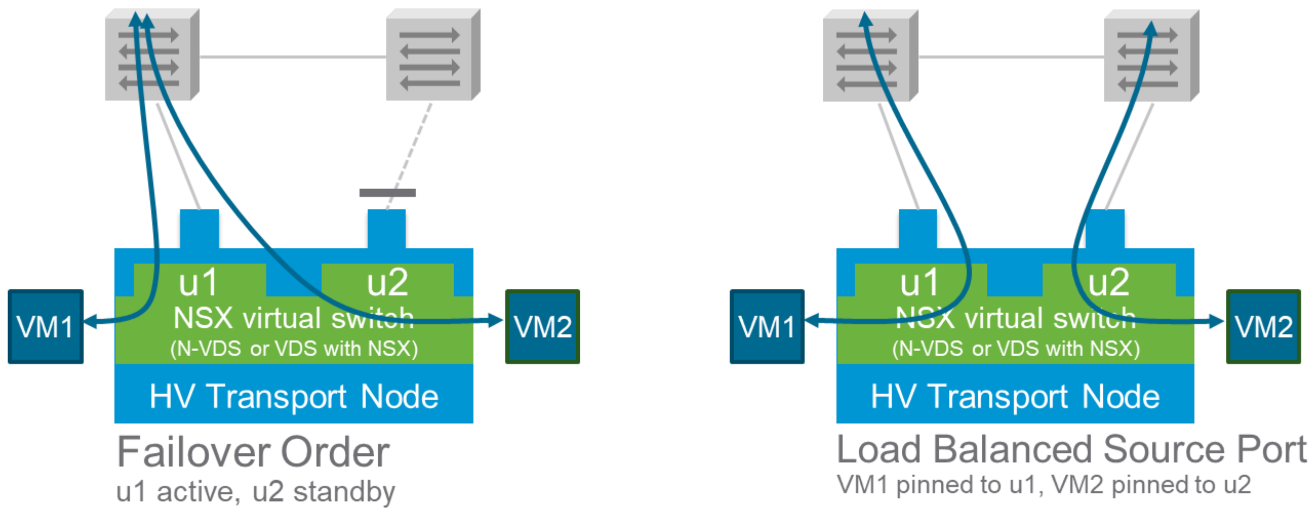


Figure 3-3: N-VDS Teaming Policies

Figure 3-3: N-VDS Teaming Policies presents an example of the failover order and source teaming policy options, illustrating how the traffic from two different VMs in the same segment is distributed across uplinks. The uplinks of the virtual switch could be any combination of single pNICs or LAGs; whether the uplinks are pNICs or LAGs has no impact on the way traffic is balanced between uplinks. When an uplink is a LAG, it is only considered down when all the physical members of the LAG are down. When defining a transport node, the user must specify a default teaming policy that will be applicable by default to the segments available to this transport node.

3.1.3.1 ESXi Hypervisor-specific Teaming Policy

ESXi hypervisor transport nodes allow defining more specific teaming policies, identified by a name, on top of the default teaming policy. It's called "named teaming policies" which can override the default teaming policy for some specific VLAN backed segments. Overlay backed segments always follow the default teaming policy. This capability is typically used to steer precisely infrastructure traffic from the host to specific uplinks.

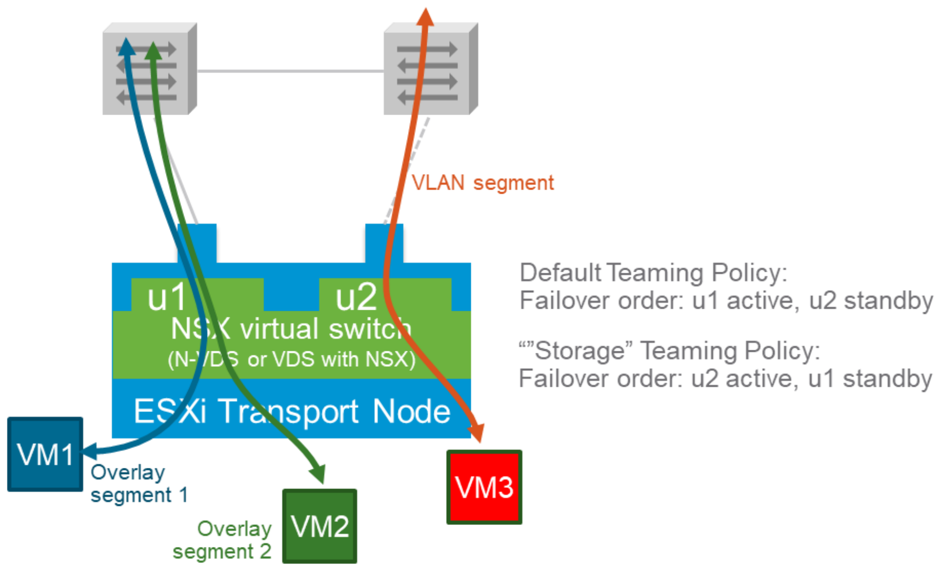


Figure 3-4: Named Teaming Policy

In the above *Figure 3-4: Named Teaming Policy*, the default failover order teaming policy specifies u1 as the active uplink and u2 as the standby uplink. By default, all the segments are thus going to send and receive traffic on u1. However, an additional failover order teaming policy called “Storage” has been added, where u2 is active and u1 standby. The VLAN segment where VM3 is attached can be mapped to the “Storage” teaming policy, thus overriding the default teaming policy for the VLAN traffic consumed by this VM3. Sometimes, it might be desirable to only send overlay traffic on a limited set of uplinks. This can also be achieved with named teaming policies for VLAN backed segment, as represented in the *Figure 3-5: Other named teaming policy use case* below:

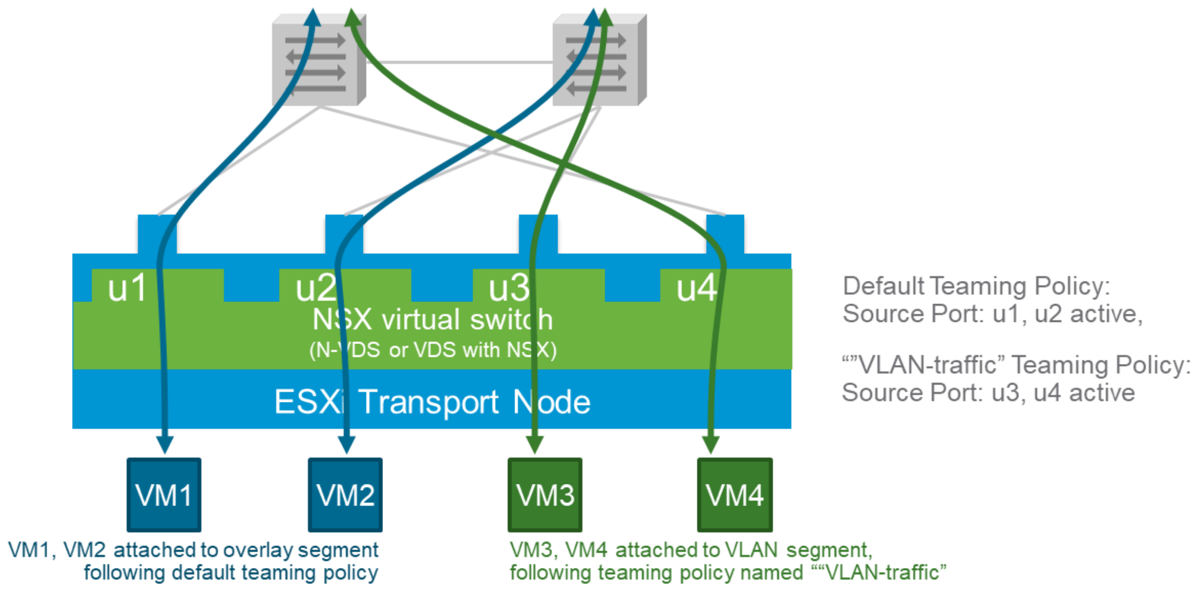

u1
u2
u3
u4
NSX virtual switch
(N-VDS or VDS with NSX)
ESXi Transport Node
VM1
VM2
VM3
VM4
Default Teaming Policy:
Source Port: u1, u2 active,
“”VLAN-traffic” Teaming Policy:
Source Port: u3, u4 active
VM1, VM2 attached to overlay segment following default teaming policy
VM3, VM4 attached to VLAN segment, following teaming policy named ““VLAN-traffic”

Figure 3-5: Other named teaming policy use case

Here, the default teaming policy only includes uplinks u1 and u2. As a result, overlay traffic is constrained to those uplinks. However, an additional teaming policy named "VLAN-traffic" is configured for load balancing traffic on uplink u3 and u4. By mapping VLAN segments to this teaming policy, overlay and VLAN traffic are segregated.

3.1.3.2 KVM Hypervisor teaming policy capabilities

KVM hypervisor transport nodes can only have a single LAG and only support the failover order default teaming policy; the load balance source teaming policies and named teaming policies are not available for KVM. A LAG must be configured for more than one physical uplink to be active on an N-VDS on a KVM hypervisor.

3.1.4 Uplink Profile

As mentioned earlier, a transport node includes at least one NSX virtual switch, implementing the NSX data plane. It is common for multiple transport nodes to share the exact same NSX virtual switch configuration. It is also very difficult from an operational standpoint to configure (and maintain) multiple parameters consistently across many devices. For this purpose, NSX defines a separate object called an uplink profile that acts as a template for the configuration of a virtual switch. The administrator can this way create multiple transport nodes with similar virtual switches by simply pointing to a common uplink profile. Even better, when the administrator modifies a parameter in the uplink profile, it is automatically updated in all the transport nodes following this uplink profile.

The following parameters are defined in an uplink profile:

- The transport VLAN used for overlay traffic. Overlay traffic will be tagged with the VLAN ID specified in this field.
- The MTU of the uplinks. NSX will assume that it can send overlay traffic with this MTU on the physical uplinks of the transport node without any fragmentation by the physical infrastructure.
- The name of the uplinks and the LAGs used by the virtual switch. LAGs are optional of course, but if you want to define some, you can give them a name, specify the number of links and the hash algorithm they will use.
- The teaming policies applied to the uplinks (default and named teaming policies)

The virtual switch uplinks defined in the uplink profile must be mapped to real, physical uplinks on the device becoming a transport node.

Figure 3-6: Transport Node Creation with Uplink Profile shows how a transport node "TN1" is created using the uplink profile "UP1".

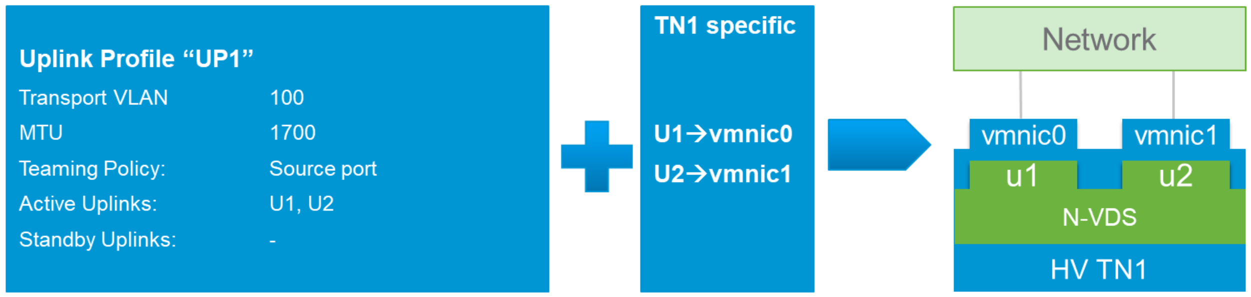


Figure 3-6: Transport Node Creation with Uplink Profile

The uplinks U1 and U2 listed in the teaming policy of the uplink profile UP1 are just variable names. When transport node TN1 is created, some physical uplinks available on the host are mapped to those variables. Here, we're mapping vmnic0 to U1 and vmnic1 to U2. If the uplink profile defined LAGs, physical ports on the host being prepared as a transport node would have to be mapped to the member ports of the LAGs defined in the uplink profile.
The benefit of this model is that we can create an arbitrary number of transport nodes following the configuration of the same uplink profile. There might be local differences in the way virtual switch uplinks are mapped to physical ports. For example, one could create a transport node TN2 still using the same UP1 uplink profile, but mapping U1 to vmnic3 and U2 to vmnic0. Then, it's possible to change the teaming policy of UP1 to failover order and setting U1 as active and U2 as standby. On TN1, this would lead vmnic0 as active and vmnic1 as standby, while TN2 would use vmnic3 as active and vmnic0 as standby.

If uplink profiles allow configuring the virtual switches of multiple transport nodes in a centralized fashion, they also allow for very granular configuration if needed. Suppose now that we want to turn a mix of ESXi host and KVM hosts into transport zone. UP1 defined above cannot be applied to KVM hosts because those only support the failover order policy. The administrator can simply create an uplink profile specific to KVM hosts, with a failover order teaming policy, while keeping an uplink profile with a source teaming policy for ESXi hosts, as represented in *Figure 3-7: Leveraging Different Uplink Profiles* below:

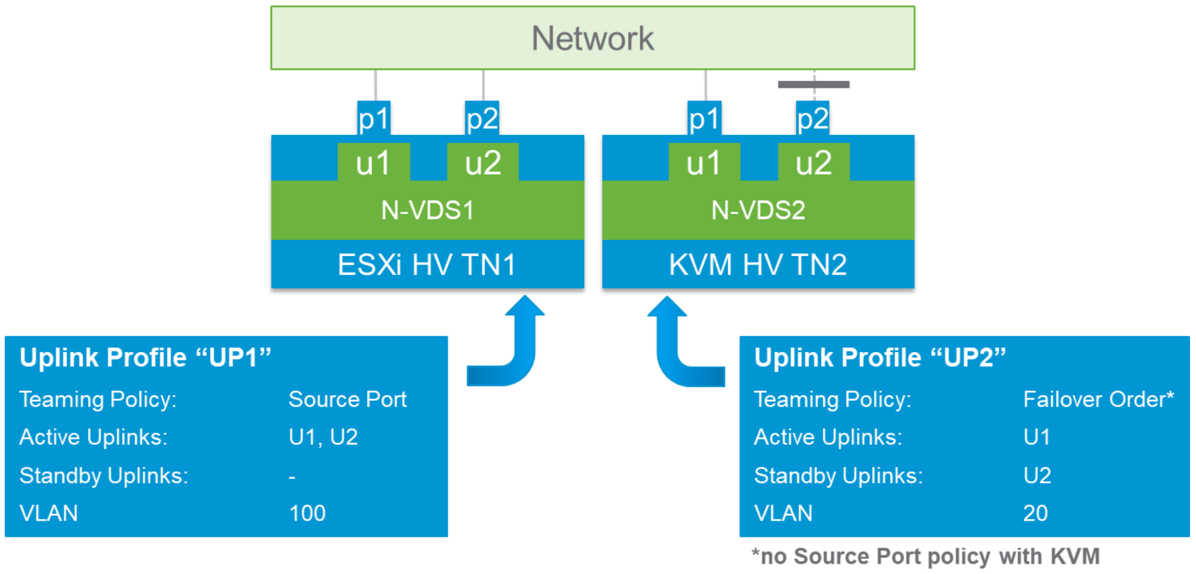


Figure 3-7: Leveraging Different Uplink Profiles

If NSX had a single centralized configuration for all the hosts, we would have been forced to fall back to the lowest common denominator failover order teaming policy for all the hosts.
The uplink profile model also allows for different transport VLANs on different hosts. This can be useful when the same VLAN ID is not available everywhere in the network, for example, the case for migration, reallocation of VLANs based on topology or geo-location change.

When running NSX on VDS, the LAG definition and the MTU fields of the uplink profile are now directly defined on the VDS, controlled by vCenter. It is still possible to associate transport node based on N-VDS and transport nodes based on VDS to the same uplink profile. It's just that the LAG definition and the MTU will be ignored on the VDS-based transport node.

3.1.5 Transport Node Profile

NSX-T 2.4 introduced the concept of Transport Node Profile (TNP in short). The TNP is a template for creating a transport node that can be applied to a group of hosts in a single shot. Just assume that there is a cluster with several hosts with the same configuration as the one represented in *Figure 3-6: Transport Node Creation with Uplink Profile* above. The TNP would capture the association between p1→port1, p2→port2 and so on. This TNP could then be applied to the cluster, thus turning all its hosts into transport nodes in a single configuration step. Further, configuration changes are kept in sync across all the hosts, leading to easier cluster management.

3.1.6 Network I/O Control

Network I/O Control, or NIOC, is the implementation in NSX-T of vSphere's Network I/O Control v3. This feature allows managing traffic contention on the uplinks of an ESXi hypervisor. NIOC allows the creation of shares, limits and bandwidth reservation for the different kinds of ESXi infrastructure traffic.

- Shares: Shares, from 1 to 100, reflect the relative priority of a traffic type against the other traffic types that are active on the same physical adapter.

- Reservation: The minimum bandwidth that must be guaranteed on a single physical adapter. Reserved bandwidth for system traffic that is unused becomes available to other types of system traffic. Unused system traffic reservations do NOT become available to VM traffic.
- Limit: The maximum bandwidth that a traffic type can consume on a single physical adapter.

The pre-determined types of ESXi infrastructure traffic are:

- Management Traffic is for host management
- Fault Tolerance (FT) is for sync and recovery.
- NFS Traffic is traffic related to a file transfer in the network file system.
- vSAN traffic is generated by virtual storage area network.
- vMotion traffic is for computing resource migration.
- vSphere replication traffic is for replication.
- vSphere Data Protection Backup traffic is generated by backup of data.
- Virtual Machine traffic is generated by virtual machines workload
- iSCSI traffic is for Internet Small Computer System Interface storage

When using an N-VDS on the transport node, the NIOC parameters are specified as a profile that is provided as part of the Uplink Profile during the ESXi Transport Node creation. If the transport node is running NSX on top of a VDS, the NIOC configuration takes place directly in vCenter. In addition to system traffic parameters, NIOC provides an additional level of granularity for the VM traffic category: share, reservation and limits can also be applied at the Virtual Machine vNIC level. This configuration is still done with vSphere, by editing the vNIC properties of the VMs. Network Resource Pools are used to allocate bandwidth on multiple VMs. For more details, see the vSphere documentation.

3.1.7 Enhanced Data Path NSX virtual switch

When creating an ESXi Transport Node, the administrator must choose between two types of NSX virtual switch: standard or Enhanced Data Path (EDP). This option is available irrespective of whether NSX is installed using an N-VDS or a VDS. The Enhanced Data Path virtual switch is optimized for the Network Function Virtualization, where the workloads typically perform networking functions with very demanding requirements in term of latency and packet rate. In order to accommodate this use case, the Enhanced Data Path virtual switch has an optimized data path, with a different resource allocation model on the host. The specifics of this virtual switch are outside the scope of this document. The important points to remember regarding this switch are:

- It can only be instantiated on an ESXi hypervisor.
- Its uses case is very specific to NFV.

The two kinds of virtual switches can however coexist on the same hypervisor. It’s not recommended for common enterprise or cloud use cases.

For the further understanding of enhanced data path N-VDS refer to following resources. For the performance related understanding refer to NFV: Raw Packet Processing Performance.

https://docs.vmware.com/en/VMware-vCloud-NFV-OpenStack-Edition/3.1/vmware-vcloud-nfv-openstack-edition-ra31/GUID-177A9560-E650-4A99-8C20-887EEB723D09.html https://docs.vmware.com/en/VMware-vCloud-NFV-OpenStack-Edition/3.1/vmware-vcloud-nfv-openstack-edition-ra31/GUID-9E12F2CD-531E-4A15-AFF7-512D5DB9BBE5.html

https://docs.vmware.com/en/VMware-vCloud-NFV-OpenStack-Edition/3.0/vmwa-vcloud-nfv30-performance-tunning/GUID-0625AE2F-8AE0-4EBC-9AC6-2E0AD222EA2B.html

3.2 Logical Switching

This section on logical switching focuses on overlay backed segments due to their ability to create isolated logical L2 networks with the same flexibility and agility that exists with virtual machines. This decoupling of logical switching from the physical network infrastructure is one of the main benefits of adopting NSX-T.

3.2.1 Overlay Backed Segments

Figure 3-8: Overlay Networking – Logical and Physical View presents logical and physical network views of a logical switching deployment.

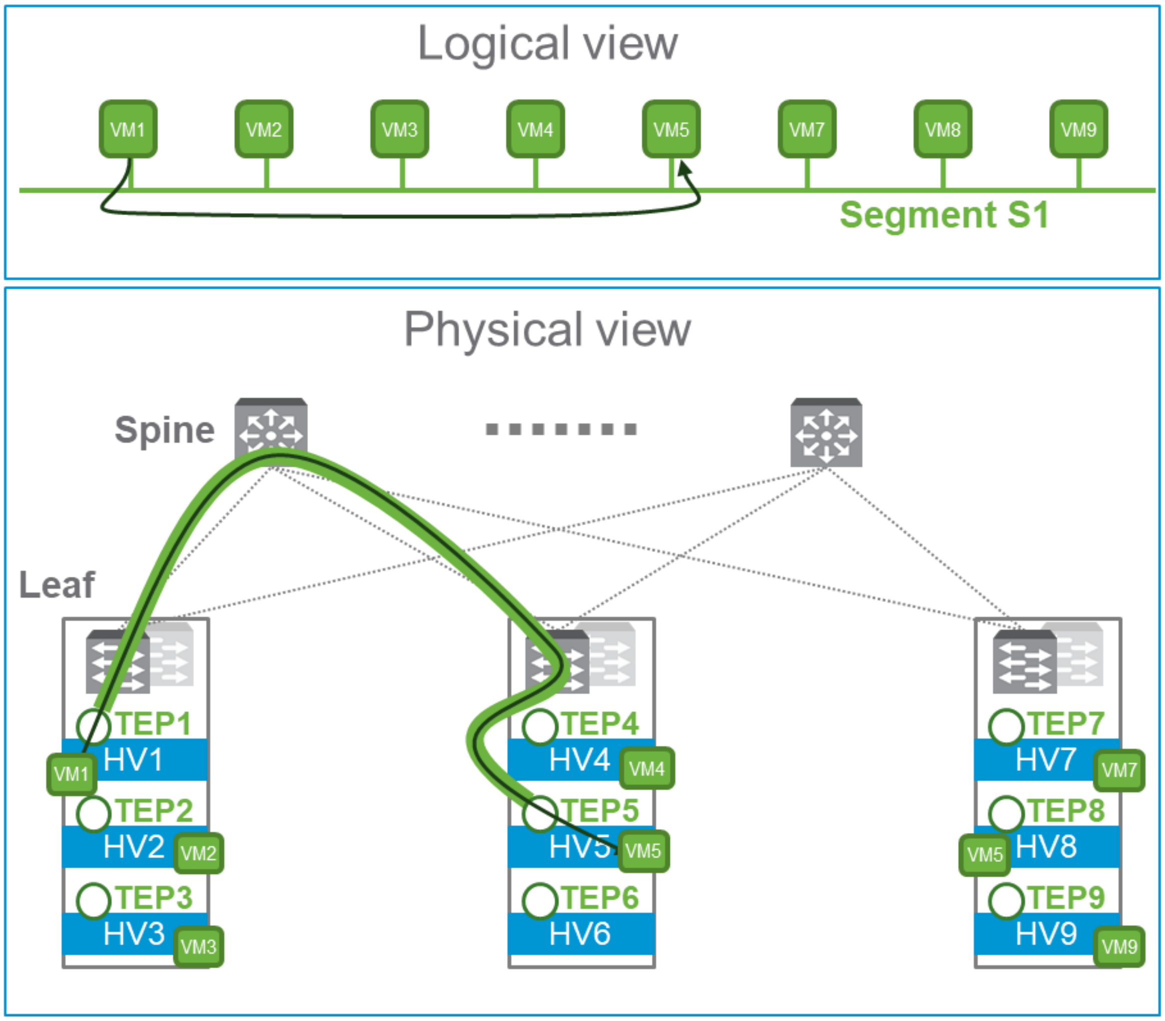


Figure 3-8: Overlay Networking – Logical and Physical View

In the upper part of the diagram, the logical view consists of five virtual machines that are attached to the same segment, forming a virtual broadcast domain. The physical representation, at the bottom, shows that the five virtual machines are running on hypervisors spread across three racks in a data center. Each hypervisor is an NSX-T transport node equipped with a tunnel endpoint (TEP). The TEPs are configured with IP addresses, and the physical network infrastructure just need to provide IP connectivity between them. Whether the TEPs are L2 adjacent in the same subnet or spread in different subnets does not matter. The VMware® NSX-T Controller™ (not pictured) distributes the IP addresses of the TEPs across the transport nodes so they can set up tunnels with their peers. The example shows “VM1” sending a frame to “VM5”. In the physical representation, this frame is transported via an IP point-to-point tunnel between transport nodes “HV1” to “HV5”.
The benefit of this NSX-T overlay model is that it allows direct connectivity between transport nodes irrespective of the specific underlay inter-rack (or even inter-datacenter) connectivity (i.e., L2 or L3). Segments can also be created dynamically without any configuration of the physical network infrastructure.

3.2.2 Flooded Traffic

The NSX-T segment behaves like a LAN, providing the capability of flooding traffic to all the devices attached to this segment; this is a cornerstone capability of layer 2. NSX-T does not differentiate between the different kinds of frames replicated to multiple destinations. Broadcast, unknown unicast, or multicast traffic will be flooded in a similar fashion across a segment. In the overlay model, the replication of a frame to be flooded on a segment is orchestrated by the different NSX-T components. NSX-T provides two different methods for flooding traffic described in the following sections. They can be selected on a per segment basis.

3.2.2.1 Head-End Replication Mode

In the head end replication mode, the transport node at the origin of the frame to be flooded sends a copy to each other transport node that is connected to this segment.

Figure 3-9: Head-end Replication Mode offers an example of virtual machine "VM1" on hypervisor "HV1" attached to segment "S1". "VM1" sends a broadcast frame on "S1". "HV1" floods the frame to the logical ports local to "HV1", then determines that there are remote transport nodes part of "S1". The NSX-T Controller advertised the TEPs of those remote interested transport nodes, so "HV1" will send a tunneled copy of the frame to each of them.

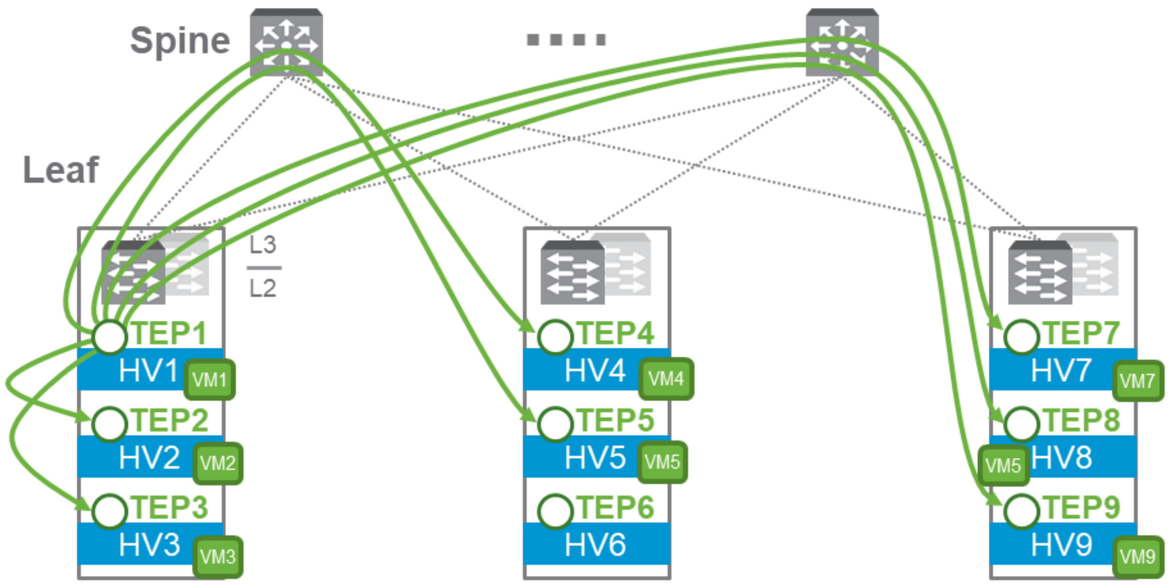


Figure 3-9: Head-end Replication Mode

The diagram illustrates the flooding process from the hypervisor transport node where "VM1" is located. "HV1" sends a copy of the frame that needs to be flooded to every peer that is interested in receiving this traffic. Each green arrow represents the path of a point-to-point tunnel through which the frame is forwarded. In this example, hypervisor "HV6" does not receive a copy of the frame. This is because the NSX-T Controller has determined that there is no recipient for this frame on that hypervisor.

In this mode, the burden of the replication rests entirely on source hypervisor. Seven copies of the tunnel packet carrying the frame are sent over the uplink of "HV1". This should be considered when provisioning the bandwidth on this uplink.

3.2.2.2 Two-tier Hierarchical Mode

In the two-tier hierarchical mode, transport nodes are grouped according to the subnet of the IP address of their TEP. Transport nodes in the same rack typically share the same subnet for their TEP IPs, though this is not mandatory. Based on this assumption, *Figure 3-10: Two-tier Hierarchical Mode* shows hypervisor transport nodes classified in three groups: subnet 10.0.0.0, subnet 20.0.0.0 and subnet 30.0.0.0. In this example, the IP subnet have been chosen to be easily readable; they are not public IPs.

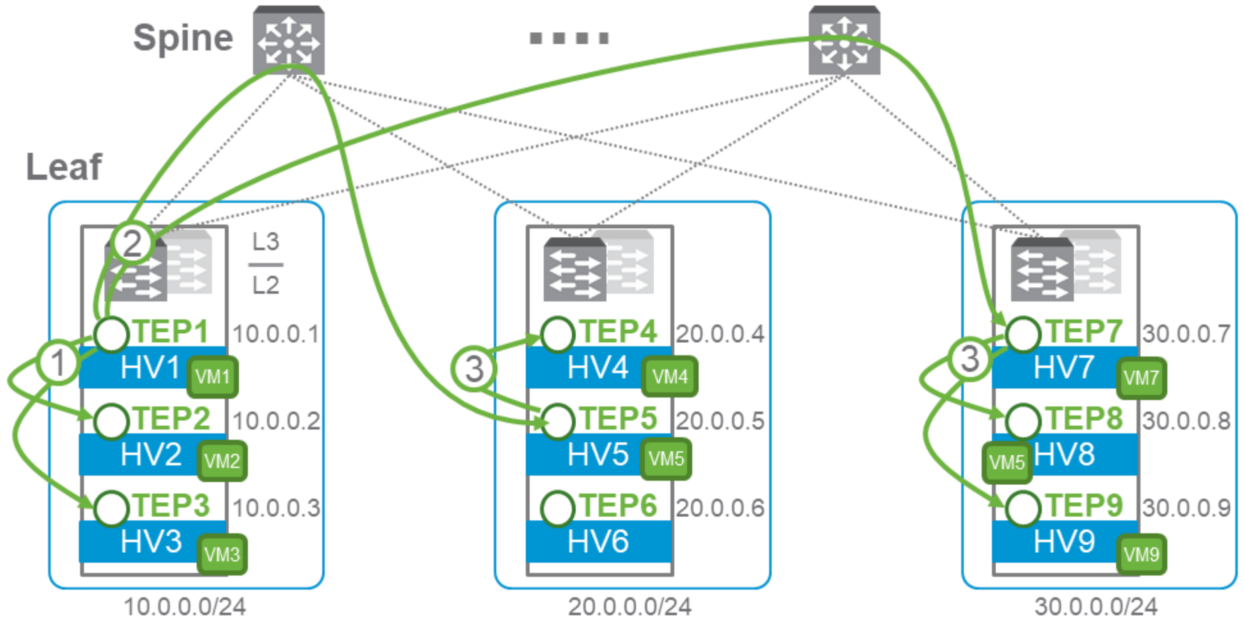


Figure 3-10: Two-tier Hierarchical Mode

Assume that “VM1” on “HV1” needs to send the same broadcast on “S1” as in the previous section on head-end replication. Instead of sending an encapsulated copy of the frame to each remote transport node attached to “S1”, the following process occurs:

1. “HV1” sends a copy of the frame to all the transport nodes within its group (i.e., with a TEP in the same subnet as its TEP). In this case, “HV1” sends a copy of the frame to “HV2” and “HV3”.
2. “HV1” sends a copy to a single transport node on each of the remote groups. For the two remote groups - subnet 20.0.0.0 and subnet 30.0.0.0 – “HV1” selects an arbitrary member of those groups and sends a copy of the packet there a bit set to indicate the need for local replication. In this example, “HV1” selected “HV5” and “HV7”.
3. Transport nodes in the remote groups perform local replication within their respective groups. “HV5” relays a copy of the frame to “HV4” while “HV7” sends the frame to “HV8” and “HV9”. Note that “HV5” does not relay to “HV6” as it is not interested in traffic from “LS1”.

The source hypervisor transport node knows about the groups based on the information it has received from the NSX-T Controller. It does not matter which transport node is selected to perform replication in the remote groups so long as the remote transport node is up and available. If this were not the case (e.g., “HV7” was down), the NSX-T Controller would update all transport nodes attached to “S1”. “HV1” would then choose “HV8” or “HV9” to perform the replication local to group 30.0.0.0.

In this mode, as with head end replication example, seven copies of the flooded frame have been made in software, though the cost of the replication has been spread across several transport nodes. It is also interesting to understand the traffic pattern on the physical infrastructure. The benefit of the two-tier hierarchical mode is that only two tunnel packets (compared to the headend mode of five packets) were sent between racks, one for each remote group. This is a significant improvement in the network inter-rack (or inter-datacenter) fabric utilization - where available bandwidth is typically less than within a rack. That number that could be higher still if there were more transport nodes interested in flooded traffic for “S1” on the remote racks. In the case where the TEPs are in another data center, the savings could be significant. Note also that this benefit in term of traffic optimization provided by the two-tier hierarchical mode only applies to environments where TEPs have their IP addresses in different subnets. In a flat Layer 2 network, where all the TEPs have their IP addresses in the same subnet, the two-tier hierarchical replication mode would lead to the same traffic pattern as the source replication mode.

The default two-tier hierarchical flooding mode is recommended as a best practice as it typically performs better in terms of physical uplink bandwidth utilization.

3.2.3 Unicast Traffic

When a frame is destined to an unknown MAC address, it is flooded in the network. Switches typically implement a MAC address table, or filtering database (FDB), that associates MAC addresses to ports in order to prevent flooding. When a frame is destined to a unicast MAC address known in the MAC address table, it is only forwarded by the switch to the corresponding port.

The NSX virtual switch maintains such a table for each segment/logical switch it is attached to. A MAC address can be associated with either a virtual NIC (vNIC) of a locally attached VM or a remote TEP (when the MAC address is located on a remote transport node reached via the tunnel identified by that TEP).

Figure 3-11: Unicast Traffic between VMs illustrates virtual machine “Web3” sending a unicast frame to another virtual machine “Web1” on a remote hypervisor transport node. In this example, the NSX virtual switch on both the source and destination hypervisor transport nodes are fully populated.

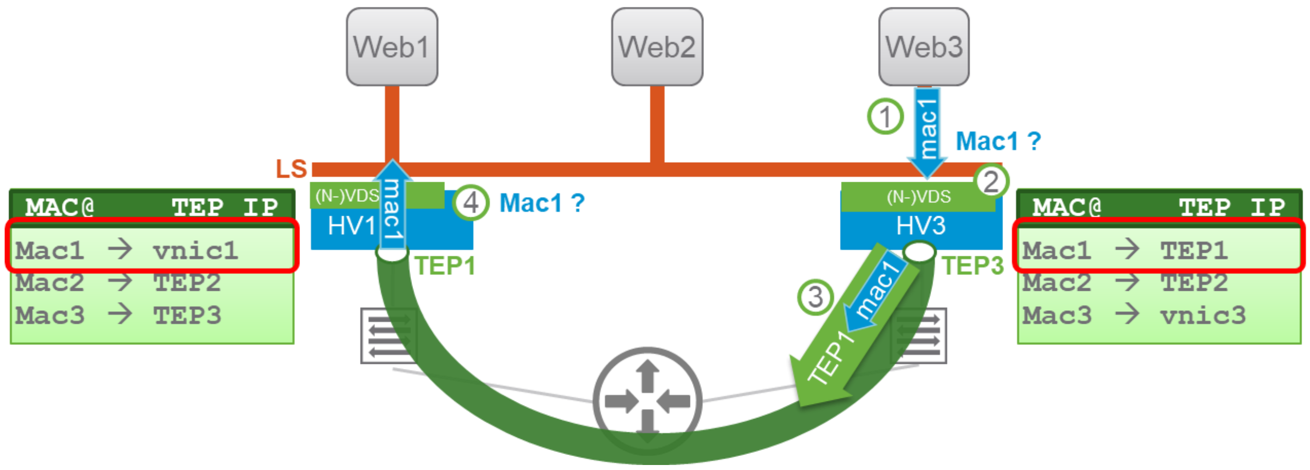


Figure 3-11: Unicast Traffic between VMs

1. “Web3” sends a frame to “Mac1”, the MAC address of the vNIC of “Web1”.
2. “HV3” receives the frame and performs a lookup for the destination MAC address in its MAC address table. There is a hit. “Mac1” is associated to the “TEP1” on “HV1”.
3. “HV3” encapsulates the frame and sends it to “TEP1”.
4. “HV1” receives the tunnel packet, addressed to itself and decapsulates it. TEP1 then performs a lookup for the destination MAC of the original frame. “Mac1” is also a hit there, pointing to the vNIC of “VM1”. The frame is then delivered to its final destination.

This mechanism is relatively straightforward because at layer 2 in the overlay network, all the known MAC addresses are either local or directly reachable through a point-to-point tunnel.
In NSX-T, the MAC address tables can be populated by the NSX-T Controller or by learning from the data plane. The benefit of data plane learning, further described in the next section, is that it is immediate and does not depend on the availability of the control plane.

3.2.4 Data Plane Learning

In a traditional layer 2 switch, MAC address tables are populated by associating the source MAC addresses of frames received with the ports where they were received. In the overlay model, instead of a port, MAC addresses reachable through a tunnel are associated with the TEP for the remote end of this tunnel. Data plane learning is a matter of associating source MAC addresses with source TEPs. Ideally data plane learning would occur through the NSX virtual switch associating the source MAC address of received encapsulated frames with the source IP of the tunnel packet. But this common method used in overlay networking would not work for NSX with the two-tier replication model. Indeed, as shown in part 3.2.2.2, it is possible that flooded traffic gets replicated by an intermediate transport node. In that case, the source IP address of the received tunneled traffic represents the intermediate transport node instead of the transport node that originated the traffic. *Figure 3-12: Data Plane Learning Using Tunnel Source IP Address* below illustrates this problem by focusing on the flooding of a frame from VM1 on HV1 using the two-tier replication model (similar to what was described earlier in *Figure 3-10: Two-tier Hierarchical Mode*.) When intermediate transport node HV5 relays the flooded traffic from HV1 to HV4, it is actually decapsulating the original tunnel traffic and re-encapsulating it, using its own TEP IP address as a source.

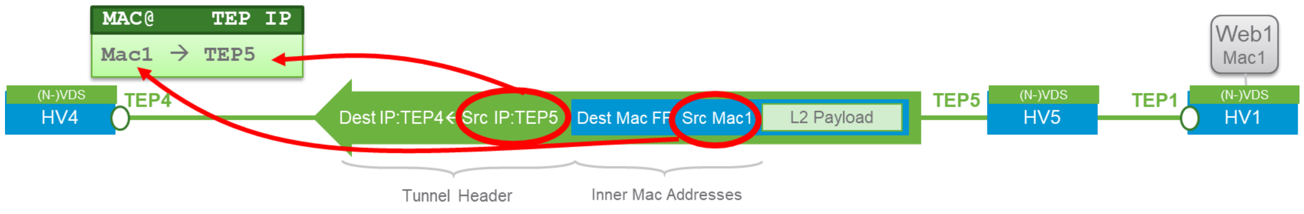


Figure 3-12: Data Plane Learning Using Tunnel Source IP Address

The problem is thus that, if the NSX virtual switch on “HV4” was using the source tunnel IP address to identify the origin of the tunneled traffic, it would wrongly associate Mac1 to TEP5.

To solve this problem, upon re-encapsulation, TEP 5 inserts an identifier for the source TEP as NSX-T metadata in the tunnel header. Metadata is a piece of information that is carried along with the payload of the tunnel. *Figure 3-13: Data Plane Learning Leveraging Metadata* displays the same tunneled frame from “Web1” on “HV1”, this time carried with a metadata field identifying “TEP1” as the origin.

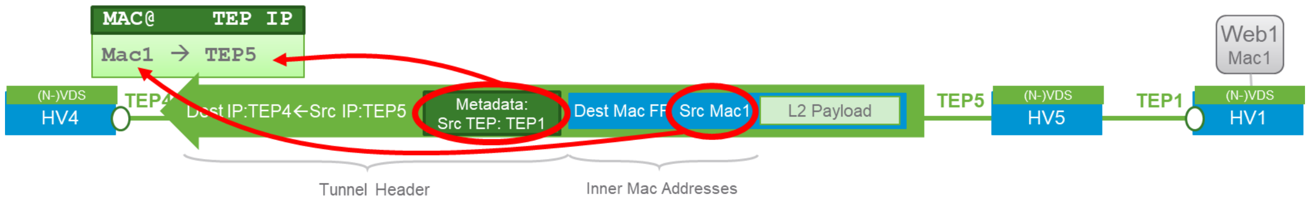


Figure 3-13: Data Plane Learning Leveraging Metadata

With this additional piece of information, “HV4” can correctly identify the origin of the tunneled traffic on replicated traffic.

3.2.5 Tables Maintained by the NSX-T Controller

While NSX-T can populate the filtering database of a segment/logical switch from the data plane just like traditional physical networking devices, the NSX-T Controller is also building a central repository for some tables that enhances the behavior of the system. These tables include:

- Global MAC address to TEP table
- Global ARP table, associating MAC addresses to IP addresses

3.2.5.1 MAC Address to TEP Tables

When the vNIC of a VM is attached to a segment/logical switch, the NSX-T Controller is notified of the MAC address as well as the TEP by which this MAC address is reachable. Unlike individual transport nodes that only learn MAC addresses corresponding to received traffic, the NSX-T Controller has a global view of all MAC addresses declared in the NSX-T environment.

The global MAC address table can proactively populate the local MAC address table of the different transport nodes before they receive any traffic. Also, in the rare case when transport node receives a frame from a VM destined to an unknown MAC address, it will send a request to look up this MAC address in the global table of the NSX-T Controller while simultaneously flooding the frame.

Not all the MAC addresses present in the data plane tables are reported to the NSX-T Controller. If a VM is allowed to send traffic on a segment/logical switch from several source MAC addresses, those secondary MAC addresses are not pushed to the NSX-T Controller. Similarly, the NSX-T Controller is not notified of MAC addresses learned from an Edge bridge connected to a physical layer 2 network. This behavior was implemented in order to protect the NSX-T Controller from an injection of an arbitrarily large number of MAC addresses into in the network.

3.2.5.2 ARP Tables

The NSX-T Controller also maintains an ARP table in order to help implement an ARP suppression mechanism. The NSX virtual switch snoops DHCP and ARP traffic to learn MAC address to IP associations. Those associations are then reported to the NSX-T Controller. An example of the process is summarized in *Figure 3-14: ARP Suppression*.

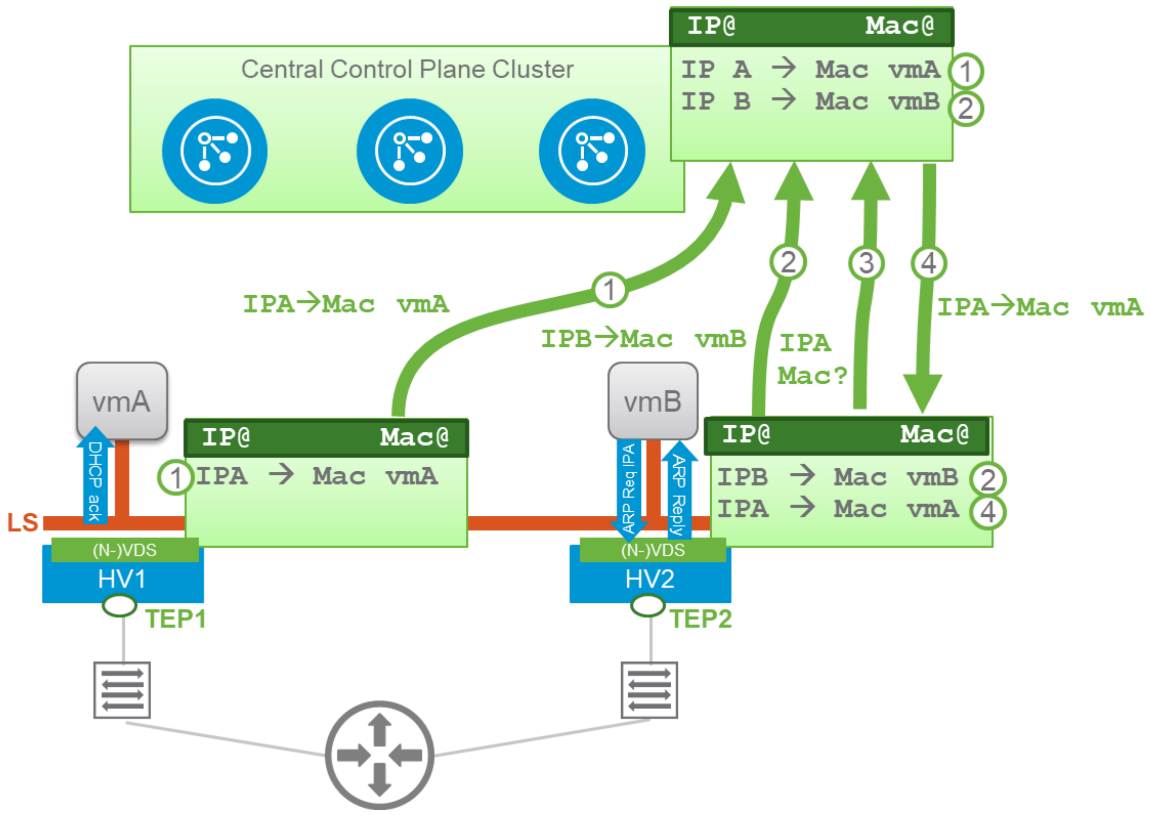


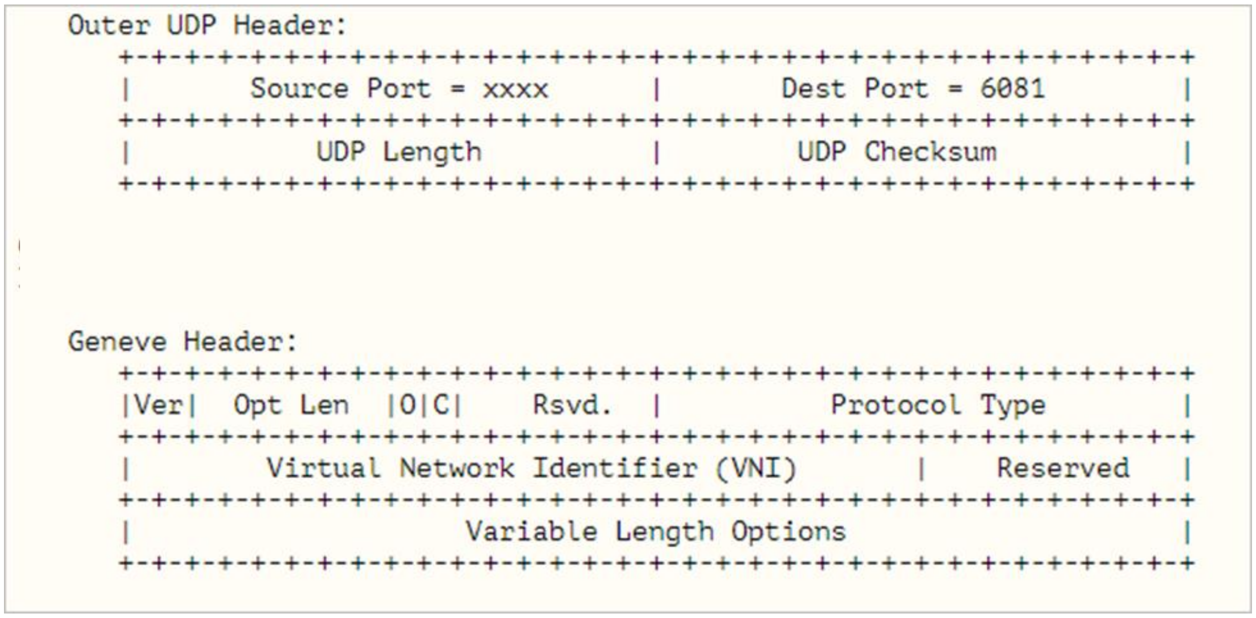
Figure 3-14: ARP Suppression

1. Virtual machine “vmA” has just finished a DHCP request sequence and been assigned IP address “IPA”. The NSX virtual switch on “HV1” reports the association of the MAC address of virtual machine “vmA” to “IPA” to the NSX-T Controller.
2. Next, a new virtual machine “vmB” comes up on “HV2” that must communicate with “vmA”, but its IP address has not been assigned by DHCP and, as a result, there has been

no DHCP snooping. The virtual switch will be able to learn this IP address by snooping ARP traffic coming from “vmB”. Either “vmB” will send a gratuitous ARP when coming up or it will send an ARP request for the MAC address of “vmA”. The virtual switch then can derive the IP address “IPB” associated to “vmB”. The association (vmB -> IPB) is then pushed to the NSX-T Controller.
3. The NSX virtual switch also holds the ARP request initiated by “vmB” and queries the NSX-T Controller for the MAC address of “vmA”.
4. Because the MAC address of “vmA” has already been reported to the NSX-T Controller, the NSX-T Controller can answer the request coming from the virtual switch, which can now send an ARP reply directly to “vmB” on the behalf of “vmA”. Thanks to this mechanism, the expensive flooding of an ARP request has been eliminated. Note that if the NSX-T Controller did not know about the MAC address of “vmA” or if the NSX-T Controller were down, the ARP request from “vmB” would still be flooded by the virtual switch.

3.2.6 Overlay Encapsulation

NSX-T uses Generic Network Virtualization Encapsulation (Geneve) for its overlay model. Geneve is currently an IETF Internet Draft that builds on the top of VXLAN concepts to provide enhanced flexibility in term of data plane extensibility.



```
Outer UDP Header:
   +-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
   |       Source Port = xxxx      |       Dest Port = 6081        |
   +-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
   |           UDP Length          |        UDP Checksum           |
   +-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+


Geneve Header:
   +-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
   |Ver|  Opt Len  |O|C|    Rsvd.  |          Protocol Type        |
   +-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
   |        Virtual Network Identifier (VNI)       |    Reserved   |
   +-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
   |                    Variable Length Options                    |
   +-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
```

Figure 3-15: Geneve Encapsulation (from IETF Draft)

VXLAN has static fields while Geneve offers flexible field. This capability can be used by anyone to adjust the need of typical workload and overlay fabric, thus NSX-T tunnels are only setup between NSX-T transport nodes. NSX-T only needs efficient support for the Geneve encapsulation by the NIC hardware; most NIC vendors support the same hardware offload for Geneve as they would for VXLAN.

Network virtualization is all about developing a model of deployment that is applicable to a variety of physical networks and diversity of compute domains. New networking features are developed in software and implemented without worry of support on the physical infrastructure. For example, the data plane learning section described how NSX-T relies on metadata inserted in the tunnel header to identify the source TEP of a forwarded frame. This metadata could not have been added to a VXLAN tunnel without either hijacking existing bits in the VXLAN header or making a revision to the VXLAN specification. Geneve allows any vendor to add its own metadata in the tunnel header with a simple Type-Length-Value (TLV) model. NSX-T defines a single TLV, with fields for:

- Identifying the TEP that sourced a tunnel packet
- A version bit used during the intermediate state of an upgrade
- A bit indicating whether the encapsulated frame is to be traced
- A bit for implementing the two-tier hierarchical flooding mechanism. When a transport node receives a tunneled frame with this bit set, it knows that it must perform local replication to its peers
- Two bits identifying the type of the source TEP

These fields are part of a VMware specific TLV. This TLV can be changed or enlarged by VMware independent of any other vendors. Similarly, other vendors or partners can insert their own TLVs. Geneve benefits from the same NIC offloads as VXLAN (the capability is advertised in the VMware compatibility list for different NIC models.) Because overlay tunnels are only setup between NSX-T transport nodes, there is no need for any hardware or software third party vendor to decapsulate or look into NSX-T Geneve overlay packets. Thus, networking feature adoption can be done in the overlay, isolated from underlay hardware refresh cycles.

3.3 Bridging Overlay to VLAN with the Edge Bridge

Even in highly virtualized environments, customers often have workloads that cannot be virtualized, because of licensing or application-specific reasons. Even for the virtualized workload some applications have embedded IP that cannot be changed or legacy application that requires layer 2 connectivity. Those VLAN backed workloads typically communicate with overlay backed VMs at layer 3, through gateways (Tier-0 or Tier-1) instantiated on the NSX-T Edges. However, there are some scenarios where layer 2 connectivity is required between VMs and physical devices. For this functionality, NSX-T introduces the NSX-T Bridge, a service that can be instantiated on an Edge for the purpose of connecting an NSX-T logical segment with a traditional VLAN at layer 2.
The most common use cases for this feature are:

- Physical to virtual/virtual to virtual migration. This is generally a temporary scenario where a VLAN backed environment is being virtualized to an overlay backed NSX data center. The NSX-T Edge Bridge is a simple way to maintain connectivity between the different components during the intermediate stages of the migration process.

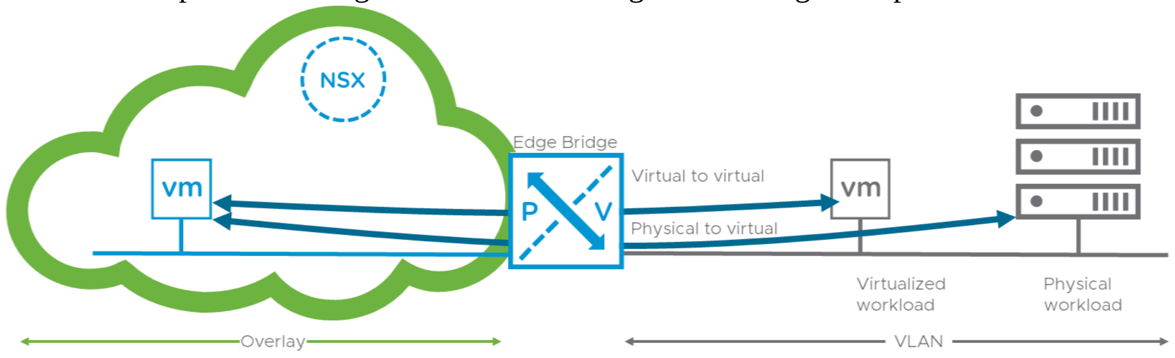


Figure 3-16: physical to virtual or virtual to virtual migration use case

- Integration of physical, non-virtualized appliances that require L2 connectivity to the virtualized environment. The most common example is a database server that requires L2 connectivity, typically because L3 connectivity has not been validated and is not supported by the vendor. This could also be the case of a service appliance that need to be inserted inline, like a physical firewall or load balancer.

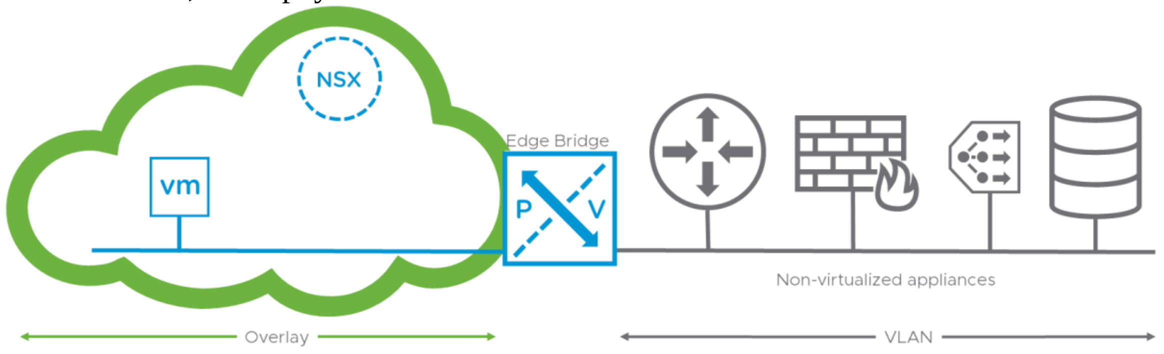


Figure 3-17: integration of non-virtualized appliances use case

Whether it is for migration purposes or for integration of non-virtualized appliances, if L2 adjacency is not needed, leveraging a gateway on the Edges (L3 connectivity) is typically more efficient, as routing allows for Equal Cost Multi Pathing, which results in higher bandwidth and a better redundancy model. A common misconception exists regarding the usage of the edge bridge, from the fact that modern SDN based adoption must not use bridging. In fact, that is not the case, the Edge Bridge can be conceived as a permanent solution for extending overlay-backed segments into VLANs. The use case of having a permeant bridging for set of workloads exist due to variety of reasons such as older application cannot change IP address, end of life gear does not allow any change, regulation, third party connectivity and span of control on those topologies or devices. However, as an architect if one desired to enable such use case must consider some level of dedicated resources and planning that ensue, such as bandwidth, operational control and protection of bridged topologies.

3.3.1 Overview of the Capabilities

The following sections present the capabilities of the NSX-T Edge Bridge.

3.3.1.1 DPDK-based performance

One of the main benefits of running a Bridge on the NSX-T Edge is the data plane performance. Indeed, the NSX-T Edge is leveraging the Data Plane Development Kit (DPDK), providing low latency, high bandwidth and scalable traffic forwarding performance.

3.3.1.2 Extend an Overlay-backed Segment/Logical Switch to a VLAN

In its most simple representation, the only thing the NSX-T Edge Bridge achieves is to convert an Ethernet frame between two different L2 representations: overlay and VLAN. In the overlay representation, the L2 frame and its payload are encapsulated in an IP-based format (as described above, NSX-T Data Center currently leverages Geneve, Generic Network Virtualization Encapsulation). In the VLAN representation, the L2 frame may include an 802.1Q trunk VLAN tag or be an IEE 802.3 frame, depending on the desired connectivity model. The Edge Bridge is currently capable of making a one-to-one association between an overlay-backed Segment (identified by a Virtual Network Identifier in the overlay header) and a specific VLAN ID.

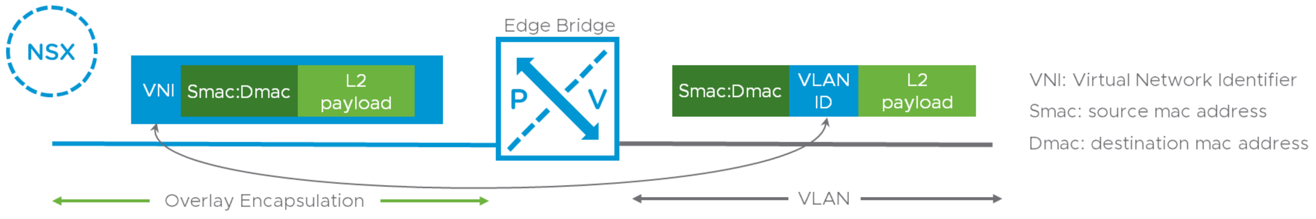


Figure 3-18: One-to-one association between segment and VLAN ID

As of NSX-T 2.4, a segment can be connected to only a single Edge Bridge. That means that L2 traffic can enter and leave the NSX overlay in a single location, thus preventing the possibility of a loop between a VLAN and the overlay. It is however possible to bridge several different segments to the same VLAN ID, if those different bridging instances are leveraging separate Edge uplinks.
Starting NSX-T 2.5, the same segment can be attached to several bridges on different Edges. This allows certain bare metal topologies to be connected with overlay segment and bridging to VLANs that can exist in separate rack without depending on physical overlay. With NSX-T 3.0, the Edge Bridge supports bridging 802.1Q tagged traffic carried in an overlay backed segment (Guest VLAN Tagging.) For more information about this feature, see the bridging white paper at:
https://communities.vmware.com/t5/VMware-NSX-Documents/Almost-everything-you-wanted-to-know-about-the-NSX-T-edge-bridge/ta-p/2776994

3.3.1.3 High Availability with Bridge Instances

The Edge Bridge operates as an active/standby service. The Edge bridge active in the data path is backed by a unique, pre-determined standby bridge on a different Edge. NSX-T Edges are deployed in a pool called an Edge Cluster. Within an Edge Cluster, the user can create a Bridge Profile, which essentially designates two Edges as the potential hosts for a pair of redundant Bridges. The Bridge Profile specifies which Edge would be primary (i.e. the preferred host for the active Bridge) and backup (the Edge that will host the backup Bridge). At the time of the creation of the Bridge Profile, no Bridge is instantiated yet. The Bridge Profile is just a template for the creation of one or several Bridge pairs.

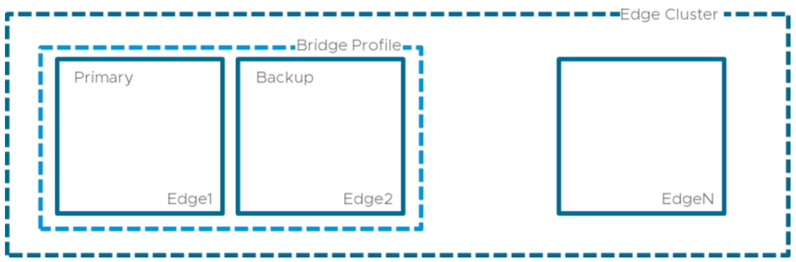


Figure 3-19: Bridge Profile, defining a redundant Edge Bridge (primary and backup)

Once a Bridge Profile is created, the user can attach a segment to it. By doing so, an active Bridge instance is created on the primary Edge, while a standby Bridge is provisioned on the backup Edge. NSX creates a Bridge Endpoint object, which represents this pair of Bridges. The attachment of the segment to the Bridge Endpoint is represented by a dedicated Logical Port, as shown in the diagram below:

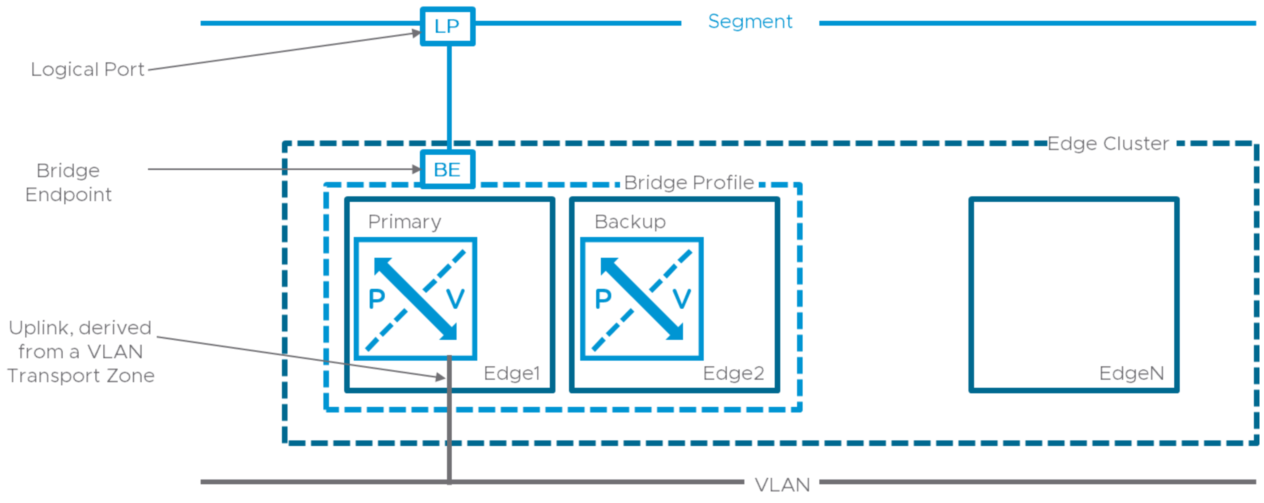


Figure 3-20: Primary Edge Bridge forwarding traffic between segment and VLAN

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.

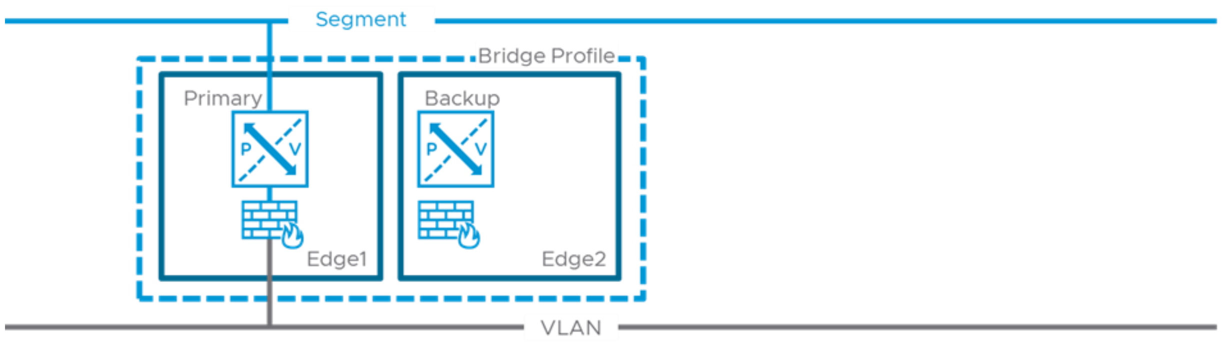


Figure 3-21: Edge Bridge Firewall

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.

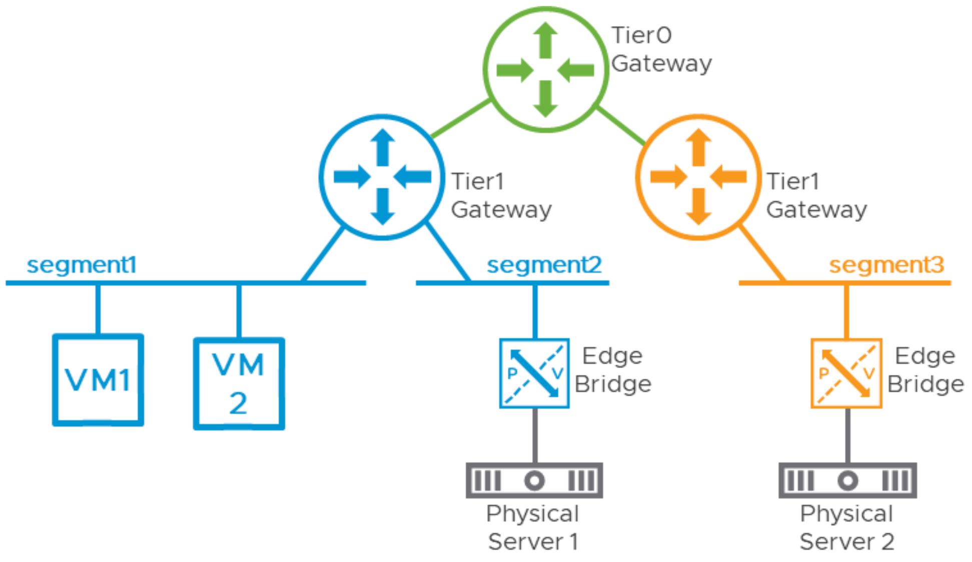


Figure 3-22: Integration with routing

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.

4 NSX-T Logical Routing

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”.

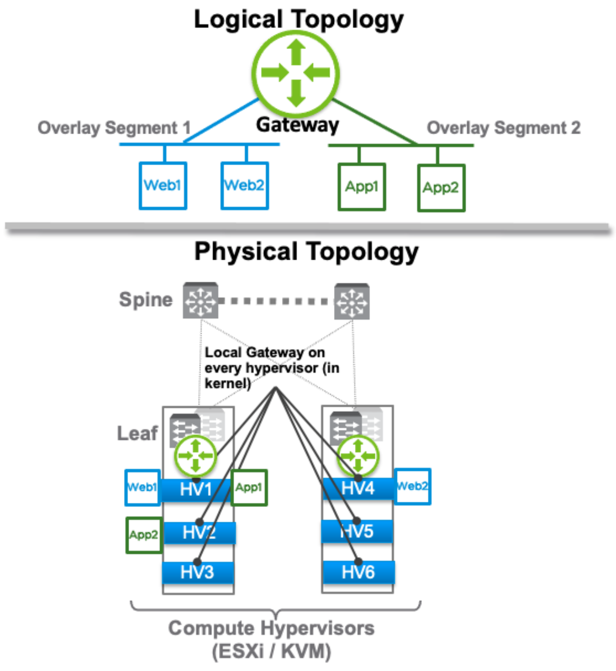


Figure 4-1: Logical and Physical View of Routing Services

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.

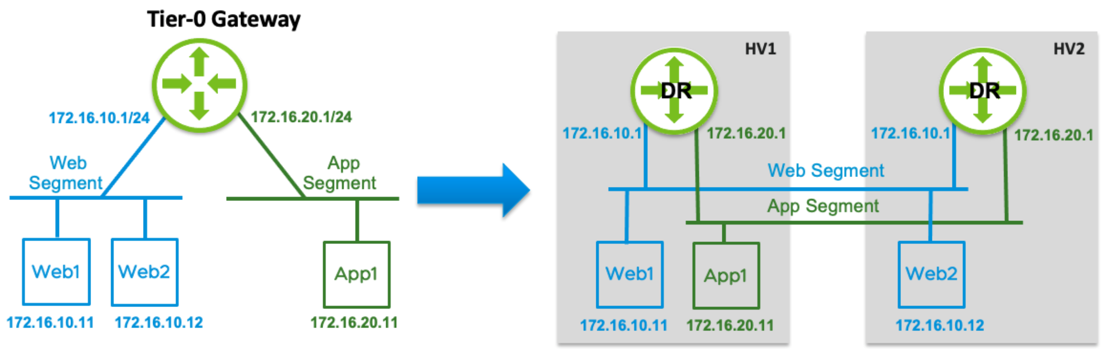


Figure 4-2: E-W Routing with Workloads on the Same Hypervisor

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.

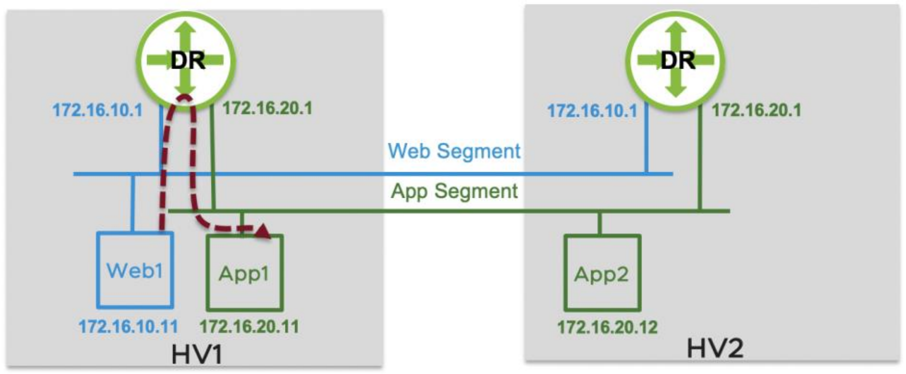


Figure 4-3: Packet Flow between two VMs on Same Hypervisor

1. "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.
2. 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".
3. 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.
4. 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.

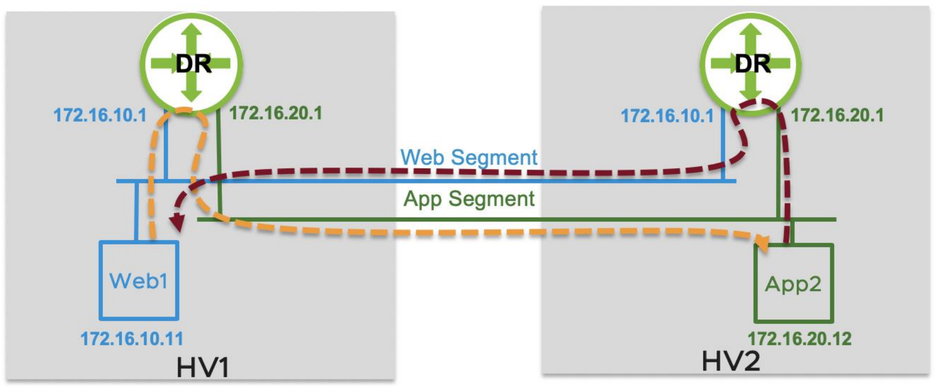


Figure 4-4: E-W Packet Flow between two Hypervisors

Figure 4-5: End-to-end E-W Packet Flow shows the corresponding physical topology and packet walk from "Web1" to "App2".

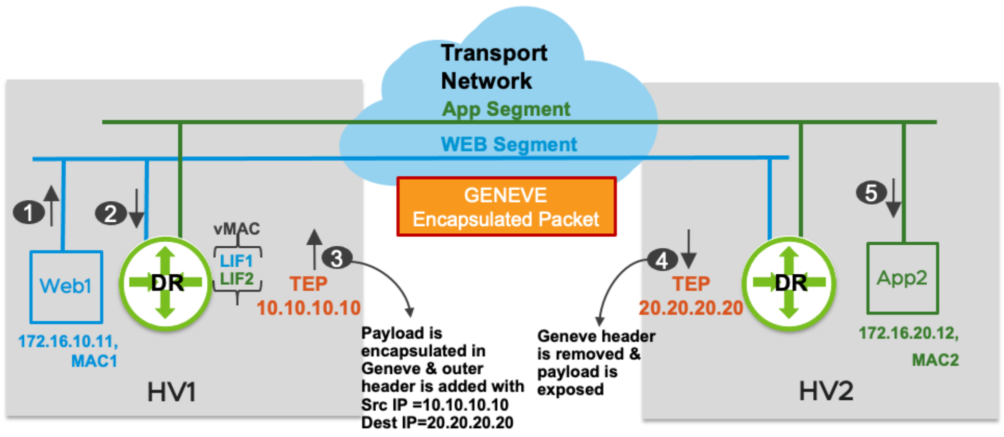

Transport Network
App Segment
WEB Segment
GENEVE Encapsulated Packet
1
2
vMAC
LIF1
LIF2
3
TEP
10.10.10.10
Web1
DR
172.16.10.11, MAC1
HV1
Payload is encapsulated in Geneve & outer header is added with Src IP =10.10.10.10 Dest IP=20.20.20.20
Geneve header is removed & payload is exposed
4
TEP
20.20.20.20
DR
5
App2
172.16.20.12, MAC2
HV2

Figure 4-5: End-to-end E-W Packet Flow

1. "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.
2. 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.

3. HV1 TEP encapsulates the original packet and sends it to the HV2 TEP with a source IP address of 10.10.10.10 and destinations 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”.
4. 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”.
5. 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.

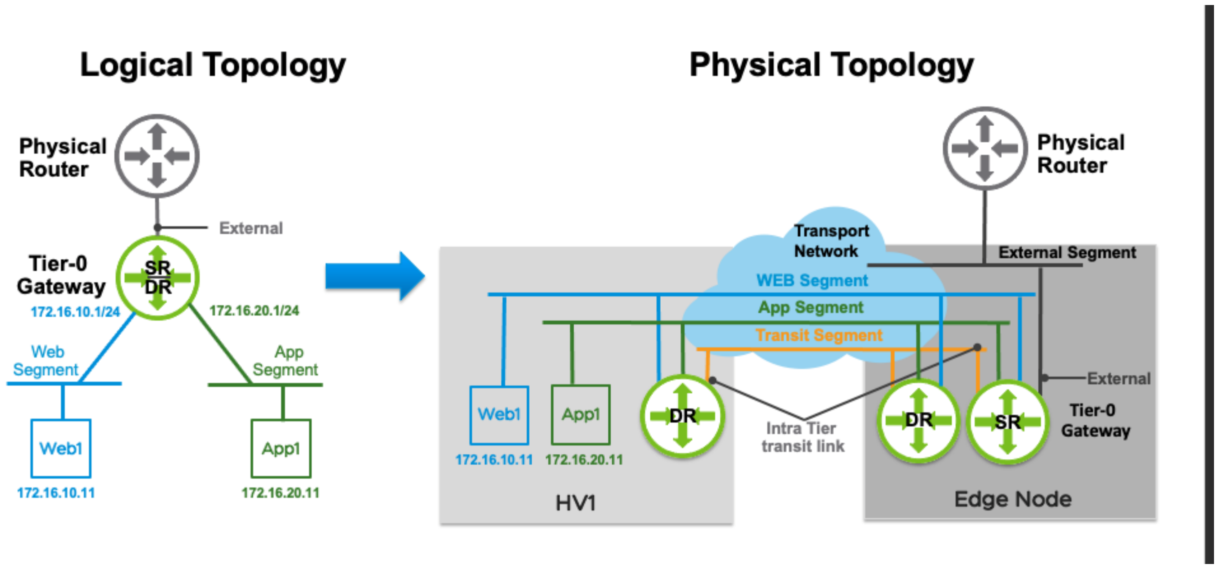


Figure 4-6: Logical Router Components and Interconnection

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.

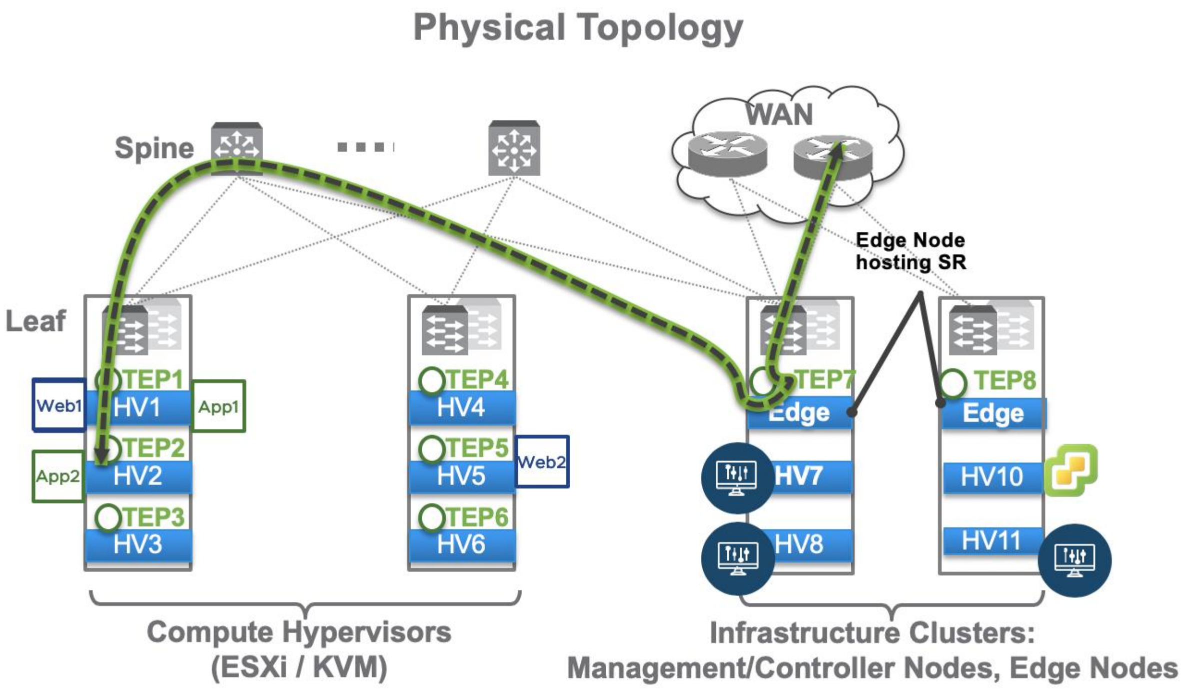


Figure 4-7: N-S Routing Packet Flow

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.

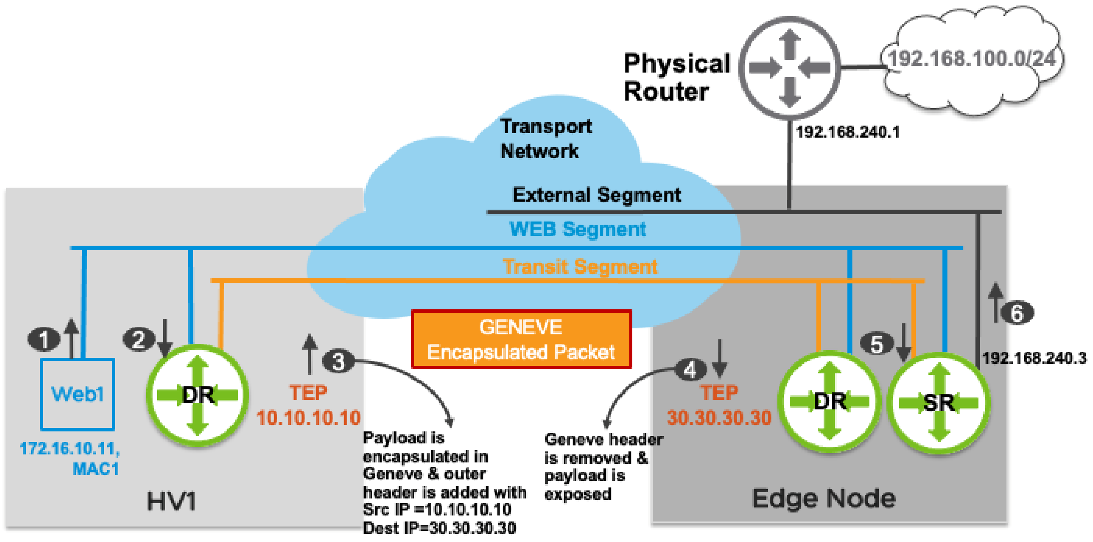


Figure 4-8: End-to-end Packet Flow – Application "Web1" to External

1. "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.
2. 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.
3. 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.
4. 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.
5. 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.
6. 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".

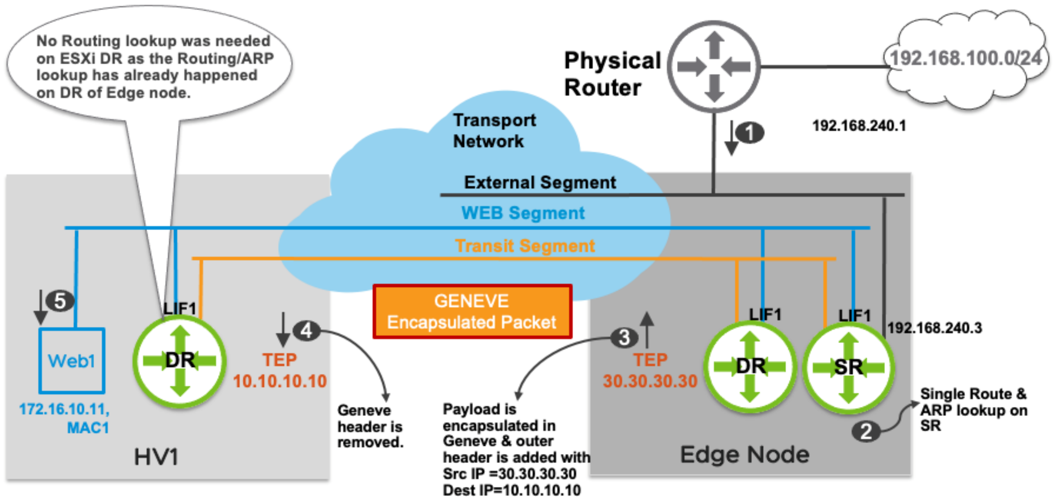

No Routing lookup was needed on ESXi DR as the Routing/ARP lookup has already happened on DR of Edge node.
Physical Router
192.168.100.0/24
Transport Network
1
192.168.240.1
External Segment
WEB Segment
Transit Segment
5
LIF1
GENEVE Encapsulated Packet
4
3
LIF1
LIF1
192.168.240.3
Web1
DR
TEP 10.10.10.10
TEP 30.30.30.30
DR
SR
172.16.10.11, MAC1
Geneve header is removed.
Payload is encapsulated in Geneve & outer header is added with Src IP =30.30.30.30 Dest IP=10.10.10.10
Single Route & ARP lookup on SR
2
HV1
Edge Node

Figure 4-9: End-to-end Packet Flow – External to Application "Web1"

1. 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.
2. 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 (10.10.10.10), which is the "HV1" host where "Web1" is located.
3. The Edge TEP encapsulates the original packet and sends it to the remote TEP with an outer packet source IP address of 30.30.30.30 and destination IP address of 10.10.10.10. The destination VNI in this Geneve encapsulated packet is of "Web Segment".
4. The HV1 host decapsulates the packet and removes the outer header upon receiving the packet. An L2 lookup is performed in the local MAC table associated with "LIF1".
5. The packet is delivered to Web1.

This time routing and ARP lookup happened on the merged SR/DR hosted on the Edge node. No such lookup was required on the DR hosted on the HV1 hypervisor, and packet was sent directly to the VM after removing the tunnel encapsulation header.

Figure 4-9: End-to-end Packet Flow – External to Application "Web1" showed a Tier-0 gateway with one external interface that leverages Edge node to connect to physical infrastructure. If this Edge node goes down, N-S connectivity along with other centralized services running on Edge node will go down as well.

To provide redundancy for centralized services and N-S connectivity, it is recommended to deploy a minimum of two edge nodes. High availability modes are discussed in section 4.6.

4.2 Two-Tier Routing

In addition to providing optimized distributed and centralized routing functions, NSX-T supports a multi-tiered routing model with logical separation between different gateways within the NSX-T infrastructure. The top-tier gateway is referred to as a Tier-0 gateway while the bottom-tier gateway is a Tier-1 gateway. This structure gives complete control and flexibility over services and policies. Various stateful services can be hosted on the Tier-1 while the Tier-0 can operate in an active-active manner.

Configuring two tier routing is not mandatory. It can be single tiered as shown in the previous section. *Figure 4-10: Two Tier Routing and Scope of Provisioning* presents an NSX-T two-tier routing architecture.

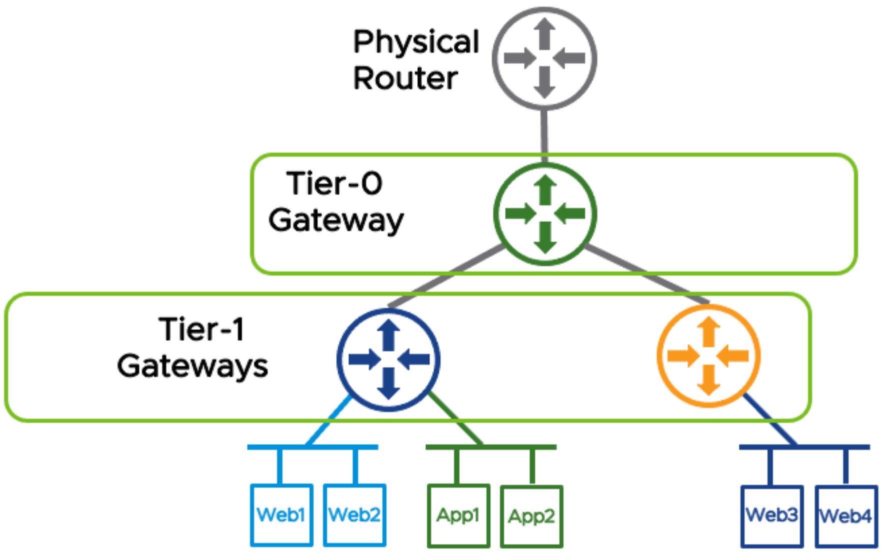


Figure 4-10: Two Tier Routing and Scope of Provisioning

Northbound, the Tier-0 gateway connects to one or more physical routers/L3 switches and serves as an on/off ramp to the physical infrastructure. Southbound, the Tier-0 gateway connects to one or more Tier-1 gateways or directly to one or more segments as shown in North-South routing section. Northbound, the Tier-1 gateway connects to a Tier-0 gateway using a RouterLink port. Southbound, it connects to one or more segments using downlink interfaces.

Concepts of DR/SR discussed in the section 4.1 remain the same for multi-tiered routing. Like Tier-0 gateway, when a Tier-1 gateway is created, a distributed component (DR) of the Tier-1 gateway is intelligently instantiated on the hypervisors and Edge nodes. Before enabling a centralized service on a Tier-0 or Tier-1 gateway, an edge cluster must be configured on this gateway. When you configure a Tier1 GW, it's when you configure an Edge cluster that the Tier-1 GW will have an SR. Configuring an Edge cluster on a Tier-0 gateway does not automatically instantiate a Tier-0 service component (SR), the service component (SR) will only be created on a specific edge node along with the external interface creation.

Unlike the Tier-0 gateway, the Tier-1 gateway does not support northbound connectivity to the physical infrastructure. A Tier-1 gateway can only connect northbound to:

- a Tier-0 gateway,
- a service port, this is used to connect a one-arm load-balancer to a segment. More details are available in Chapter 6.

Note that connecting Tier-1 to Tier-0 is a one-click configuration or one API call configuration regardless of components instantiated (DR and SR) for that gateway.

4.2.1 Interface Types on Tier-1 and Tier-0 Gateway

External and Service interfaces were previously introduced in the services router section. *Figure 4-11: Anatomy of Components with Logical Routing* shows these interfaces types along with a new "RouterLink" interface in a two-tiered topology.

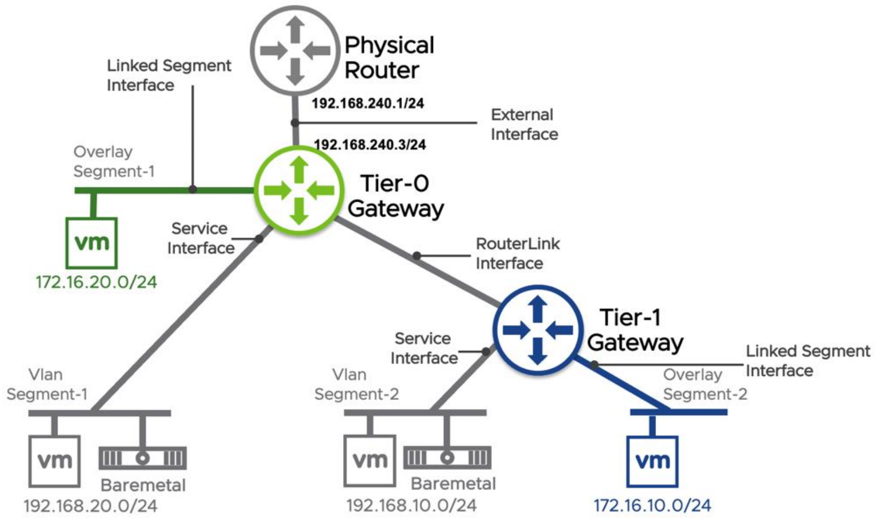


Figure 4-11: Anatomy of Components with Logical Routing

- **External Interface:** Interface connecting to the physical infrastructure/router. Static routing and BGP are supported on this interface. This interface only exists on Tier-0 gateway. This interface was referred to as Uplink interface in previous releases. This interface type will also be used to extend a VRF (Virtual Routing and Forwarding) from the physical networking fabric into the NSX domain.
- **RouterLink Interface/Linked Port**: Interface connecting Tier-0 and Tier-1 gateways. Each Tier-0-to-Tier-1 peer connection is provided a /31 subnet within the 100.64.0.0/16 reserved address space (RFC6598). This link is created automatically when the Tier-0 and Tier-1 gateways are connected. This subnet can be changed when the Tier-0 gateway is being created. It is not possible to change it afterward.
- **Service Interface:** Interface connecting VLAN segments to provide connectivity to VLAN backed physical or virtual workloads. Service interface can also be connected to overlay/VLAN segments for standalone load balancer use cases explained in load balancer Chapter 6. Service Interface supports static and dynamic routing starting with NSX-T 3.0. It is supported on both Tier-0 and Tier-1 gateways configured in

Active/Standby high-availability configuration mode explained in section 4.6.2. Note that a Tier-0 or Tier-1 gateway must have an SR component to realize service interfaces. This interface was referred to as centralized service interface in previous releases.

- **Loopback:** Tier-0 gateway supports the loopback interfaces. A Loopback interface is a virtual interface, and it can be redistributed into a routing protocol.

4.2.2 Route Types on Tier-0 and Tier-1 Gateways

There is no dynamic routing between Tier-0 and Tier-1 gateways. The NSX-T platform takes care of the auto-plumbing between Tier-0 and Tier-1 gateways. The following list details route types on Tier-0 and Tier-1 gateways.

- **Tier-0 Gateway**
  - Connected – Connected routes on Tier-0 include external interface subnets, service interface subnets, loopback and segment subnets connected to Tier-0. In *Figure 4-12: Routing Advertisement*, 172.16.20.0/24 (Connected segment), 192.168.20.0/24 (Service Interface) and 192.168.240.0/24 (External interface) are connected routes for the Tier-0 gateway.
  - Static – User configured static routes on Tier-0.
  - NAT IP – NAT IP addresses owned by the Tier-0 gateway discovered from NAT rules configured on Tier-0 Gateway.
  - BGP – Routes learned via BGP neighbors.
  - IPsec Local IP – Local IPsec endpoint IP address for establishing VPN sessions.
  - DNS Forwarder IP – Listener IP for DNS queries from clients. Also used as the source IP to forward DNS queries to the upstream DNS server.
  - Inter SR. SRs of a same Tier-0 gateway in the same edge cluster will create an automatic iBGP peering adjacency between them to exchange routing information. This topology is only supported with Active/Active topologies and with NSX-T Federation.

- **Tier-1 Gateway**
  - Connected – Connected routes on Tier-1 include segment subnets connected to Tier-1 and service interface subnets configured on Tier-1 gateway.
    In *Figure 4-12: Routing Advertisement*, 172.16.10.0/24 (Connected segment) and 192.168.10.0/24 (Service Interface) are connected routes for Tier-1 gateway.
  - Static– User configured static routes on Tier-1 gateway.
  - NAT IP – NAT IP addresses owned by the Tier-1 gateway discovered from NAT rules configured on the Tier-1 gateway.
  - LB VIP – IP address of load balancing virtual server.
  - LB SNAT – IP address or a range of IP addresses used for Source NAT by load balancer.
  - IPsec Local IP – Local IPsec endpoint IP address for establishing VPN sessions.
  - DNS Forwarder IP – Listener IP for DNS queries from clients. Also used as the source IP to forward DNS queries to the upstream DNS server.

Route Advertisement on the Tier-1 and Tier-0 Logical Router

The Tier-0 gateway could use static routing or BGP to connect to the physical routers. The Tier-1 gateway cannot connect to physical routers directly; it must connect to a Tier-0 gateway to provide N-S connectivity to the subnets attached to it. When a Tier-1 gateway is connected to a Tier-0 gateway, a default route is automatically created on the Tier-1. That default route is pointing to the RouterLink IP address that is owned by the Tier-0.

Figure 4-12: Routing Advertisement explains the route advertisement on both the Tier-1 and Tier-0 gateway.

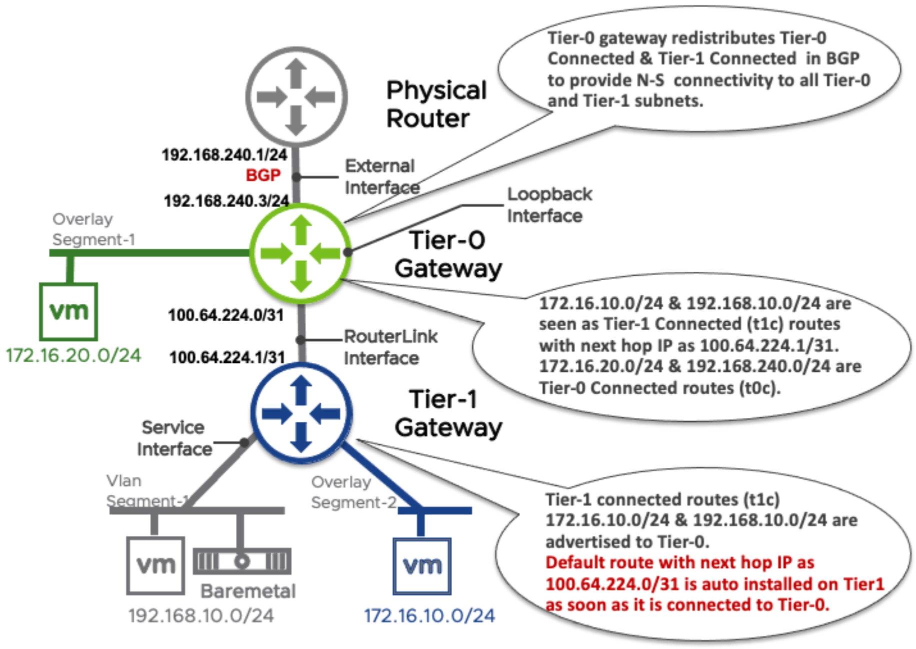

Tier-0 gateway redistributes Tier-0 Connected & Tier-1 Connected in BGP to provide N-S connectivity to all Tier-0 and Tier-1 subnets.
Physical Router
192.168.240.1/24
BGP
192.168.240.3/24
External Interface
Loopback Interface
Overlay Segment-1
Tier-0 Gateway
vm
172.16.20.0/24
100.64.224.0/31
100.64.224.1/31
RouterLink Interface
172.16.10.0/24 & 192.168.10.0/24 are seen as Tier-1 Connected (t1c) routes with next hop IP as 100.64.224.1/31. 172.16.20.0/24 & 192.168.240.0/24 are Tier-0 Connected routes (t0c).
Tier-1 Gateway
Service Interface
Vlan Segment-1
Overlay Segment-2
vm
Baremetal
192.168.10.0/24
vm
172.16.10.0/24
Tier-1 connected routes (t1c) 172.16.10.0/24 & 192.168.10.0/24 are advertised to Tier-0.
Default route with next hop IP as 100.64.224.0/31 is auto installed on Tier1 as soon as it is connected to Tier-0.

Figure 4-12: Routing Advertisement

"Tier-1 Gateway" advertises connected routes to Tier-0 Gateway. *Figure 4-12: Routing Advertisement* shows an example of connected routes (172.16.10.0/24 and 192.168.10.0/24). If there are other route types, like NAT IP etc. as discussed in section 4.2.2 a user can advertise those route types as well. As soon as "Tier-1 Gateway" is connected to "Tier-0 Gateway", the management plane configures a default route on "Tier-1 Gateway" with next hop IP address as RouterLink interface IP of "Tier-0 Gateway" i.e. 100.64.224.0/31 in the example above.

Tier-0 Gateway sees 172.16.10.0/24 and 192.168.10.1/24 as Tier-1 Connected routes (t1c) with a next hop of 100.64.224.1/31. Tier-0 Gateway also has Tier-0 "Connected" routes (172.16.20.0/24) in *Figure 4-12: Routing Advertisement*.

Northbound, "Tier-0 Gateway" redistributes the Tier-0 connected and Tier-1 connected routes in BGP and advertises these routes to its BGP neighbor, the physical router.

4.2.3 Fully Distributed Two Tier Routing

NSX-T provides a fully distributed routing architecture. The motivation is to provide routing functionality closest to the source. NSX-T leverages the same distributed routing architecture discussed in distributed router section and extends that to multiple tiers.

Figure 4-13: Logical Routing Instances shows both logical and per transport node views of two Tier-1 gateways serving two different tenants and a Tier-0 gateway. Per transport node view shows that the distributed component (DR) for Tier-0 and the Tier-1 gateways have been instantiated on two hypervisors.

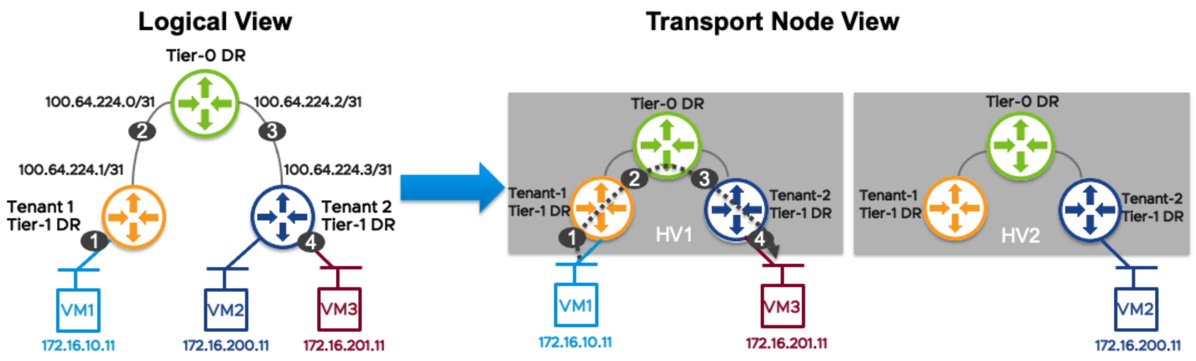


Figure 4-13: Logical Routing Instances

If "VM1" in tenant 1 needs to communicate with "VM3" in tenant 2, routing happens locally on hypervisor "HV1". This eliminates the need to route of traffic to a centralized location to route between different tenants or environments.

Multi-Tier Distributed Routing with Workloads on the same Hypervisor
The following list provides a detailed packet walk between workloads residing in different tenants but hosted on the same hypervisor.

1. "VM1" (172.16.10.11) in tenant 1 sends a packet to "VM3" (172.16.201.11) in tenant 2. The packet is sent to its default gateway interface located on tenant 1, the local Tier-1 DR.
2. Routing lookup happens on the tenant 1 Tier-1 DR and the packet is routed to the Tier-0 DR following the default route. This default route has the RouterLink interface IP address (100.64.224.0/31) as a next hop.
3. Routing lookup happens on the Tier-0 DR. It determines that the 172.16.201.0/24 subnet is learned from the tenant 2 Tier-1 DR (100.64.224.3/31) and the packet is routed there.
4. Routing lookup happens on the tenant 2 Tier-1 DR. This determines that the 172.16.201.0/24 subnet is directly connected. L2 lookup is performed in the local MAC table to determine how to reach "VM3" and the packet is sent.

The reverse traffic from "VM3" follows the similar process. A packet from "VM3" to destination 172.16.10.11 is sent to the tenant-2 Tier-1 DR, then follows the default route to the Tier-0 DR. The Tier-0 DR routes this packet to the tenant 1 Tier-1 DR and the packet is delivered to “VM1”. During this process, the packet never left the hypervisor to be routed between tenants.

Multi-Tier Distributed Routing with Workloads on different Hypervisors

Figure 4-14: Logical Routing End-to-end Packet Flow Between Hypervisor shows the packet flow between workloads in different tenants which are also located on different hypervisors.

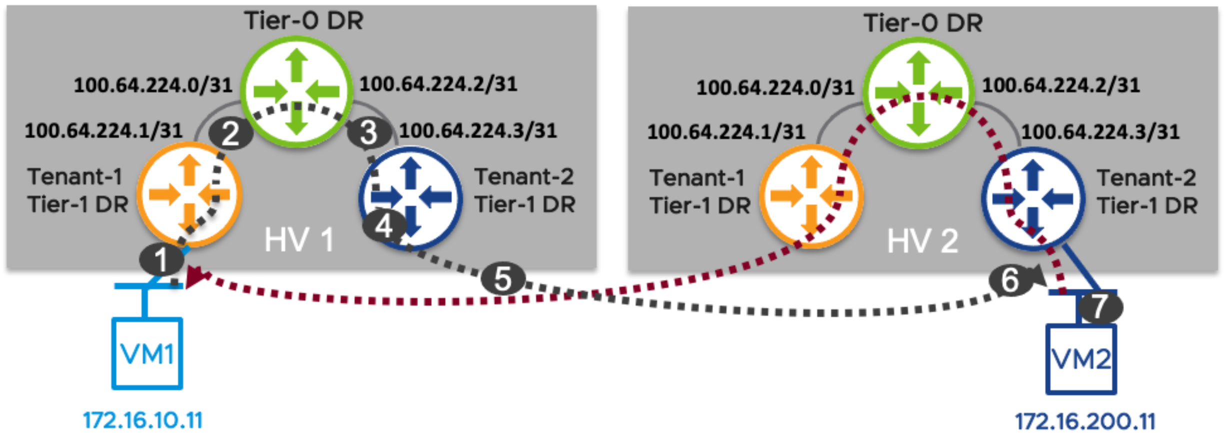


Figure 4-14: Logical Routing End-to-end Packet Flow Between Hypervisor

The following list provides a detailed packet walk between workloads residing in different tenants and hosted on the different hypervisors.

1. “VM1” (172.16.10.11) in tenant 1 sends a packet to “VM2” (172.16.200.11) in tenant 2. VM1 sends the packet to its default gateway interface located on the local Tier-1 DR in HV1.
2. Routing lookup happens on the tenant 1 Tier-1 DR and the packet follows the default route to the Tier-0 DR with a next hop IP of 100.64.224.0/31.
3. Routing lookup happens on the Tier-0 DR which determines that the 172.16.200.0/24 subnet is learned via the tenant 2 Tier-1 DR (100.64.224.3/31) and the packet is routed accordingly.
4. Routing lookup happens on the tenant 2 Tier-1 DR which determines that the 172.16.200.0/24 subnet is a directly connected subnet. A lookup is performed in ARP table to determine the MAC address associated with the “VM2” IP address. This destination MAC is learned via the remote TEP on hypervisor “HV2”.
5. The “HV1” TEP encapsulates the packet and sends it to the “HV2” TEP, finally leaving the host.
6. The “HV2” TEP decapsulates the packet and recognize the VNI in the Geneve header. A L2 lookup is performed in the local MAC table associated to the LIF where “VM2” is connected.
7. The packet is delivered to “VM2”.

The return packet follows the same process. A packet from “VM2” gets routed to the local hypervisor Tier-1 DR and is sent to the Tier-0 DR. The Tier-0 DR routes this packet to tenant 1 Tier-1 DR which performs the L2 lookup to find out that the MAC associated with “VM1” is on remote hypervisor “HV1”. The packet is encapsulated by “HV2” and sent to “HV1”, where this packet is decapsulated and delivered to “VM1". It is important to notice that in this use case, routing is performed locally on the hypervisor hosting the VM sourcing the traffic.

4.3 Routing Capabilities

NSX-T supports static routing and the dynamic routing protocol BGP on Tier-0 Gateways for IPv4 and IPv6 workloads. In addition to static routing and BGP, Tier-0 gateway also supports a dynamically created iBGP session between its Services router component. This feature is referred as Inter-SR routing and is available for active-active Tier-0 topologies only.

Tier-1 Gateways support static routes but do not support any dynamic routing protocols.

4.3.1 Static Routing

Northbound, static routes can be configured on Tier-1 gateways with the next hop IP as the Routerlink IP of the Tier-0 gateway (100.64.0.0/16 range or a range defined by user for Routerlink interface). Southbound, static routes can also be configured on Tier-1 gateway with a next hop as a layer 3 device reachable via Service interface.

Tier-0 gateways can be configured with a static route toward external subnets with a next hop IP of the physical router. Southbound, static routes can be configured on Tier-0 gateways with a next hop of a layer 3 device reachable via Service interface.

ECMP is supported with static routes to provide load balancing, increased bandwidth, and fault tolerance for failed paths or Edge nodes. *Figure 4-15: Static Routing Configuration* shows a Tier-0 gateway with two external interfaces leveraging Edge node, EN1 and EN2 connected to two physical routers. Two equal cost static default routes configured for ECMP on Tier-0 Gateway. Up to eight paths are supported in ECMP. The current hash algorithm for ECMP is two-tuple, based on source and destination IP of the traffic.

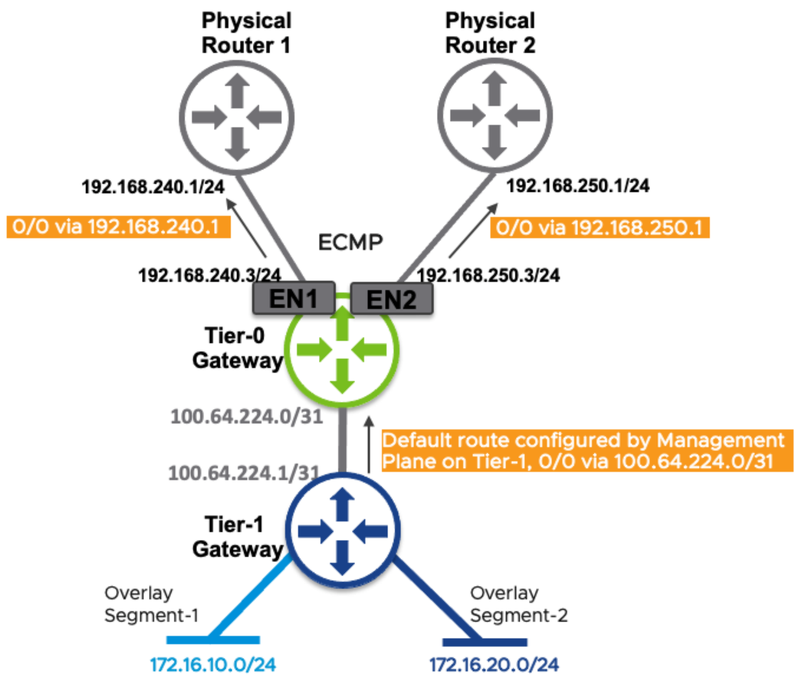


Figure 4-15: Static Routing Configuration

BFD can also be enabled for faster failure detection of next hop and is configured in the static route. In NSX-T 3.0, BFD keep alive TX/RX timer can range from a minimum of 50ms (for Bare Metal Edge Node) to maximum of 10,000ms. Default BFD keep alive TX/RX timers are set to 500ms with three retries.

4.3.2 Dynamic Routing

BGP is the de facto protocol on the WAN and in most modern data centers. A typical leaf-spine topology has eBGP running between leaf switches and spine switches.

Tier-0 gateways support eBGP and iBGP on the external interfaces with physical routers. BFD can also be enabled per BGP neighbor for faster failover. BFD timers depend on the Edge node type. Bare metal Edge supports a minimum of 50ms TX/RX BFD keep alive timer while the VM form factor Edge supports a minimum of 500ms TX/RX BFD keep alive timer.

With NSX-T 3.0 release, the following BGP features are supported:

- Two and four bytes AS numbers in *asplain*, *asdot* and *asdot+* format.
- eBGP multi-hop support, allowing eBGP peering to be established on loopback interfaces.
- iBGP
- eBGP multi-hop BFD
- ECMP support with BGP neighbors in same or different AS numbers. (Multi-path relax)
- BGP Allow AS in

- BGP route aggregation support with the flexibility of advertising a summary route only to the BGP peer or advertise the summary route along with specific routes. A more specific route must be present in the routing table to advertise a summary route.
- Route redistribution in BGP to advertise Tier-0 and Tier-1 Gateway internal routes as mentioned in section 4.2.2.
- Inbound/outbound route filtering with BGP peer using prefix-lists or route-maps.
- Influencing BGP path selection by setting Weight, Local preference, AS Path Prepend, or MED.
- Standard, Extended and Large BGP community support.
- BGP well-known community names (e.g., no-advertise, no-export, no-export-subconfed) can also be included in the BGP route updates to the BGP peer.
- BGP communities can be set in a route-map to facilitate matching of communities at the upstream router.
- Graceful restart (Full and Helper mode) in BGP.
- BGP peering authentication using plaintext or MD5.
- MP-BGP as the control plane protocol for VXLAN overlays or IPv6 address families.

Active/active ECMP services supports up to eight paths. The ECMP hash algorithm is 5-tuple northbound of Tier-0 SR. ECMP hash is based on the source IP address, destination IP address, source port, destination port and IP protocol. The hashing algorithm determines how incoming traffic is forwarded to the next-hop device when there are multiple paths. ECMP hashing algorithm from DR to multiple SRs is 2-tuple and is based on the source IP address and destination IP address.

Graceful Restart (GR)
Graceful restart in BGP allows a BGP speaker to preserve its forwarding table while the control plane restarts. It is recommended to enable BGP Graceful restart when the BGP peer has multiple supervisors. A BGP control plane restart could happen due to a supervisor switchover in a dual supervisor hardware, planned maintenance, or active routing engine crash. As soon as a GR-enabled router restarts (control plane failure), it preserves its forwarding table, marks the routes as stale, and sets a grace period restart timer for the BGP session to reestablish. If the BGP session reestablishes during this grace period, route revalidation is done, and the forwarding table is updated. If the BGP session does not reestablish within this grace period, the router flushes the stale routes.

The BGP session will not be GR capable if only one of the peers advertises it in the BGP OPEN message; GR needs to be configured on both ends. GR can be enabled/disabled per Tier-0 gateway. The GR restart timer is 180 seconds by default and cannot be change after a BGP peering adjacency is in the established state, otherwise the peering needs to be negotiated again.

4.4 VRF Lite

4.4.1 VRF Lite Generalities

Virtual Routing Forwarding (VRF) is a virtualization method that consists of creating multiple logical routing instances within a physical routing appliance. It provides a complete control plane isolation between routing instances. VRF instances are commonly used in enterprise and service providers networks to provide control and data plane isolation, allowing several use cases such as overlapping IP addressing between tenants, isolation of regulated workload, isolation of external and internal workload as well as hardware resources consolidation. Starting with NSX-T 3.0 it is possible to extent the VRF present on the physical network onto the NSX-T domain. Creating a development environment that replicates the production environment is a typical use case for VRF.

Another representative use case for VRF is when multiple environments needs to be isolated from each other. As stated previously, VRF instances are isolated between each other by default; allowing communications between these environments using the Route Leaking VRF feature is possible. While this feature allows inter-VRF communications, it is important to emphasize that scalability can become an issue if a design permits all VRF to communicate between each other. In this case, VRF might not be the option. VRF should not be replaced in lieu of the DFW construct.

Figure 4-16: Networking VRF Architecture pictures a traditional VRF architecture. Logical (Switch Virtual Interface – VLAN interface) or Physical interface should be dedicated to a single VRF instance. In the following diagram, interface e1/1 and e2/2 belong to VRF-A while interface e1/2 and e2/2 belong to VRF-B. Each VRF will run their own dynamic routing protocol (or use static routes)

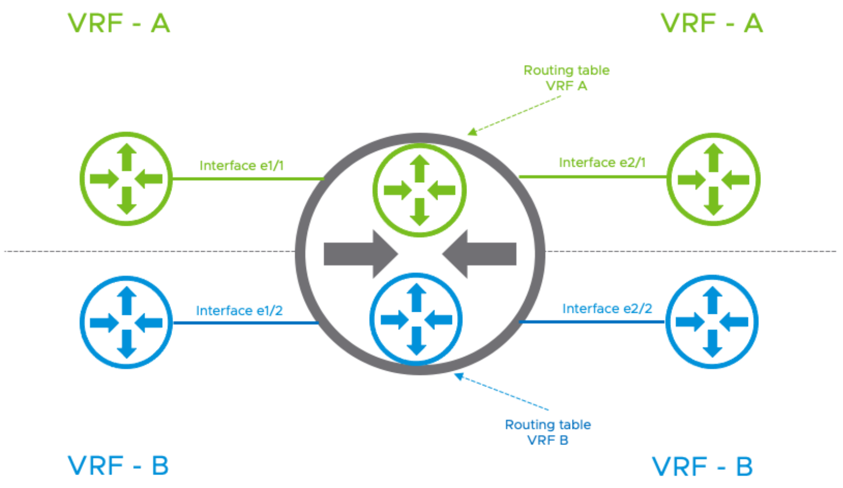


Figure 4-16: Networking VRF Architecture

With NSX-T 2.x, several multi-tenant designs are possible.
The first option was to deploy a Tier-1 gateway for each tenant while a shared Tier-0 provides connectivity to the physical networking fabric for all tenants. *Figure 4-17: NSX-T 2.x Multi-tenant Architecture. – Shared Tier-0 Gateway* diagrams that option.

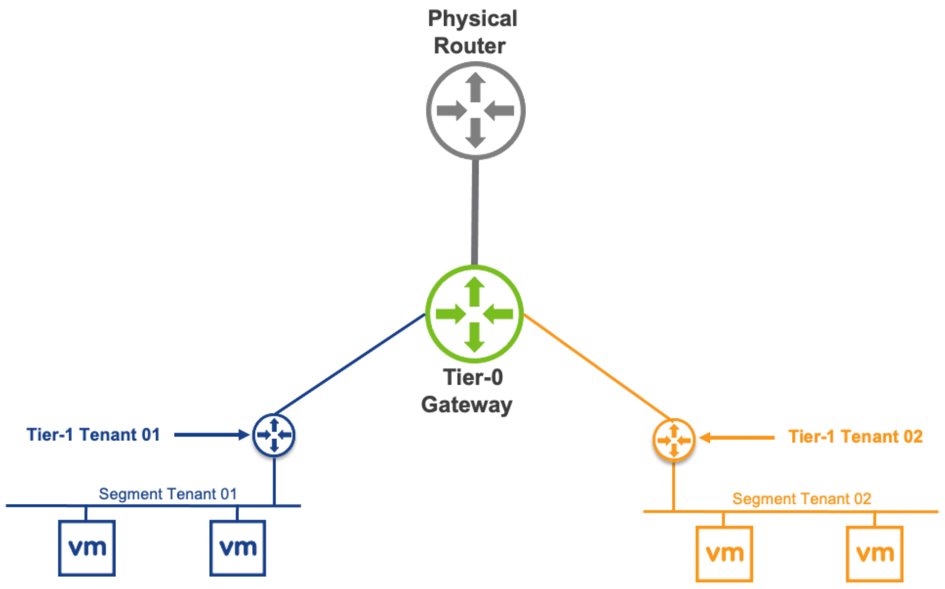


Figure 4-17: NSX-T 2.x Multi-tenant Architecture. – Shared Tier-0 Gateway

Another supported design is to deploy a separate Tier-0 gateway for each tenant on a dedicated tenant edge node. *Figure 4-18: NSX-T 2.x Multi-tenant Architecture - Dedicated Tier0 for Each Tenant* shows a traditional multi-tenant architecture using dedicated Tier-0 per tenant in NSX-T 2.X .

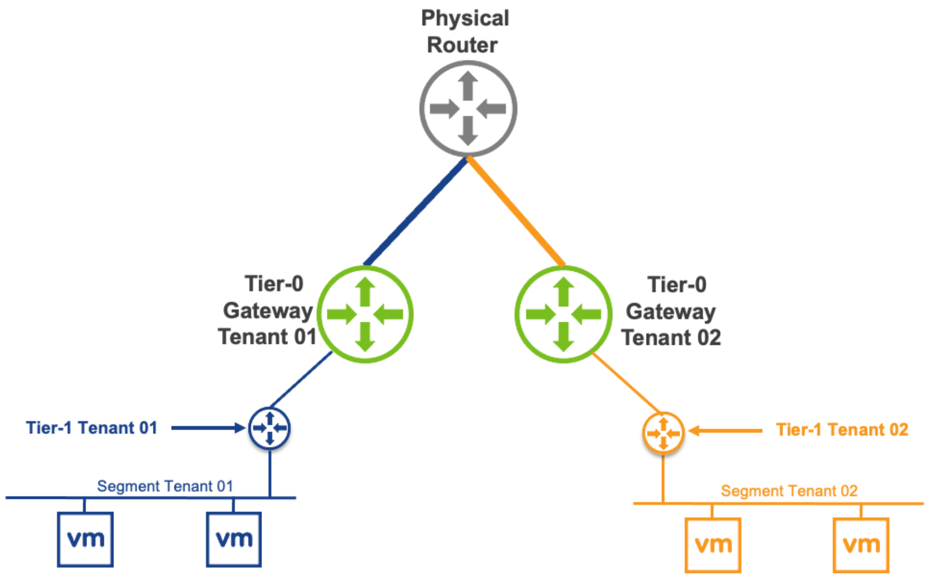


Figure 4-18: NSX-T 2.x Multi-tenant Architecture - Dedicated Tier0 for Each Tenant

In traditional networking, VRF instances are hosted on a physical appliance and share the resources with the global routing table. Starting with NSX-T 3.0, Virtual Routing and Forwarding (VRF) instances configured on the physical fabric can be extended to the NSX-T domain. A VRF Tier-0 gateway must be hosted on a traditional Tier-0 gateway identified as the “Parent Tier-0”. *Figure 4-19*: Tier-0 VRF Gateways Hosted on a Parent Tier-0 Gateway diagrams an edge node hosting a traditional Tier-0 gateway with two VRF gateways. Control plane is completely isolated between all the Tier-0 gateways instances.

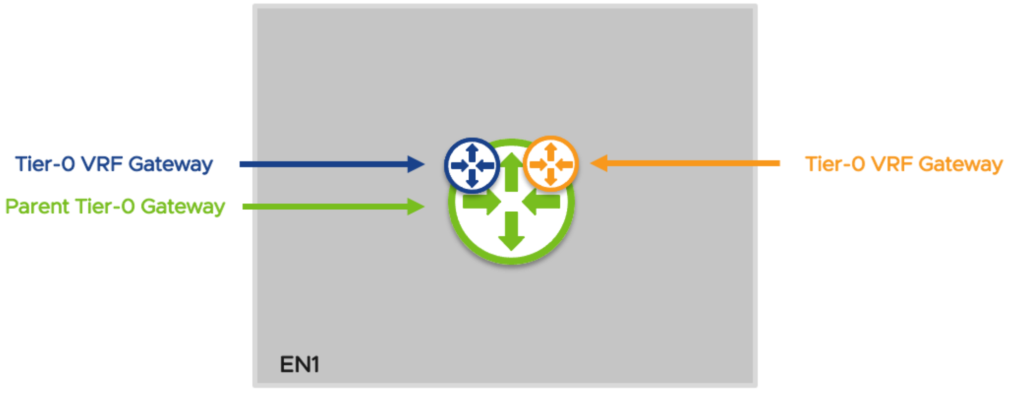


Figure 4-19: Tier-0 VRF Gateways Hosted on a Parent Tier-0 Gateway

The parent Tier-0 gateway can be considered as the global routing table and must have connectivity to the physical fabric. A unique Tier-0 gateway instance (DR and SR) will be created and dedicated to a VRF. *Figure 4-20: Detailed Representation of the SR/DR Component for Tier-0 VRF Hosted on an Edge Node* shows a detailed representation of the Tier-0 VRF gateway with their respective Service Router and Distributed Router components.

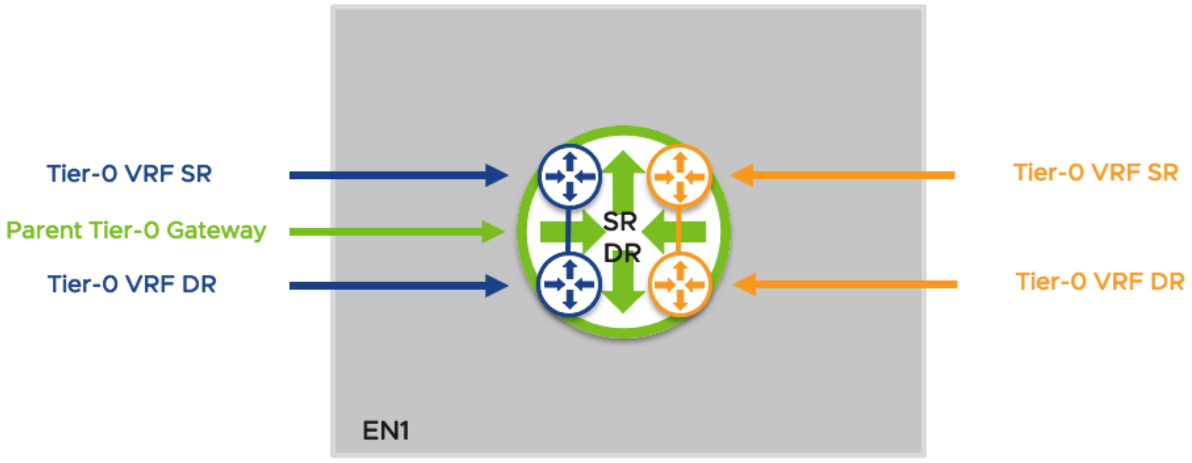


Figure 4-20: Detailed Representation of the SR/DR Component for Tier-0 VRF Hosted on an Edge Node

Figure 4-21: NSX-T 3.0 Multi-Tenant Architecture. Dedicated Tier-0 VRF Instance for Each VRF shows a typical single tier routing architecture with two Tier-0 VRF gateways connected to their parent Tier-0 gateway. Traditional segments are connected to a Tier-0 VRF gateway.

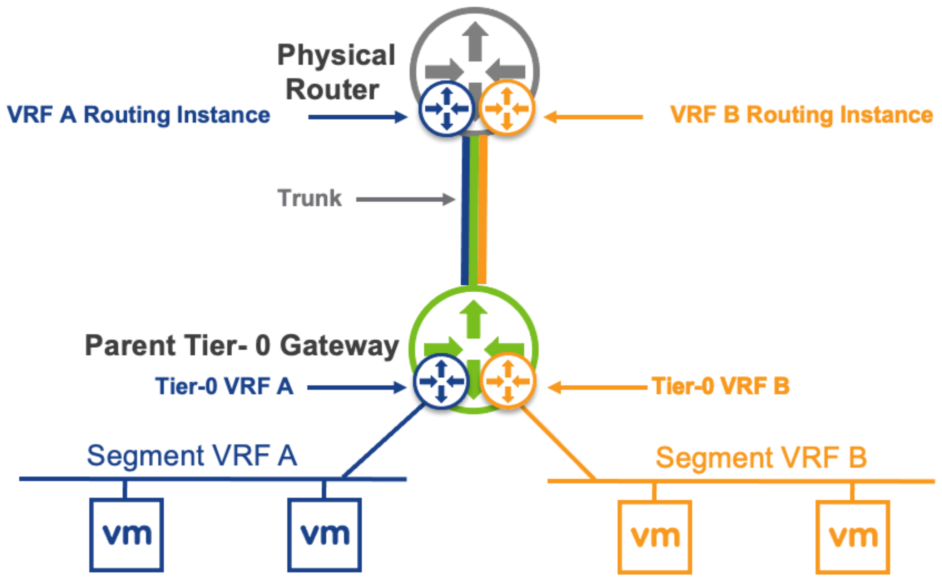


Figure 4-21: NSX-T 3.0 Multi-Tenant Architecture. Dedicated Tier-0 VRF Instance for Each VRF

Since control plane is isolated between Tier-0 VRF instances and the parent Tier-0 gateway, each Tier-0 VRF needs their own routing configuration using either static routes or BGP. It implies that each Tier-0 VRF will have their own dedicated BGP process and needs to have their dedicated BGP peers. From a data plane standpoint, 802.1q VLAN tags are used to differentiate traffic between the VRFs instances as demonstrated in the previous figure.

NSX-T 3.0 supports BGP and static routes for the Tier-0 VRF gateway. It offers the flexibility to use static routes on a particular Tier-0 VRF while another Tier-0 VRF would use BGP.

Figure 4-22: BGP Peering Tier-0 VRF Gateways and VRF on the Networking Fabric shows a topology with two Tier-0 VRF instances and their respective BGP peers on the physical networking fabric. It is important to emphasize that the Parent Tier-0 gateway has a BGP peering adjacency with the physical routers using their respective global routing table and BGP process.

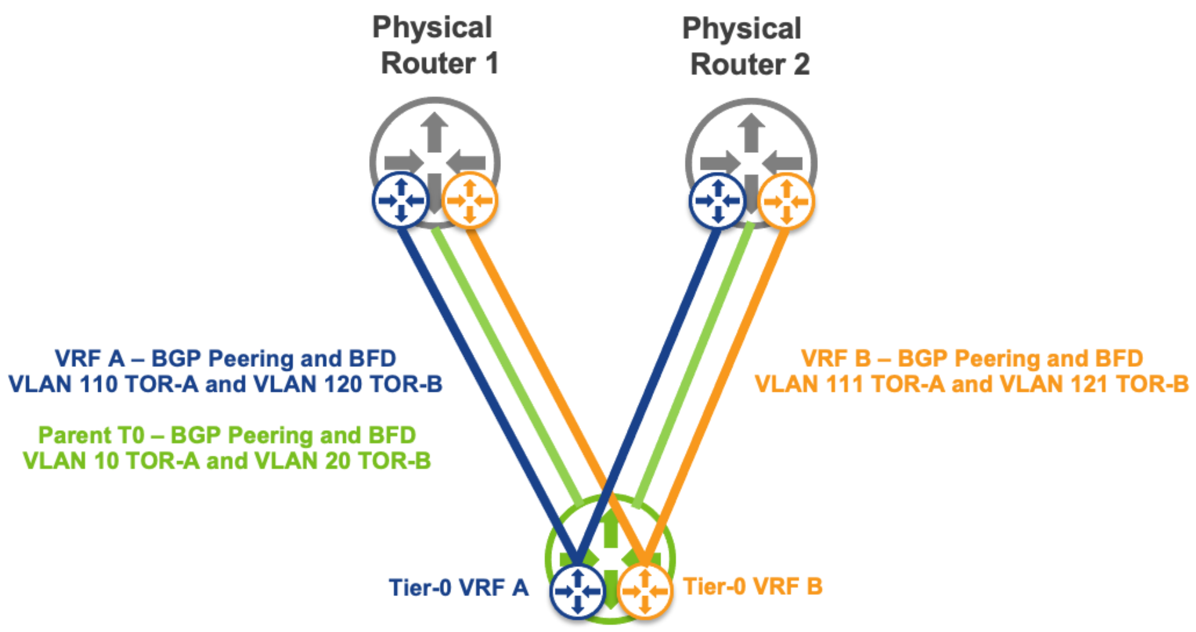

Physical Router 1
Physical Router 2
VRF A – BGP Peering and BFD
VLAN 110 TOR-A and VLAN 120 TOR-B
Parent T0 – BGP Peering and BFD
VLAN 10 TOR-A and VLAN 20 TOR-B
VRF B – BGP Peering and BFD
VLAN 111 TOR-A and VLAN 121 TOR-B
Tier-0 VRF A
Tier-0 VRF B

Figure 4-22: BGP Peering Tier-0 VRF Gateways and VRF on the Networking Fabric

When a Tier-0 VRF is attached to parent Tier-0, multiple parameters will be inherited by design and cannot be changed:

- Edge Cluster
- High Availability mode (Active/Active – Active/Standby)
- BGP Local AS Number
- Internal Transit Subnet
- Tier-0, Tier-1 Transit Subnet.

All other configuration parameters can be independently managed:

- External Interface IP addresses
- BGP neighbor
- Prefix list, route-map, Redistribution
- Firewall rules
- NAT rules

As mentioned previously, The Tier-0 VRF is hosted on the Parent Tier-0 and will follow the high availability mode and state of its Parent Tier-0. Both Active/Active or Active/Standby high availability mode are supported on the Tier-0 VRF gateways. It is not possible to have an Active/Active Tier-0 VRF hosted on an Active/Standby Parent Tier-0.

In a traditional Active/Standby design, a Tier-0 gateway failover can be triggered if all northbound BGP peers are unreachable. Similar to the high availability construct between the Tier-0 VRF and the Parent Tier-0, the BGP peering design must match between the VRF Tier-0 and the Parent Tier-0. Inter-SR routing is not supported in Active/Active VRF topologies. *Figure 4-23: Supported BGP Peering Design* represents a BGP instance from both parent Tier-0 and Tier-0 VRF point of view. This topology is supported as each Tier-0 SR (on the parent and on the VRF itself) have a redundant path towards the network infrastructure. Both the Parent Tier-0 gateway and the Tier-0 VRF gateway are peering with the same physical networking device but on a different BGP process. The Parent Tier-0 gateways peer with both top of rack switches on their respective global BGP process while the Tier-0 VRF gateways peer with both top of rack switch on another BGP process dedicated to the VRF. In this case the Tier-0 VRF leverages physical redundancy towards the networking fabric if one of its northbound links fails.

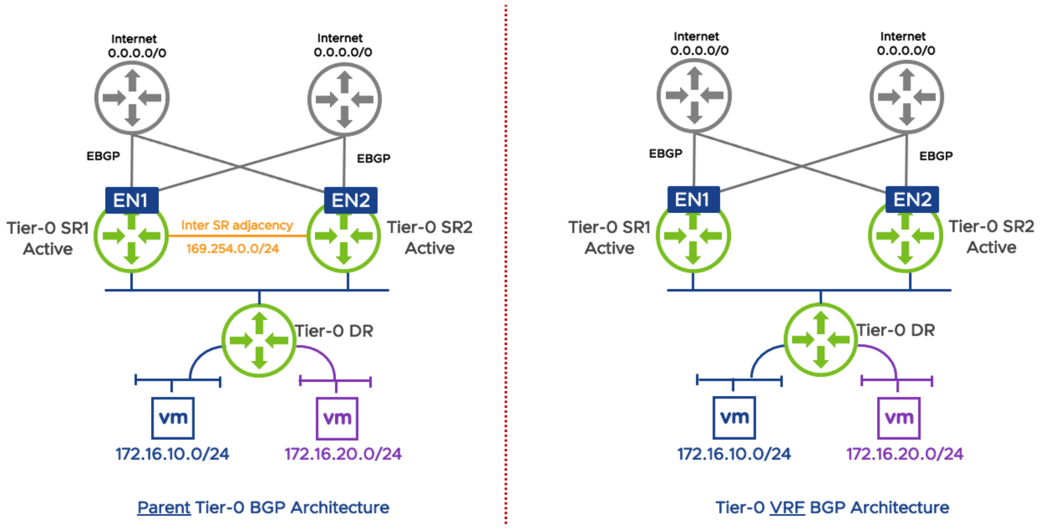


Figure 4-23: Supported BGP Peering Design

Figure 4-24: Unsupported Active/Active Topology with VRF represents an unsupported VRF Active/Active design where different routes are learned from different physical routers. Both the Parent Tier-0 and VRF Tier-0 gateways are learning their default route from a single physical router. The active VRF Tier-0 must learn specific routes from a single BGP peer. This kind of scenario would be supported for traditional Tier-0 architecture as Inter-SR would provide a redundant path to the networking fabric. This VRF architecture is not supported in NSX-T 3.0.

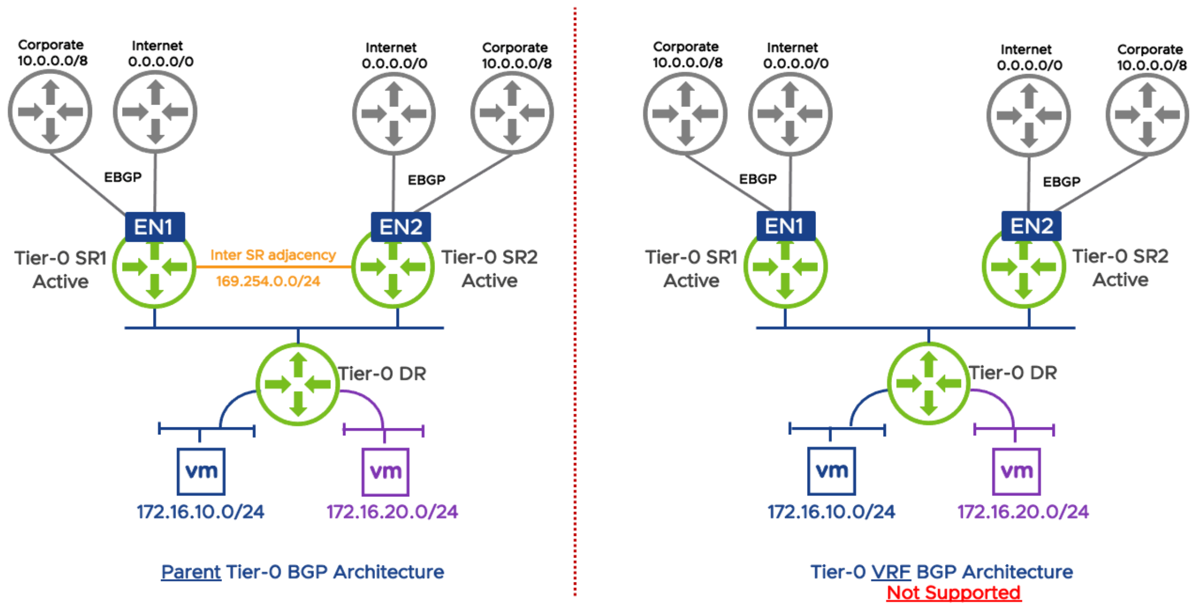


Figure 4-24: Unsupported Active/Active Topology with VRF

Figure 4-25: Unsupported Active-Active Topology with VRF – Failure demonstrates the traffic being as one internet router fails and Tier-0 VRF gateways can't leverage another redundant path to reach the destination. Since the Parent Tier-0 gateway has an established BGP peering adjacency, failover will not be triggered, and traffic will be blackholed on the Tier-0 VRF.

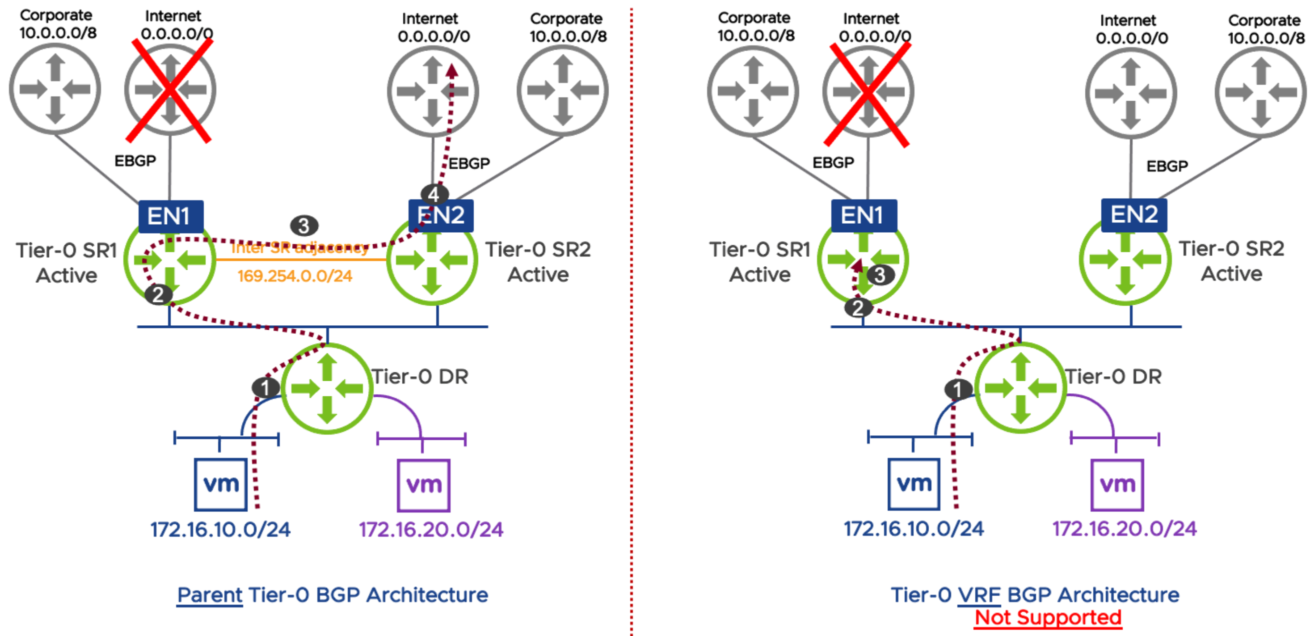


Figure 4-25: Unsupported Active-Active Topology with VRF – Failure

On the Parent Tier-0:

1. VM “172.16.10.0” sends its IP traffic towards the internet through the Tier-0 DR.
2. Since the Tier-0 topology is Active/Active, the Tier-0 DR sends the traffic to both Tier-0 SR1 and Tier-0 SR2 using a 2 tuple.
3. From a Tier-0 SR1 point of view, the traffic that needs to be routed towards the internet will be sent towards Tier-0 SR2 as there is an inter-SR BGP adjacency and that Tier-0 SR2 learns the route from another internet switch.
4. Traffic is received by the Tier-0 SR2 and routed towards the physical fabric.

On the Tier-0 VRF:

1. VM “172.16.10.0” sends its IP traffic towards the internet through the Tier-0 DR.
2. Since the Tier-0 topology is Active/Active, the Tier-0 DR sends the traffic to both Tier-0 SR1 and Tier-0 SR2 using a 2 tuple.
3. From a Tier-0 SR1 point of view, the traffic is blackholed as there is no inter-SR BGP adjacency between the Tier-0 SRs VRF.

Following the same BGP peering design and principle for Active/Standby topologies is also mandatory for VRF architectures as the Tier-0 VRF will inherit the behavior of the parent Tier-0 gateway.

Figure 4-26: Unsupported Design BGP Architecture Different Peering with the Networking Fabric represents another unsupported design with VRF architecture.

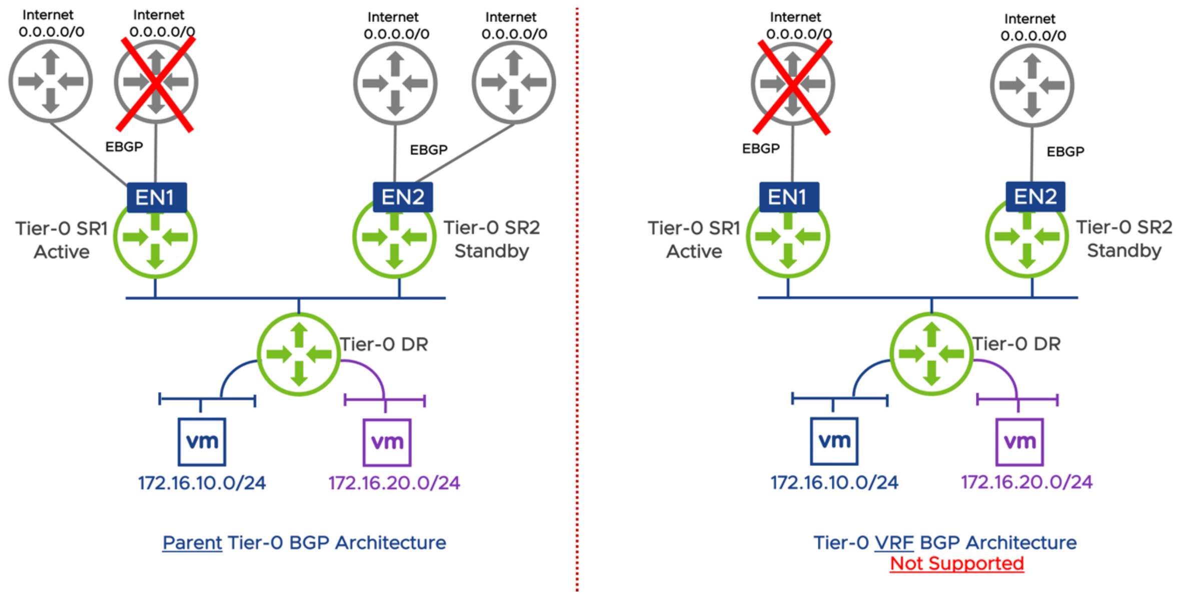


Figure 4-26: Unsupported Design BGP Architecture Different Peering with the Networking Fabric

In this design, traffic will be blackholed on the Tier-0 VRF SR1 as the internet router fails. Since the Tier-0 VRF share its high availability running mode with the Parent Tier-0, it is important to note that the Tier-0 SR1 will not failover to the Tier-0 SR2. The reason behind this behavior is because a failover is triggered only if all northbound BGP sessions change to the “down” state.

Since Tier-0 SR1 still has an active BGP peering with a northbound router on the physical networking fabric, failover will not occur, and traffic will be blackholed on the VRF that have only one BGP peer active.

Traditional Tier-1 gateways can be connected to Tier-0 VRF to provide a multi-tier routing architecture as demonstrated in *Figure 4-27: Multi-Tier Routing Architecture and VRF-lite*.

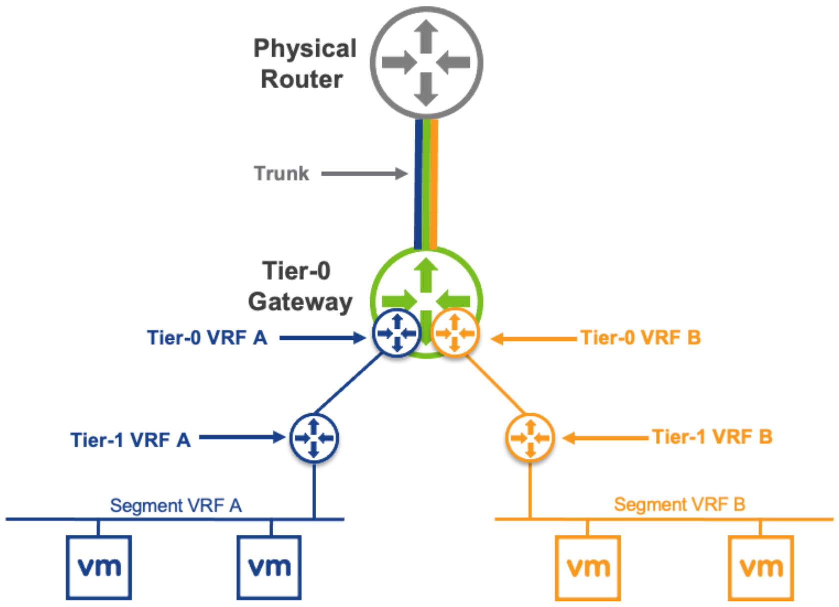


Figure 4-27: Multi-Tier Routing Architecture and VRF-lite

Stateful services can either run on a Tier-0 VRF gateway or a Tier-1 gateway except for VPN and Load Balancing as these features are not supported on a Tier-0 VRF. Tier-1 SR in charge of the stateful services for a particular VRF will be hosted on the same edge nodes as the Parent Tier-0 Gateway. *Figure 4-28: Stateful Services Supported on Tier-1* represents stateful services running on traditional Tier-1 gateways SR.

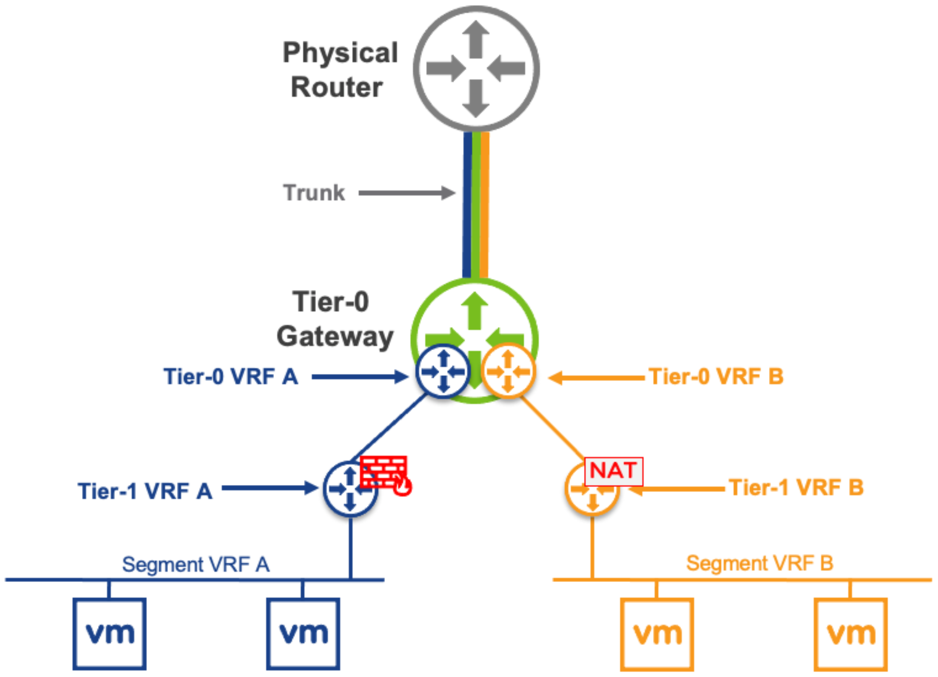


Figure 4-28: Stateful Services Supported on Tier-1

By default, data-plane traffic between VRF instances is isolated in NSX-T. By configuring VRF Route Leaking, traffic can be exchanged between VRF instances. As a result, static routes must be configured on the Tier-0 VRF instances to allow traffic to be exchanged. The next hop for these static routes must not be a Tier-0 gateway (VRF or Parent). As a result, multi-tier routing architecture must be implemented to allow traffic to be exchanged between the VRF instances. *Figure 4-29: VRF Route Leaking with Static Routes* demonstrates a supported topology for VRF route leaking Two static routes are necessary:

- Static Route on Tier-0 VRF A
  - Destination Subnet: 172.16.20.0/24
  - Next Hop
    - IP Address of Tier-1 DR in VRF B (e.g. 100.64.80.3)
    - Admin Distance: 1
    - Scope: VRF-B
- Static Route on Tier-0 VRF B
  - Destination Subnet: 172.16.10.0/24
  - Next Hop
    - IP Address of Tier-1 DR in VRF A (e.g. 100.64.80.1)
    - Admin Distance: 1
    - Scope: VRF-A

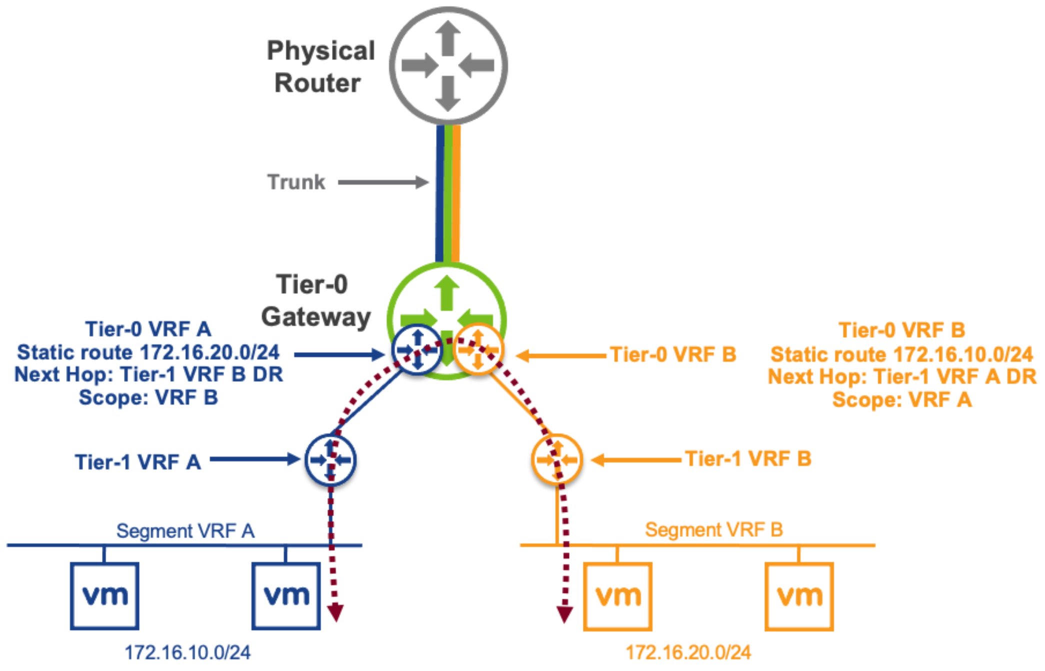


Figure 4-29: VRF Route Leaking with Static Routes

VRF-lite also supports northbound VRF route leaking as traffic can be exchanged between a virtual workload on an VRF overlay segment and a bare metal server hosted in a different VRF on the physical networking fabric. NSX-T VRF route leaking requires that the next hop for the static route must not be a Tier-0 gateway. Static routes pointing to the directly connected IP addresses uplink would not be a recommended design as the static route would fail if an outage would occur on that link or neighbor (Multiple static routes would be needed for redundancy).

A loopback or virtual IP address host route (/32) can be advertised in the network in the destination VRF. Since the host route is advertised by both top of rack switches, two ECMP routes will be installed in the Tier-0 VRF. *Figure 4-30: VRF Leaking Traffic with Northbound Destination* demonstrates the Tier-0 VRF gateways will use all available healthy paths to the networking fabric to reach the server in VRF-B.

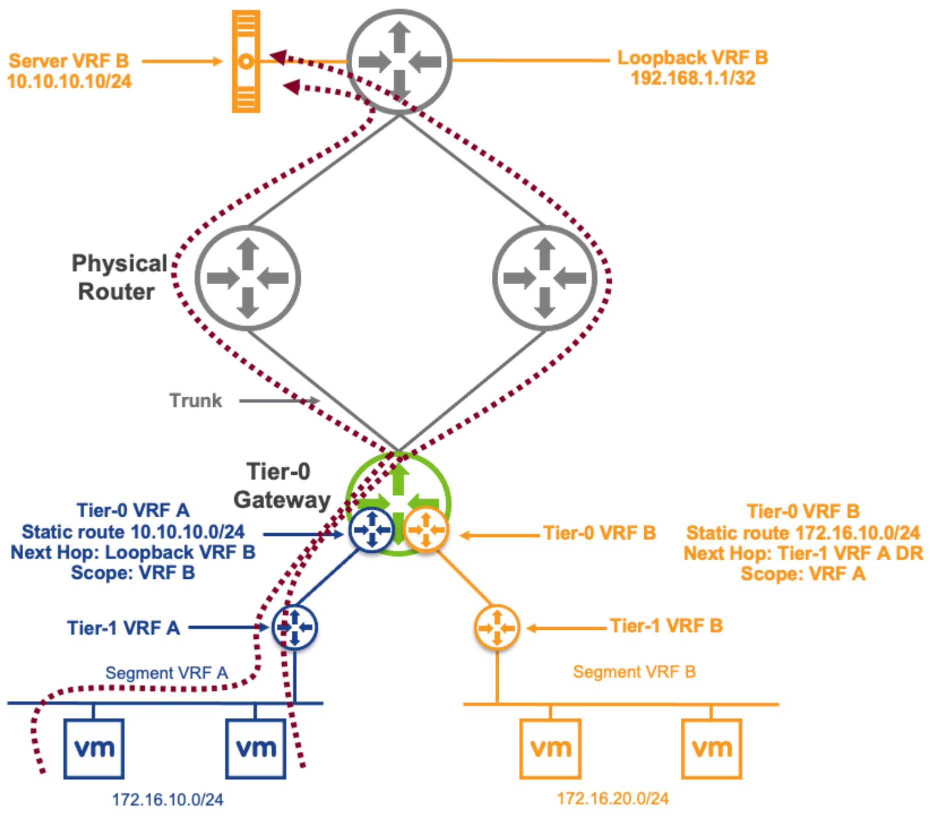


Figure 4-30: VRF Leaking Traffic with Northbound Destination

Two static routes are necessary:

- Static Route on Tier-0 VRF A
    - Destination Subnet: 10.10.10.0/24
    - Next Hop
        - 192.168.1.1 (Loopback interface)
        - Admin Distance: 1
        - Scope: VRF-B
- Static Route on Tier-0 VRF B
    - Destination Subnet: 172.16.10.0/24
    - Next Hop
        - IP Address of Tier-1 DR in VRF A (e.g. 100.64.80.1)
        - Admin Distance: 1
        - Scope: VRF-A

In case of a physical router outage, the next hop for the static route on the Tier-0 VRF A can still be reached using a different healthy BGP peer advertising that host route.

4.5 IPv6 Routing Capabilities

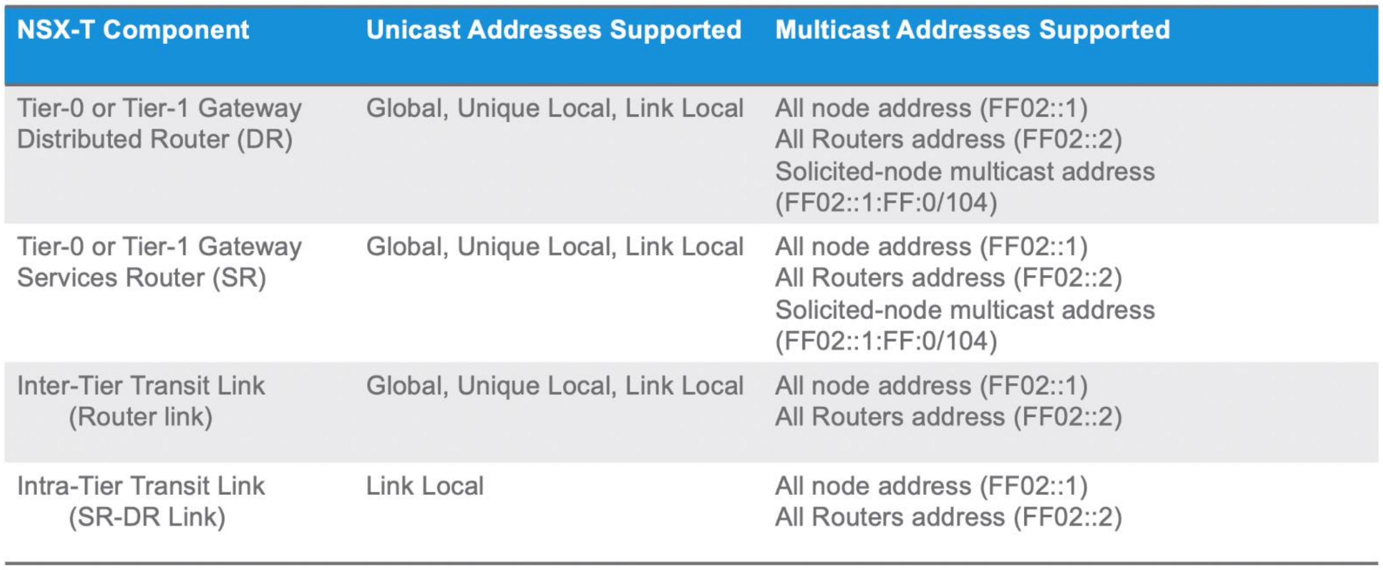
NSX-T Data Center also supports dual stack for the interfaces on a Tier-0 or Tier-1 Gateway. Users can leverage distributed services like distributed routing and distributed firewall for East-

West traffic in a single tier topology or multi-tiered topology for IPv6 workloads now. Users can also leverage centralized services like Gateway Firewall for North-South traffic.

NSX-T Datacenter supports the following unicast IPv6 addresses:

- **Global Unicast:** Globally unique IPv6 address and internet routable
- **Link-Local:** Link specific IPv6 address and used as next hop for IPv6 routing protocols
- **Unique local:** Site specific unique IPv6 addresses used for inter-site communication but not routable on internet. Based on RFC4193.

The following table shows a summarized view of supported IPv6 unicast and multicast address types on NSX-T Datacenter components.



NSX-T Component	Unicast Addresses Supported	Multicast Addresses Supported
Tier-0 or Tier-1 Gateway Distributed Router (DR)	Global, Unique Local, Link Local	All node address (FF02::1) All Routers address (FF02::2) Solicited-node multicast address (FF02::1:FF:0/104)
Tier-0 or Tier-1 Gateway Services Router (SR)	Global, Unique Local, Link Local	All node address (FF02::1) All Routers address (FF02::2) Solicited-node multicast address (FF02::1:FF:0/104)
Inter-Tier Transit Link (Router link)	Global, Unique Local, Link Local	All node address (FF02::1) All Routers address (FF02::2)
Intra-Tier Transit Link (SR-DR Link)	Link Local	All node address (FF02::1) All Routers address (FF02::2)

Table 4-1: Type of IPv6 Addresses Supported on Tier-0 and Tier-1 Gateway Components

Figure 4-31: Single Tier and Multi-tier IPv6 Routing Topology shows a single tiered routing topology on the left side with a Tier-0 Gateway supporting dual stack on all interfaces and a multi-tiered routing topology on the right side with a Tier-0 Gateway and Tier-1 Gateway supporting dual stack on all interfaces. A user can either assign static IPv6 addresses to the workloads or use a DHCPv6 relay supported on gateway interfaces to get dynamic IPv6 addresses from an external DHCPv6 server.

For a multi-tier IPv6 routing topology, each Tier-0-to-Tier-1 peer connection is provided a /64 unique local IPv6 address from a pool i.e. fc5f:2b61:bd01::/48. A user has the flexibility to change this subnet range and use another subnet if desired. Similar to IPv4, this IPv6 address is auto plumbed by system in background.

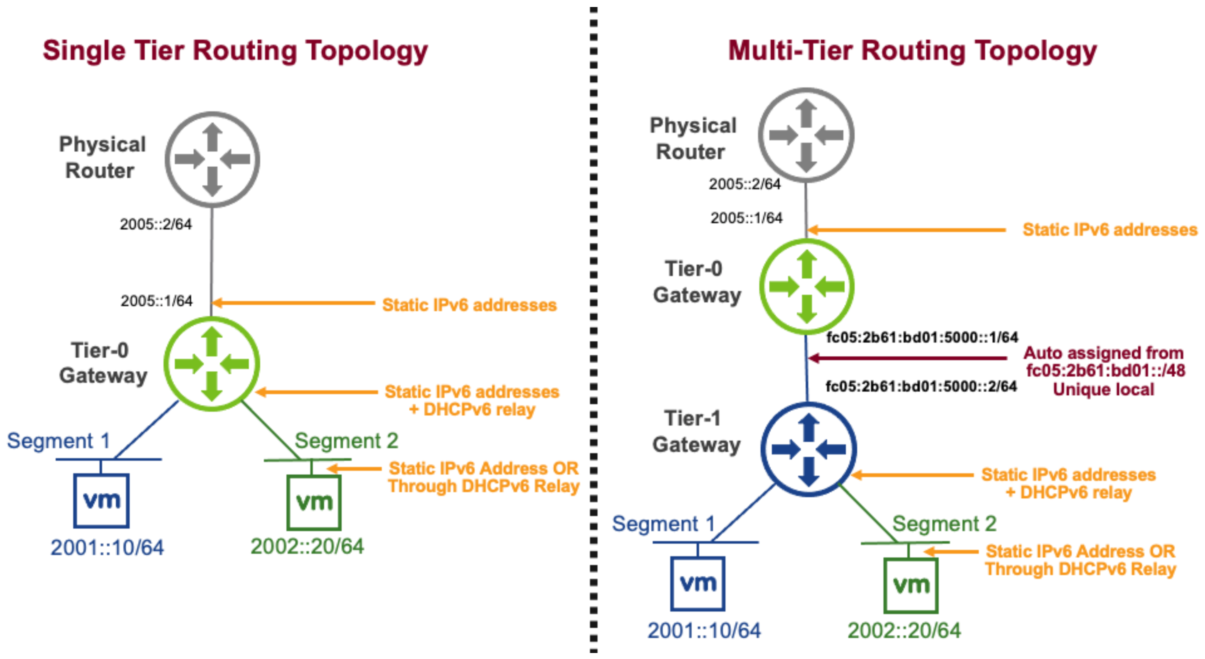

Single Tier Routing Topology
Physical Router
2005::2/64
2005::1/64
Static IPv6 addresses
Tier-0 Gateway
Static IPv6 addresses + DHCPv6 relay
Segment 1
Segment 2
Static IPv6 Address OR Through DHCPv6 Relay
vm
2001::10/64
2002::20/64
Multi-Tier Routing Topology
Physical Router
2005::2/64
2005::1/64
Static IPv6 addresses
Tier-0 Gateway
fc05:2b61:bd01:5000::1/64
Auto assigned from fc05:2b61:bd01::/48 Unique local
fc05:2b61:bd01:5000::2/64
Tier-1 Gateway
Static IPv6 addresses + DHCPv6 relay
Segment 1
Segment 2
Static IPv6 Address OR Through DHCPv6 Relay
2001::10/64
2002::20/64

Figure 4-31: Single Tier and Multi-tier IPv6 Routing Topology

Tier-0 Gateway supports following IPv6 routing features:

- Static routes with IPv6 Next-hop
- MP-eBGP with IPv4 and IPv6 address families
- Multi-hop eBGP
- IBGP
- ECMP support with static routes, EBGP and IBGP
- Outbound and Inbound route influencing using Weight, Local Pref, AS Path prepend and MED.
- IPv6 Route Redistribution
- IPv6 Route Aggregation
- IPv6 Prefix List and Route map
- IPv6 Loopback Interfaces

Tier-1 Gateway supports following IPv6 routing features:

- Static routes with IPv6 Next-hop

IPv6 routing between Tier-0 and Tier-1 Gateway is auto plumbed similar to IPv4 routing. As soon as Tier-1 Gateway is connected to Tier-0 Gateway, the management plane configures a default route (::/0) on Tier-1 Gateway with next hop IPv6 address as Router link IP of Tier-0 Gateway (fc05:2b61:bd01:5000::1/64, as shown in *Figure 4-32: IPv6 Routing in a Multi-tier Topology*). To provide reachability to subnets connected to the Tier-1 Gateway, the Management Plane (MP) configures routes on the Tier-0 Gateway for all the LIFs connected to Tier-1 Gateway with a next hop IPv6 address as Tier-1 Gateway Router link IP (fc05:2b61:bd01:5000::2/64, as shown in *Figure 4-32: IPv6 Routing in a Multi-tier Topology*). 2001::/64 & 2002:/64 are seen as “Tier-1 Connected” routes on Tier-0.

Northbound, Tier-0 Gateway redistributes the Tier-0 connected and Tier-1 Connected routes in BGP and advertises these to its eBGP neighbor, the physical router.

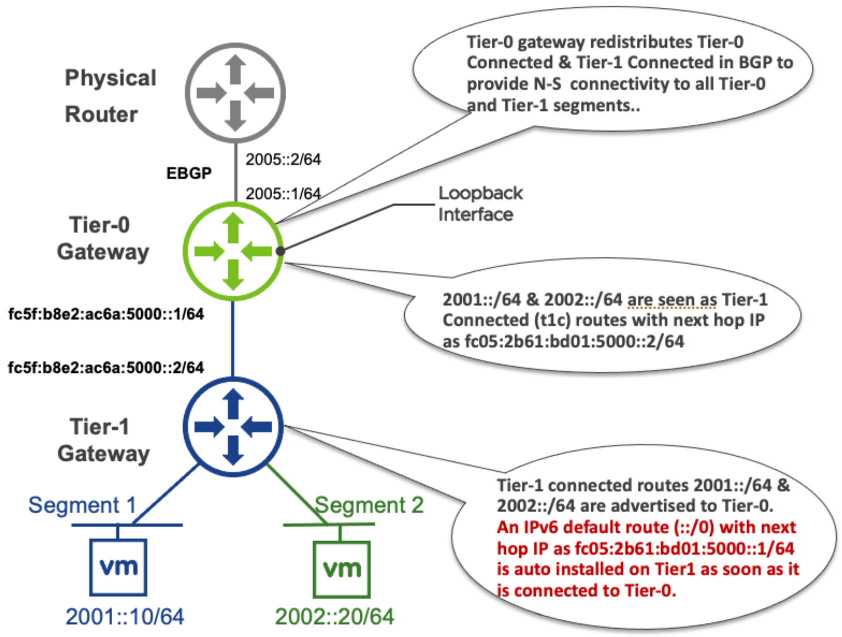

Physical Router
Tier-0 gateway redistributes Tier-0 Connected & Tier-1 Connected in BGP to provide N-S connectivity to all Tier-0 and Tier-1 segments..
EBGP
2005::2/64
2005::1/64
Loopback Interface
Tier-0 Gateway
fc5f:b8e2:ac6a:5000::1/64
fc5f:b8e2:ac6a:5000::2/64
2001::/64 & 2002::/64 are seen as Tier-1 Connected (t1c) routes with next hop IP as fc05:2b61:bd01:5000::2/64
Tier-1 Gateway
Segment 1
Segment 2
Tier-1 connected routes 2001::/64 & 2002::/64 are advertised to Tier-0. An IPv6 default route (::/0) with next hop IP as fc05:2b61:bd01:5000::1/64 is auto installed on Tier1 as soon as it is connected to Tier-0.
vm
vm
2001::10/64
2002::20/64

Figure 4-32: IPv6 Routing in a Multi-tier Topology

4.6 Services High Availability

NSX Edge nodes run in an Edge cluster, hosting centralized services, and providing connectivity to the physical infrastructure. Since the services are run on the SR component of a Tier-0 or Tier-1 gateway, the following concept is relevant to SR. This SR service runs on an Edge node and has two modes of operation – active/active or active/standby. When a Tier-1 gateway is configured to be hosted on an Edge cluster, an SR is automatically instantiated even if no services are configured or running on the Tier-1. When a Tier-1 SR is instantiated, the Tier-0 DR is removed from the hypervisors and located on the edge nodes only.

4.6.1 Active/Active

Active/Active – This is a high availability mode where SRs hosted on Edge nodes act as active forwarders. Stateless services such as layer 3 forwarding are IP based, so it does not matter which Edge node receives and forwards the traffic. All the SRs configured in active/active configuration mode are active forwarders. This high availability mode is only available on Tier-0 gateway.

Stateful services typically require tracking of connection state (e.g., sequence number check, connection state), thus traffic for a given session needs to go through the same Edge node. As of NSX-T 3.0, active/active HA mode does not support stateful services such as Gateway Firewall or stateful NAT. Stateless services, including reflexive NAT and stateless firewall, can leverage the active/active HA model.

Left side of *Figure 4-33: Tier-0 Gateway Configured in Active/Active HA Mode* shows a Tier-0 gateway (configured in active/active high availability mode) with two external interfaces leveraging two different Edge nodes, EN1 and EN2. Right side of the diagram shows that the services router component (SR) of this Tier-0 gateway instantiated on both Edge nodes, EN1 and EN2. A Compute host, ESXi is also shown in the diagram that only has distributed component (DR) of Tier-0 gateway.

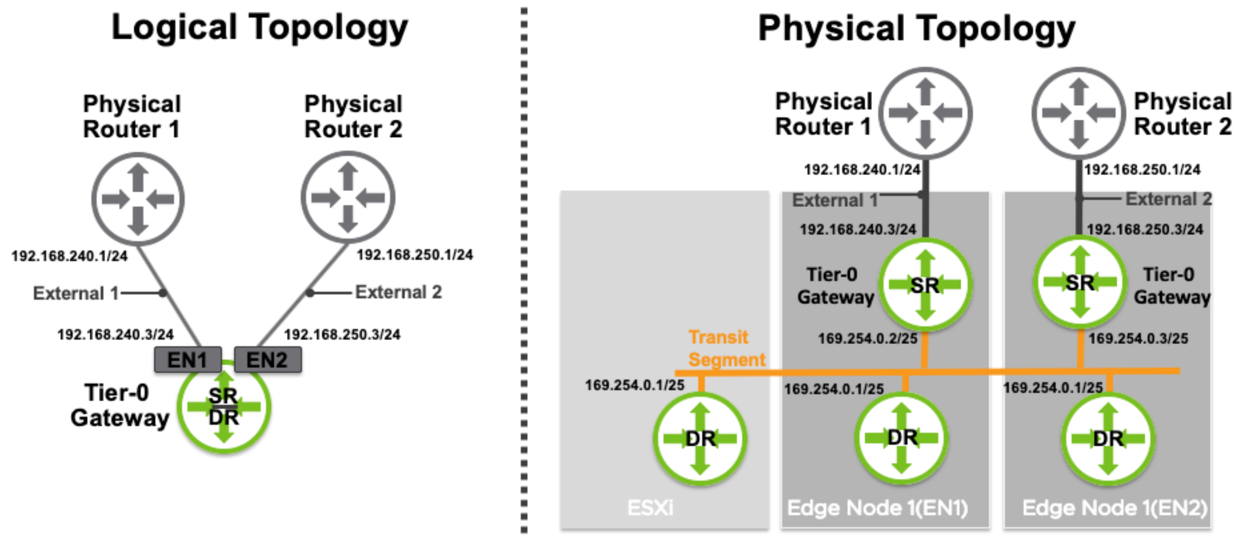


Figure 4-33: Tier-0 Gateway Configured in Active/Active HA Mode

Note that Tier-0 SR on Edge nodes, EN1 and EN2 have different IP addresses northbound toward physical routers and different IP addresses southbound towards Tier-0 DR. Management plane configures two default routes on Tier-0 DR with next hop as SR on EN1 (169.254.0.2) and SR on EN2 (169.254.0.3) to provide ECMP for overlay traffic coming from compute hosts.

North-South traffic from overlay workloads hosted on Compute hosts will be load balanced and sent to SR on EN1 or EN2, which will further do a routing lookup to send traffic out to the physical infrastructure.

A user does not have to configure these static default routes on Tier-0 DR. Automatic plumbing of default route happens in background depending upon the HA mode configuration.

Inter-SR Routing

To provide redundancy for physical router failure, Tier-0 SRs on both Edge nodes must establish routing adjacency or exchange routing information with different physical router or TOR. These physical routers may or may not have the same routing information. For instance, a route 192.168.100.0/24 may only be available on physical router 1 and not on physical router 2.

For such asymmetric topologies, users can enable Inter-SR routing. This feature is only available on Tier-0 gateway configured in active/active high availability mode. *Figure 4-34: Inter-SR Routing* shows an asymmetric routing topology with Tier-0 gateway on Edge node, EN1 and EN2 peering with physical router 1 and physical router 2, both advertising different routes.

When Inter-SR routing is enabled by the user, an overlay segment is auto plumbed between SRs (similar to the transit segment auto plumbed between DR and SR) and each end gets an IP address assigned in 169.254.0.128/25 subnet by default. An IBGP session is automatically created between Tier-0 SRs and northbound routes (EBGP and static routes) are exchanged on this IBGP session.

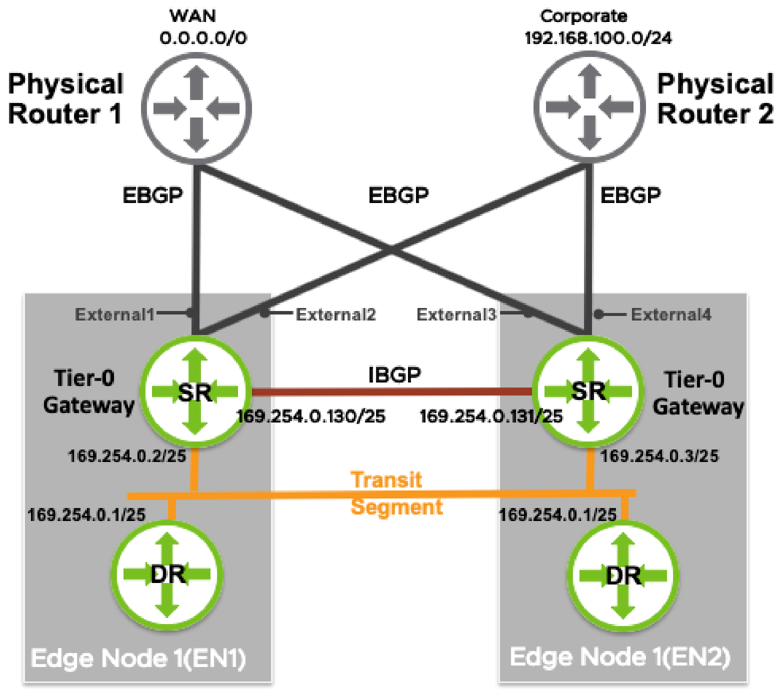


Figure 4-34: Inter-SR Routing

As explained in previous figure, Tier-0 DR has auto plumbed default routes with next hops as Tier-0 SRs and North-South traffic can go to either SR on EN1 or EN2. In case of asymmetric routing topologies, a particular Tier-0 SR may or may not have the route to a destination. In that case, traffic can follow the IBGP route to another SR that has the route to destination.

Figure 4-34: Inter-SR Routing shows a topology where Tier-0 SR on EN1 is learning a default WAN route 0.0.0.0/0 and a corporate prefix 192.168.100.0/24 from physical router 1 and physical router 2 respectively. If "External 1" interface on Tier-0 fails and the traffic from compute workloads destined to WAN lands on Tier-0 SR on EN1, this traffic can follow the default route (0.0.0.0/0) learned via IBGP from Tier-0 SR on EN2.Traffic is being sent to EN2 through the Geneve overlay. After a route lookup on Tier-0 SR on EN2, this N-S traffic can be sent to physical router 1 using "External interface 3".

Graceful Restart and BFD Interaction with Active/Active – Tier-0 SR Only
If an Edge node is connected to a TOR switch that does not have the dual supervisor or the ability to retain forwarding traffic when the control plane is restarting, enabling GR in eBGP TOR does not make sense. There is no value in preserving the forwarding table on either end or sending traffic to the failed or restarting device. In case of an active SR failure (i.e., the Edge node goes down), physical router failure, or path failure, forwarding will continue using another active SR or another TOR. BFD should be enabled with the physical routers for faster failure detection.

It is recommended to enable GR If the Edge node is connected to a dual supervisor system that supports forwarding traffic when the control plane is restarting. This will ensure that forwarding table data is preserved and forwarding will continue through the restarting supervisor or control plane. Enabling BFD with such a system would depend on the device-specific BFD implementation. If the BFD session goes down during supervisor failover, then BFD should not be enabled with this system. If the BFD implementation is distributed such that the BFD session would not go down in case of supervisor or control plane failure, then enable BFD as well as GR.

4.6.2 Active/Standby

Active/Standby – This is a high availability mode where only one SR act as an active forwarder. This mode is required when stateful services are enabled. Services like NAT are in constant state of sync between active and standby SRs on the Edge nodes. This mode is supported on both Tier-1 and Tier-0 SRs. Preemptive and Non-Preemptive modes are available for both Tier-0 and Tier-1 SRs. Default mode for gateways configured in active/standby high availability configuration is non-preemptive.

A user can select the preferred member (Edge node) when a gateway is configured in active/standby preemptive mode. When enabled, preemptive behavior allows a SR to resume active role on preferred edge node as soon as it recovers from a failure.

For Tier-1 Gateway, active/standby SRs have the same IP addresses northbound. Only the active SR will reply to ARP requests, while the standby SR interfaces operational state is set as down so that they will automatically drop packets.

For Tier-0 Gateway, active/standby SRs have different IP addresses northbound and both have eBGP sessions established on their uplinks. Both Tier-0 SRs (active and standby) receive routing updates from physical routers and advertise routes to the physical routers; however, the standby Tier-0 SR prepends its local AS three times in the BGP updates so that traffic from the physical routers prefer the active Tier-0 SR.

Southbound IP addresses on active and standby Tier-0 SRs are the same and the operational state of standby SR southbound interface is down. Since the operational state of southbound Tier-0 SR interface is down, the Tier-0 DR does not send any traffic to the standby SR. *Figure 4-35: Active and Standby Routing Control with eBGP* shows active and standby Tier-0 SRs on Edge nodes “EN1” and “EN2”.

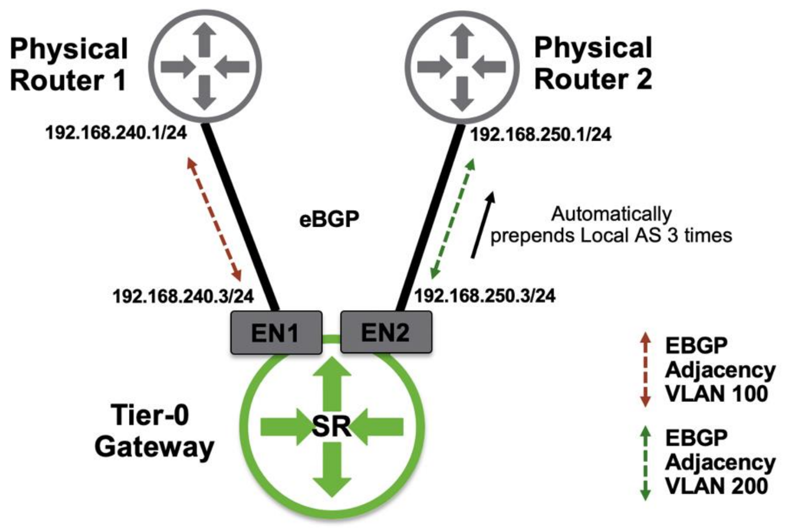


Figure 4-35: Active and Standby Routing Control with eBGP

The placement of active and standby SR in terms of connectivity to TOR or northbound infrastructure becomes an important design choice, such that any component failure should not result in a failure of both active and standby service. Diversity of connectivity to TOR for bare metal edge nodes and host-specific availability consideration for hosts where Edge node VMs are hosted, becomes an important design choice. These choices are described in the NSX-T Design Considerations.

4.6.2.1 Graceful Restart and BFD Interaction with Active/Standby

Active/standby services have an active/active control plane with active/standby data forwarding. In this redundancy model, eBGP is established on active and standby Tier-0s SR with their respective TORs. If the Edge node is connected to a system that does not have the dual supervisor or the ability to keep forwarding traffic when the control plane is restarting, enabling GR in eBGP does not make sense. There is no value in preserving the forwarding table on either end as well as no point sending traffic to the failed or restarting device. When the active Tier-0 SR goes down, the route advertised from standby Tier-0 becomes the best route and forwarding continues using the newly active SR. If the TOR switch supports BFD, it is recommended to run BFD on both the eBGP neighbors for faster failure detection.

It is recommended to enable GR If the Edge node is connected to a dual supervisor system that supports forwarding traffic when the control plane is restarting. This will ensure that the forwarding table is table is preserved and forwarding will continue through the restarting supervisor or control plane. Enabling BFD with such system depends on BFD implementation of hardware vendor. If the BFD session goes down during supervisor failover, then BFD should not be enabled with this system; however, if the BFD implementation is distributed such that that the BFD session would not go down in case of supervisor or control plane failure, then enable BFD as well as GR.

4.6.3 High Availability Failover Triggers

An active SR on an Edge node is declared down when one of the following conditions is met:

- Edge nodes in an Edge cluster exchange BFD keep lives on two interfaces of the Edge node, management and overlay tunnel interfaces. Failover will be triggered when a SR fails to receive keep lives on both interfaces.
- All BGP sessions or northbound routing on the SR is down. This is only applicable on Tier-0 SR. When static routes are used on a Bare Metal Edge node with NSX-T 3.0, the failover will be triggered when the status of all PNIC carrying the uplinks is down.
- Edge nodes also run BFD with compute hosts. When all the overlay tunnels are down to remote Edges and compute hypervisors, an SR would be declared down.

4.7 Edge Node

Edge nodes are service appliances with pools of capacity, dedicated to running network and security services that cannot be distributed to the hypervisors. Edge node also provides connectivity to the physical infrastructure. Previous sections mentioned that centralized services will run on the SR component of Tier-0 or Tier-1 gateways. These features include:

- Connectivity to physical infrastructure (static routing / BGP / MP-BGP)
- VRF-lite
- NAT
- DHCP server
- Metadata proxy
- Gateway Firewall
- Load Balancer
- L2 Bridging
- Service Interface
- VPN

As soon as one of these services is configured or an external interface is defined on the Tier-0 gateway, a SR is instantiated on the Edge node. The Edge node is also a transport node just like compute nodes in NSX-T, and like a compute node it can connect to more than one transport zones. A specific Edge node can be connected to only one overlay transport zone and depending upon the topology, is connected to one or more VLAN transport zones for N-S connectivity.

There are two transport zones on the Edge:

- **Overlay Transport Zone**: Any traffic that originates from a VM participating in NSX-T domain may require reachability to external devices or networks. This is typically described as external North-South traffic. Traffic from VMs may also require some centralized service like NAT, load balancer etc. To provide reachability for N-S traffic and to consume centralized services, overlay traffic is sent from compute transport nodes to Edge nodes. Edge node needs to be configured with a single overlay transport zone so that it can decapsulate the overlay traffic received from compute nodes as well as encapsulate the traffic sent to compute nodes.
- **VLAN Transport Zone**: Edge nodes connect to physical infrastructure using VLANs. Edge node needs to be configured for VLAN transport zone to provide external or N-S connectivity to the physical infrastructure. Depending upon the N-S topology, an edge node can be configured with one or more VLAN transport zones.

Edge node can have one or more N-VDS to provide desired connectivity. Each N-VDS on the Edge node uses an uplink profile which can be same or unique per N-VDS. Teaming policy defined in this uplink profile defines how the N-VDS balances traffic across its uplinks. The uplinks can in turn be individual pNICs or LAGs.

Types of Edge Nodes
Edge nodes are available in two form factors – VM and bare metal. Both leverage the data plane development kit (DPDK) for faster packet processing and high performance. There are different VM form factors available. Each of them has a different resource footprint and can be used to achieve different guidelines. These are detailed in the below table.

Size	Memory	vCPU	Disk	Specific Usage Guidelines
Small	4GB	2	200 GB	PoC only, LB functionality is not available.
Medium	8GB	4	200 GB	Suitable for production with centralized services like NAT, Gateway Firewall. Load balancer functionality can be leveraged for POC.
Large	32GB	8	200 GB	Suitable for production with centralized services like NAT, Gateway Firewall, load balancer etc.
Extra Large	64GB	16	200GB	Suitable for production with centralized services like NAT, Gateway Firewall, load balancer etc. Typically deployed, where higher performance is desired for services like Layer 7 Load balancer and VPN.
Bare metal Edge	32GB	8	200 GB	Suitable for production with centralized services like NAT, Gateway Firewall, load balancer etc. Typically deployed, where higher performance at low packet size and sub-second N-S convergence is desired.

The Table 4-2 Edge VM Form Factor and Usage Guidelines

The Bare Metal Edge resources specified above specify the minimum resources needed. It is recommended to deploy an edge node on a bare metal server with the following specifications for maximum performance:

- Memory: 256GB
- CPU Cores: 24
- Disk Space: 200GB

When NSX-T Edge is installed as a VM, vCPUs are allocated to the Linux IP stack and DPDK. The number of vCPU assigned to a Linux IP stack or DPDK depends on the size of the Edge VM. A medium Edge VM has two vCPUs for Linux IP stack and two vCPUs dedicated for

DPDK. This changes to four vCPUs for Linux IP stack and four vCPUs for DPDK in a large size Edge VM. Starting with NSX-T 3.0, several AMD CPUs are supported both for the virtualized and Bare Metal Edge node form factor. Specifications can be found in the NSX Documentation at:
https://docs.vmware.com/en/VMware-NSX-T-Data-Center/3.1/installation/GUID-22F87CA8-01A9-4F2E-B7DB-9350CA60EA4E.html.

4.8 Multi-TEP support on Edge Node

Staring with NSX-T 2.4 release, Edge nodes support multiple overlay tunnels (multi-TEP) configuration to load balance overlay traffic for overlay segments/logical switches. Multi-TEP is supported in both Edge VM and bare metal. *Figure 4-36: Bare metal Edge -Same N-VDS for overlay and external traffic with Multi-TEP* shows two TEPs configured on the bare metal Edge. Each overlay segment/logical switch is pinned to a specific tunnel end point IP, TEP IP1 or TEP IP2. Each TEP uses a different uplink, for instance, TEP IP1 uses Uplink1 that's mapped to pNIC P1 and TEP IP2 uses Uplink2 that's mapped to pNIC P2. This feature offers a better design choice by load balancing overlay traffic across both physical pNICs and also simplifies N-VDS design on the Edge.

Notice that a single N-VDS is used in this topology that carries both overlay and external traffic. In-band management feature is leveraged for management traffic. Overlay traffic gets load balanced by using multi-TEP feature on Edge and external traffic gets load balanced using "Named Teaming Policy".

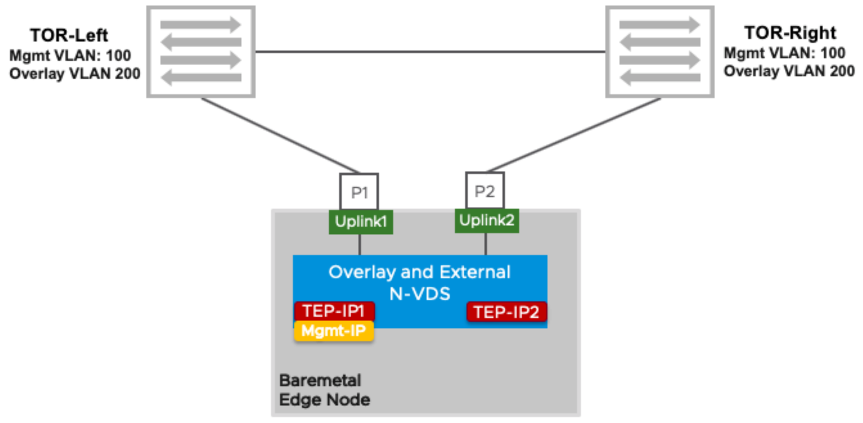


Figure 4-36: Bare metal Edge -Same N-VDS for overlay and external traffic with Multi-TEP

Following pre-requisites must be met for multi-TEP support:
- TEP configuration must be done on one N-VDS only.
- All TEPs must use same transport VLAN for overlay traffic.
- All TEP IPs must be in same subnet and use same default gateway.

During a pNIC failure, Edge performs a TEP failover by migrating TEP IP and its MAC address to another uplink. For instance, if pNIC P1 fails, TEP IP1 along with its MAC address will be migrated to use Uplink2 that's mapped to pNIC P2. In case of pNIC P1 failure, pNIC P2 will carry the traffic for both TEP IP1 and TEP IP2.

A Case for a Better Design:

This version of the design guide introduced a simpler way to configure Edge connectivity, referred as "Single N-VDS Design". The key reasons for adopting "Single N-VDS Design":

- **Multi-TEP support for Edge** – Details of multi-TEP is described as above. Just like an ESXi transport node supporting multiple TEP, Edge node has a capability to support multiple TEP per uplink with following advantages:
    - Removes critical topology restriction with bare metal – straight through LAG
    - Allowing the use of multiple pNICs for the overlay traffic in both bare metal and VM form factor.
- An Edge VM supporting multiple TEP can have two uplinks from the same N-VDS, allowing utilization of both pNICs. Efficient load sharing among host to Edge VM.
- **Multiple teaming policy per N-VDS** – Default and Named Teaming Policy
    - Allows specific uplink to be designated or pinned for a given VLAN
    - Allowing uplinks to be active/standby or active-only to drive specific behavior of a given traffic types while co-existing other traffic type following entirely different paths
- **Normalization of N-VDS configuration** – All form factors or Edge and deployments uses single N-VDS along with host. Single teaming policy for overlay – Load Balanced Source. Single policy for N-S peering – Named teaming Policy
- **Reduction in management and control plane load** – With each N-VDS, additional resources are used such as IP addressing for management, connections to NSX manager and BFD sessions to all transport nodes as well all the Edge nodes. The BFD sessions are fully meshed, in other words the session counts increase with each N-VDS with N(N-1) expansion. The CPU resources are also consumed by multiple N-VDS within the same Edge VM.

4.8.1 Bare Metal Edge Node

NSX-T bare metal Edge runs on a physical server and is installed using an ISO file or PXE boot. Legacy BIOS mode is the only supported booting mode on NSXT-T 3.0. A bare metal Edge differs from the VM form factor Edge in terms of performance. It provides sub-second convergence, faster failover, and higher throughput at low packet size (discussed in performance Chapter 8). There are certain hardware requirements including CPU specifics and supported NICs can be found in the NSX Edge Bare Metal Requirements section of the NSX-T installation guide.

When a bare metal Edge node is installed, a dedicated interface is retained for management. If redundancy is desired, two NICs can be used for management plane high availability. These management interfaces can also be 1G. Bare metal Edge also supports in-band management where management traffic can leverage an interface being used for overlay or external (N-S) traffic.

Bare metal Edge node supports a maximum of 16 physical NICs for overlay traffic and external traffic to top of rack (TOR) switches. For each of these 16 physical NICs on the server, an internal interface is created following the naming scheme "fp-ethX". These internal interfaces are assigned to the DPDK Fast Path. There is a flexibility in assigning these Fast Path interfaces (fp-eth) for overlay or external connectivity.

4.8.1.1 Management Plane Configuration Choices with Bare Metal Node

This section covers all the available options in managing the bare metal node. There are four options as describe in below diagram:

Out of Band Management with Single pNIC

Left side of *Figure 4-37: Bare Metal Edge Management Configuration Choices* shows a bare metal edge node with 3 physical NICs. The dedicated pNIC for management and is used to send/receive management traffic. The management pNIC can be 1Gbps. There is no redundancy for management traffic in this topology. If P1 goes down, the management traffic will fail. However, Edge node will continue to function as this doesn't affect data plane traffic.

In Band Management – Data Plane (fast-path) NIC carrying Management Traffic

This capability was added in NSX-T 2.4 release. It is not mandatory to have a dedicated physical interface to carry management traffic. This traffic can leverage one of the DPDK fast-path interfaces. On the right side of the *Figure 4-37: Bare Metal Edge Management Configuration Choices*, P2 is selected to send management traffic. In-band management configuration is available via CLI on the Edge node. A user needs to provide following two parameters to configure in-band management.

- VLAN for management traffic.
- MAC address of the DPDK Fast Path interface chosen for this management traffic.

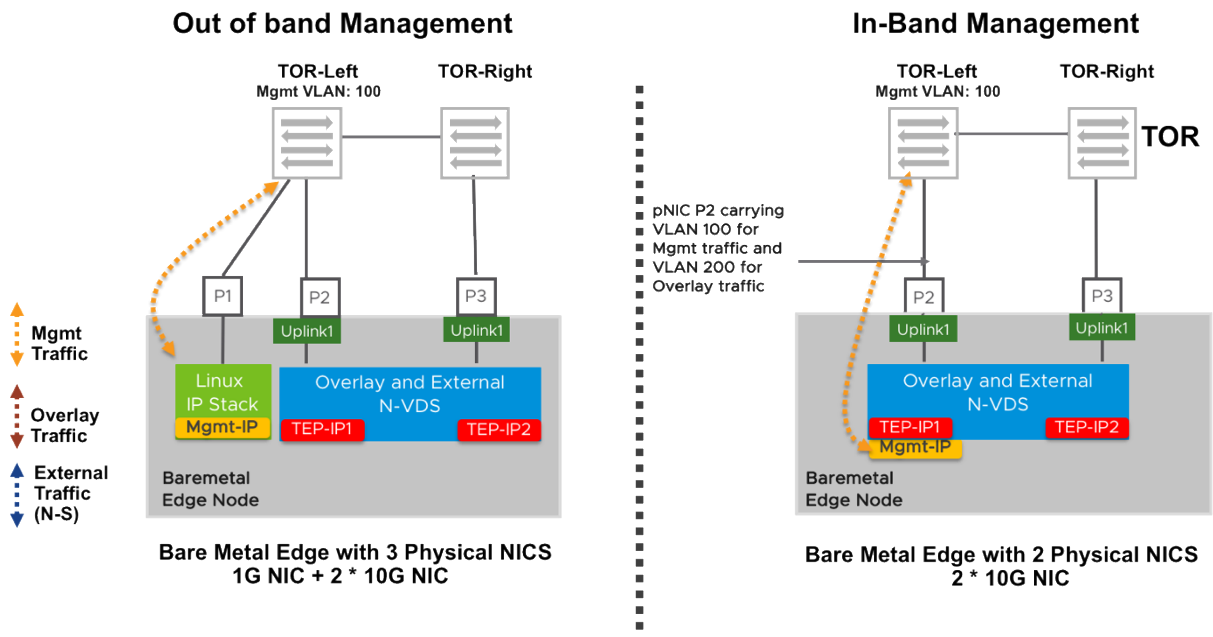


Figure 4-37: Bare Metal Edge Management Configuration Choices

Additionally, one can configure the management redundancy via LAG, however only one of the LAG members can be active at a time.

4.8.1.2 Single N-VDS Bare Metal Configuration with 2 pNICs

Figure 4-38: Bare Metal Edge Configured for Multi-TEP - Single N-VDS for Overlay and External Traffic shows 2 pNIC bare metal Edge using a single N-VDS design for data plane. The left side of the diagram shows the bare metal Edge with four physical NICs where management traffic has dedicated two physical NICs (P1 & P2) configured in active/standby mode.

A single N-VDS “Overlay and External N-VDS" is used in this topology that carries both overlay and External traffic. Overlay traffic from different overlay segments/logical switches gets pinned to TEP IP1 or TEP IP2 and gets load balanced across both uplinks, Uplink1 and Uplink2. Notice that, both TEP IPs use same transport VLAN i.e. VLAN 200 which is configured on both top of rack switches.

Two VLANs segments, i.e. "External VLAN Segment 300" and "External VLAN Segment 400" are used to provide northbound connectivity to Tier-0 gateway. Same VLAN segment can also be used to connect Tier-0 Gateway to TOR-Left and TOR-Right, however it is not recommended because of inter-rack VLAN dependencies leading to spanning tree related convergence. External traffic from these VLAN segments is load balanced across uplinks using named teaming policy which pins a VLAN segment to a specific uplink.

This topology provides redundancy for management, overlay and external traffic, in event of a pNIC failure on Edge node/TOR and TOR Failure.

The right side of the diagram shows two pNICs bare metal edge configured with the same N-VDS “Overlay and External N-VDS" for carrying overlay and external traffic as above that is also leveraging in-band management.

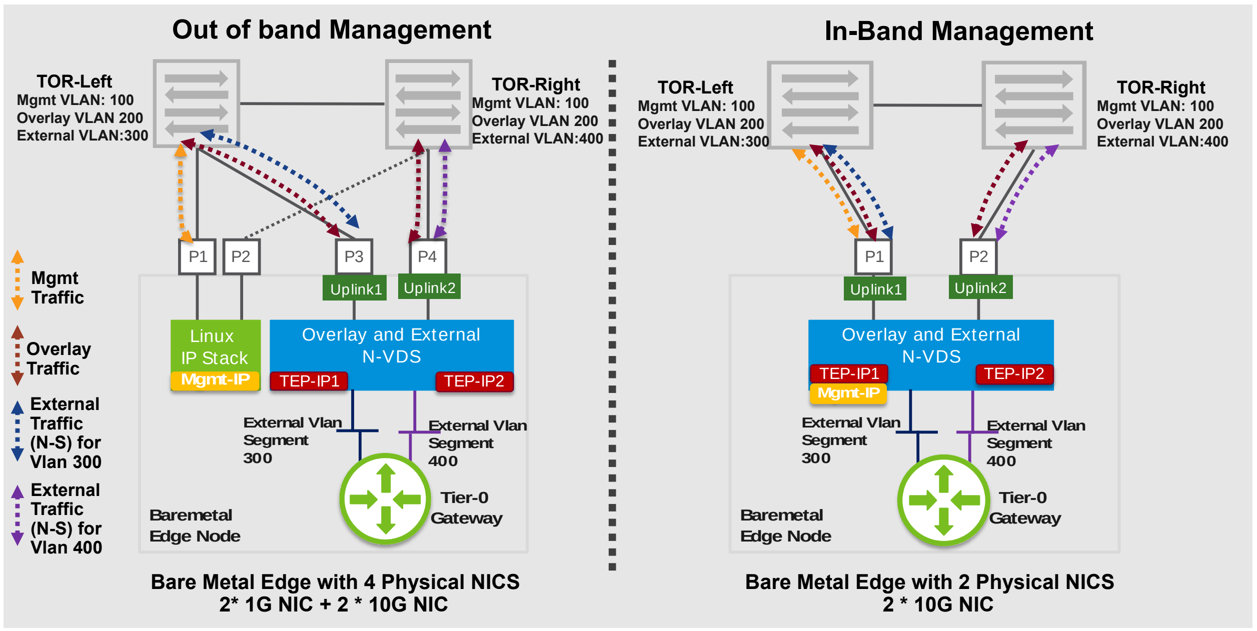
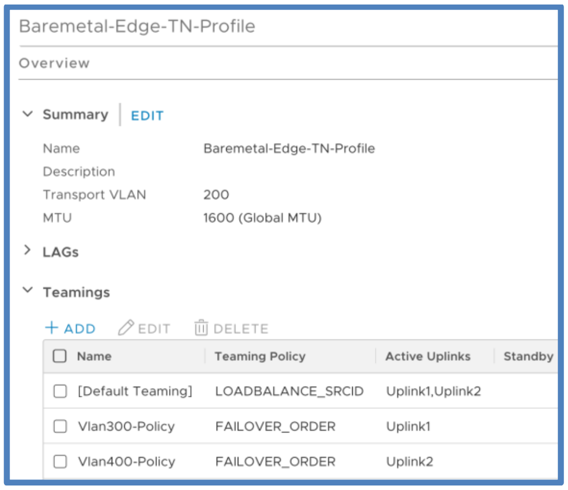


Figure 4-38: Bare Metal Edge Configured for Multi-TEP - Single N-VDS for Overlay and External Traffic (With dedicated pNICs for Management and In-Band Management)

Both above topologies use the same transport node profile as shown in *Figure 4-39: Bare Metal Edge Transport Node Profile*. This configuration shows a default teaming policy that uses both Uplink1 and Uplink2. This default policy is used for all the segments/logical switches created on this N-VDS. Two additional teaming policies, “Vlan300-Policy” and “Vlan400-Policy” have been defined to override the default teaming policy and send traffic to “Uplink1” and “Uplink2” respectively.

"External VLAN segment 300" is configured to use the named teaming policy “Vlan300-Policy” that sends traffic from this VLAN only on “Uplink1”. "External VLAN segment 400" is configured to use a named teaming policy “Vlan400-Policy” that sends traffic from this VLAN only on “Uplink2”.

Based on these teaming policies, TOR-Left will receive traffic for VLAN 100 (Mgmt.), VLAN 200 (overlay) and VLAN 300 (Traffic from VLAN segment 300) and hence, should be configured for these VLANs. Similarly, TOR-Right will receive traffic for VLAN 100 (Mgmt.), VLAN 200 (overlay) and VLAN 400 (Traffic from VLAN segment 400). A sample configuration screenshot is shown below.



Baremetal-Edge-TN-Profile

Overview

Summary | EDIT

Name	Baremetal-Edge-TN-Profile
Description	
Transport VLAN	200
MTU	1600 (Global MTU)

LAGs

Teamings

+ ADD EDIT DELETE

Name	Teaming Policy	Active Uplinks	Standby
[Default Teaming]	LOADBALANCE_SRCID	Uplink1,Uplink2	
Vlan300-Policy	FAILOVER_ORDER	Uplink1	
Vlan400-Policy	FAILOVER_ORDER	Uplink2	

Figure 4-39: Bare Metal Edge Transport Node Profile

Figure 4-40: 4-way ECMP Using Bare Metal Edges shows a logical and physical topology where a Tier-0 gateway has four external interfaces. External interfaces 1 and 2 are provided by bare metal Edge node “EN1”, whereas External interfaces 3 and 4 are provided by bare metal Edge node “EN2”. Both the Edge nodes are in the same rack and connect to TOR switches in that rack. Both the Edge nodes are configured for Multi-TEP and use named teaming policy to send traffic from VLAN 300 to TOR-Left and traffic from VLAN 400 to TOR-Right. Tier-0 Gateway establishes BGP peering on all four external interfaces and provides 4-way ECMP.

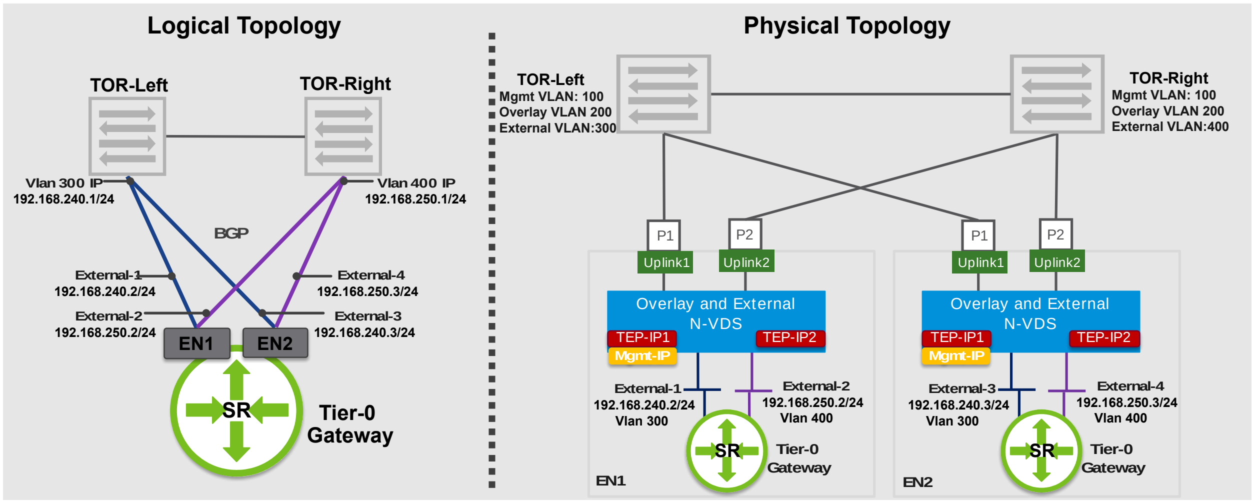

Logical Topology
TOR-Left
TOR-Right
Vlan 300 IP 192.168.240.1/24
Vlan 400 IP 192.168.250.1/24
BGP
External-1 192.168.240.2/24
External-4 192.168.250.3/24
External-2 192.168.250.2/24
External-3 192.168.240.3/24
EN1
EN2
SR
Tier-0 Gateway
Physical Topology
TOR-Left Mgmt VLAN: 100 Overlay VLAN 200 External VLAN:300
TOR-Right Mgmt VLAN: 100 Overlay VLAN 200 External VLAN:400
P1
P2
Uplink1
Uplink2
Overlay and External N-VDS
TEP-IP1
TEP-IP2
Mgmt-IP
External-1 192.168.240.2/24 Vlan 300
External-2 192.168.250.2/24 Vlan 400
External-3 192.168.240.3/24 Vlan 300
External-4 192.168.250.3/24 Vlan 400
SR
Tier-0 Gateway
EN1
EN2

Figure 4-40: 4-way ECMP Using Bare Metal Edges

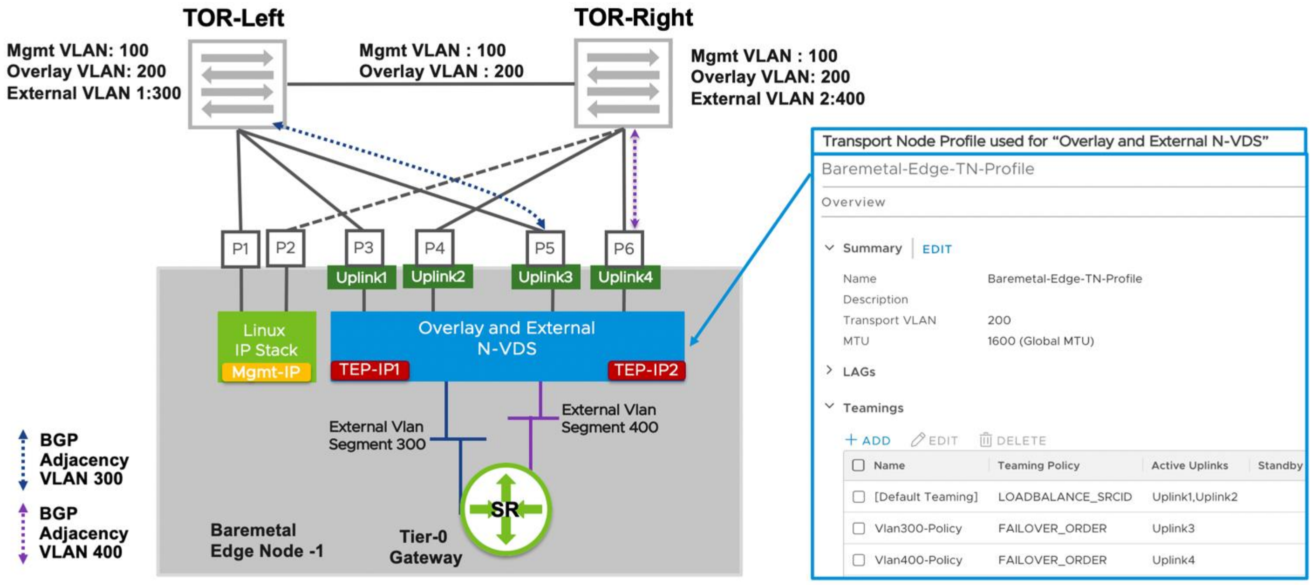
4.8.1.3 Single N-VDS Bare Metal Configuration with Six pNICs

Figure 4-41: Bare Metal Edge with Six pNICs - Same N-VDS for Overlay and External traffic shows NSX-T bare metal Edge with six physical NICs. Management traffic has two dedicated pNICs configured in Active/Standby. Two pNICs, P3 and P4 are dedicated for overlay traffic and two pNICs (P5 and P6) are dedicated for external traffic.

A single N-VDS “Overlay and External N-VDS" is used in this topology that carries both overlay and External traffic. However, different uplinks are used to carry overlay and external traffic. Multi-TEP is configured to provide load balancing for the overlay traffic on Uplink1 (mapped to pNIC P3) and Uplink2 (mapped to pNIC P4). Notice that, both TEP IPs use same transport VLAN i.e. VLAN 200 which is configured on both top of rack switches.

Figure 4-41: Bare Metal Edge with Six pNICs - Same N-VDS for Overlay and External traffic also shows a configuration screenshot of named teaming policy defining two additional teaming policies, “Vlan300-Policy” and “Vlan400-Policy”.
"External VLAN segment 300" is configured to use a named teaming policy “Vlan300-Policy” that sends traffic from this VLAN only on Uplink3 (mapped to pNIC P5). "External VLAN segment 400" is configured to use a named teaming policy “Vlan400-Policy” that sends traffic from this VLAN only on Uplink4 (mapped to pNIC P6). Hence, BGP traffic from Tier-0 on VLAN 300 always goes to TOR-Left and BGP traffic from Tier-0 on VLAN 400 always goes to TOR-Right.

This topology provides redundancy for management, overlay and external traffic. This topology also provides a simple, high bandwidth and deterministic design as there are dedicated physical NICs for different traffic types (overlay and External traffic).



Baremetal-Edge-TN-Profile

Overview

Summary EDIT

Name	Baremetal-Edge-TN-Profile
Description	
Transport VLAN	200
MTU	1600 (Global MTU)

LAGs

Teamings

+ ADD EDIT DELETE

Name	Teaming Policy	Active Uplinks	Standby
[Default Teaming]	LOADBALANCE_SRCID	Uplink1,Uplink2	
Vlan300-Policy	FAILOVER_ORDER	Uplink3	
Vlan400-Policy	FAILOVER_ORDER	Uplink4	

Figure 4-41: Bare Metal Edge with Six pNICs - Same N-VDS for Overlay and External traffic

4.8.2 VM Edge Node

NSX-T VM Edge in VM form factor can be installed using an OVA, OVF, or ISO file. NSX-T Edge VM is only supported on ESXi host.

An NSX-T Edge VM has four internal interfaces: eth0, fp-eth0, fp-eth1, and fp-eth2. Eth0 is reserved for management, while the rest of the interfaces are assigned to DPDK Fast Path. These interfaces are allocated for external connectivity to TOR switches and for NSX-T overlay tunneling. There is complete flexibility in assigning Fast Path interfaces (fp-eth) for overlay or external connectivity. As an example, fp-eth0 could be assigned for overlay traffic with fp-eth1, fp-eth2, or both for external traffic.

There is a default teaming policy per N-VDS that defines how the N-VDS balances traffic across its uplinks. This default teaming policy can be overridden for VLAN segments only using “named teaming policy”. To develop desired connectivity (e.g., explicit availability and traffic engineering), more than one N-VDS per Edge node may be required. Each N-VDS instance can have a unique teaming policy, allowing for flexible design choices.

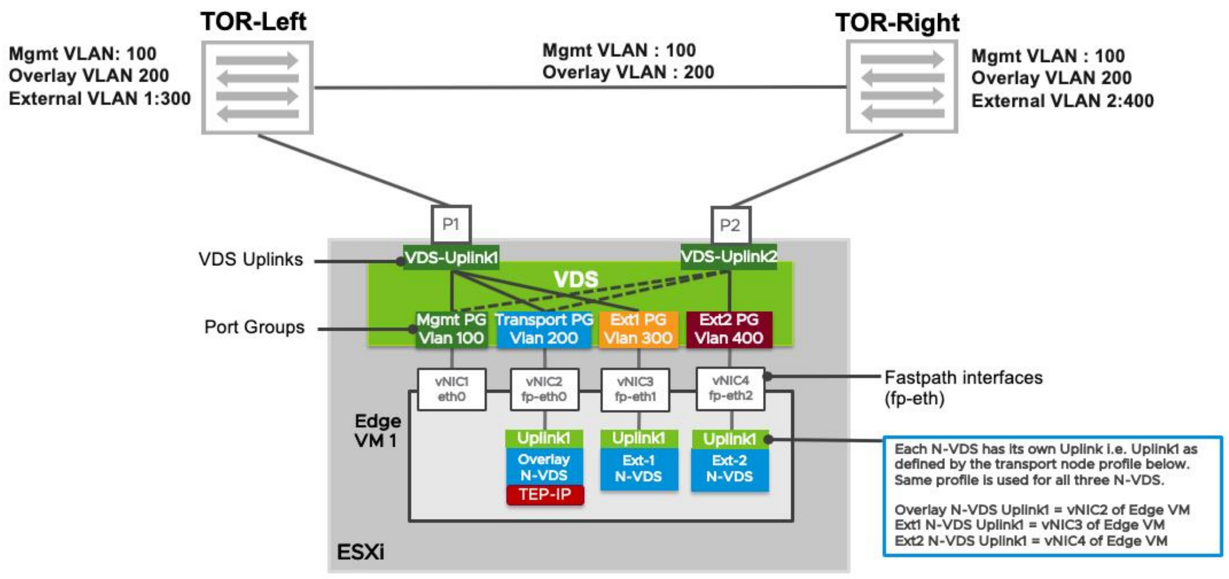
4.8.2.1 Multiple N-VDS per Edge VM Configuration – NSX-T 2.4 or Older

The “three N-VDS per Edge VM design” as commonly called has been deployed in production. This section briefly covers the design, so the reader does not miss the important decision which design to adopt based on NSX-T release target.

The multiple N-VDS per Edge VM design recommendation is valid regardless of the NSX-T release. This design must be followed if the deployment target is NSX-T release 2.4 or older. The design recommendation is still completely applicable and viable to Edge VM deployment running NSX-T 2.5 release. In order to simplify consumption for the new design recommendation, the pre-2.5 release design has been moved to Appendix 5. The design choices that moved to appendix covers

- 2 pNICs bare metal design necessitating straight through LAG topology
- Edge clustering design consideration for bare metal
- 4 pNICs bare metal design added to support existing deployment
- Edge node design with 2 and 4 pNICs

It’s a mandatory to adopt Appendix 5 recommendation for NSX-T release up to 2.5. The newer design as described in section The Design Recommendation with Edge Node NSX-T Release 2.5 Onward will not operate properly if adopted in release before NSX-T 2.5.



Each N-VDS has its own Uplink i.e. Uplink1 as defined by the transport node profile below. Same profile is used for all three N-VDS.

Overlay N-VDS Uplink1 = vNIC2 of Edge VM
Ext1 N-VDS Uplink1 = vNIC3 of Edge VM
Ext2 N-VDS Uplink1 = vNIC4 of Edge VM

Figure 4-42: Edge Node VM Installed Leveraging VDS Port Groups on a 2 pNIC host

Figure 4-42: Edge Node VM Installed Leveraging VDS Port Groups on a 2 pNIC host shows an ESXi host with two physical NICs. Edges "VM1" is hosted on ESXi host leveraging the VDS port groups, each connected to both TOR switches. This figure 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 vNIC of Edge VM. All three N-VDS use the same teaming policy i.e. Failover order with one active uplink.

4.8.2.2 VLAN TAG Requirements

Edge VM deployment shown in *Figure 4-42: Edge Node VM Installed Leveraging VDS Port Groups on a 2 pNIC host* remains valid and is ideal for deployments where only one VLAN is necessary on each vNIC of the Edge VM. However, it doesn't cover all the deployment use cases. For instance, if a user cannot add service interfaces to connect VLAN backed workloads in above topology as that requires to allow one or more VLANs on the VDS DVPG (distributed virtual port group). If these DVPGs are configured to allow multiple VLANs, no change in DVPG configuration is needed when new service interfaces (workload VLAN segments) are added.

When these DVPGs are configured to carry multiple VLANs, a VLAN tag is expected from Edge VM for traffic belonging to different VLANs.

VLAN tags can be applied to both overlay and external traffic at either N-VDS level or VSS/VDS level. On N-VDS, overlay and external traffic can be tagged using the following configuration:

- Uplink Profile where the transport VLAN can be set which will tag overlay traffic only
- VLAN segment connecting Tier-0 gateway to external devices- This configuration will apply a VLAN tag to the external traffic only.

Following are the three ways to configure VLAN tagging on VSS or VDS:

- EST (External Switch Tagging)
- VST (Virtual Switch Tagging)
- VGT (virtual guest tagging)

For the details where each tagging can be applicable refer to following resources:

https://kb.vmware.com/s/article/1003806#vgtPoints

https://www.vmware.com/pdf/esx3_VLAN_wp.pdf

Figure 4-43: VLAN Tagging on Edge Mode shows an Edge node hosted on an ESXi host. In this example, VLAN tags are applied to both overlay and external traffic using uplink profile and VLAN segments connecting Tier-0 Gateway to physical infrastructure respectively. As a result, VDS port groups that provides connectivity to Edge VM receive VLAN tagged traffic. Hence, they should be configured to allow these VLANs in VGT (Virtual guest tagging) mode.

Uplink profile used for "Overlay N-VDS" has a transport VLAN defined as VLAN 200. This will ensure that the overlay traffic exiting vNIC2 has an 802.1Q VLAN 200 tag. Overlay traffic received on VDS port group "Transport PG" is VLAN tagged. That means that this Edge VM vNIC2 will have to be attached to a port group configured for Virtual Guest Tagging (VGT).

Tier-0 Gateway connects to the physical infrastructure using "External-1" and "External-2" interface leveraging VLAN segments "External VLAN Segment 300" and "External VLAN Segment 400" respectively. In this example, "External Segment 300" and "External Segment 400" are configured with a VLAN tag, 300 and 400 respectively. External traffic received on VDS port groups "Ext1 PG" and Ext2 PG" is VLAN tagged and hence, these port groups should be configured in VGT (Virtual guest tagging) mode and allow those specific VLANs.

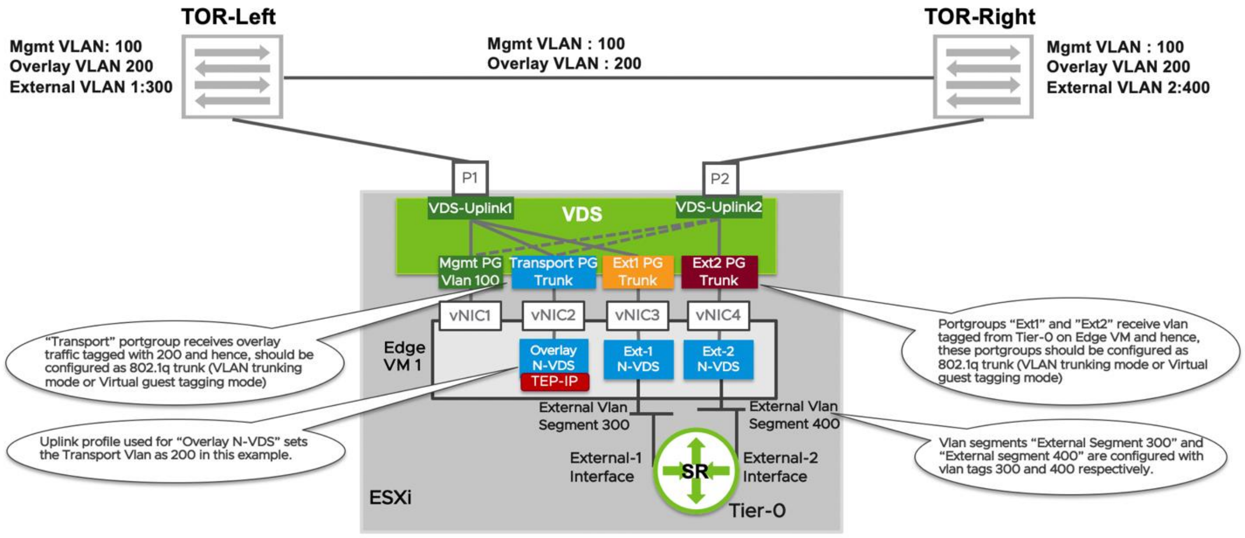

TOR-Left
TOR-Right
Mgmt VLAN: 100
Overlay VLAN 200
External VLAN 1:300
Mgmt VLAN : 100
Overlay VLAN : 200
Mgmt VLAN : 100
Overlay VLAN 200
External VLAN 2:400
P1
P2
VDS-Uplink1
VDS
VDS-Uplink2
Mgmt PG Vlan 100
Transport PG Trunk
Ext1 PG Trunk
Ext2 PG Trunk
vNIC1
vNIC2
vNIC3
vNIC4
Edge VM 1
Overlay N-VDS
TEP-IP
Ext-1 N-VDS
Ext-2 N-VDS
"Transport" portgroup receives overlay traffic tagged with 200 and hence, should be configured as 802.1q trunk (VLAN trunking mode or Virtual guest tagging mode)
Uplink profile used for "Overlay N-VDS" sets the Transport Vlan as 200 in this example.
Portgroups "Ext1" and "Ext2" receive vlan tagged from Tier-0 on Edge VM and hence, these portgroups should be configured as 802.1q trunk (VLAN trunking mode or Virtual guest tagging mode)
Vlan segments "External Segment 300" and "External segment 400" are configured with vlan tags 300 and 400 respectively.
External Vlan Segment 300
External Vlan Segment 400
External-1 Interface
External-2 Interface
SR
Tier-0
ESXi

Figure 4-43: VLAN Tagging on Edge Mode

4.8.2.3 Single N-VDS Based Configuration - Starting with NSX-T 2.5 release

Starting NSX-T 2.4 release, Edge nodes support Multi-TEP configuration to load balance overlay traffic for segments/logical switches. Similar to the bare metal Edge one N-VDS design, Edge VM also supports same N-VDS for overlay and external traffic.

Even though this multi-TEP feature was available in NSX-T 2.4 release, the release that supports this design is NSX-T 2.5 release onward. It is mandatory to use the multiple VDS design for release NSX-T 2.4 or older as described in Appendix 5.

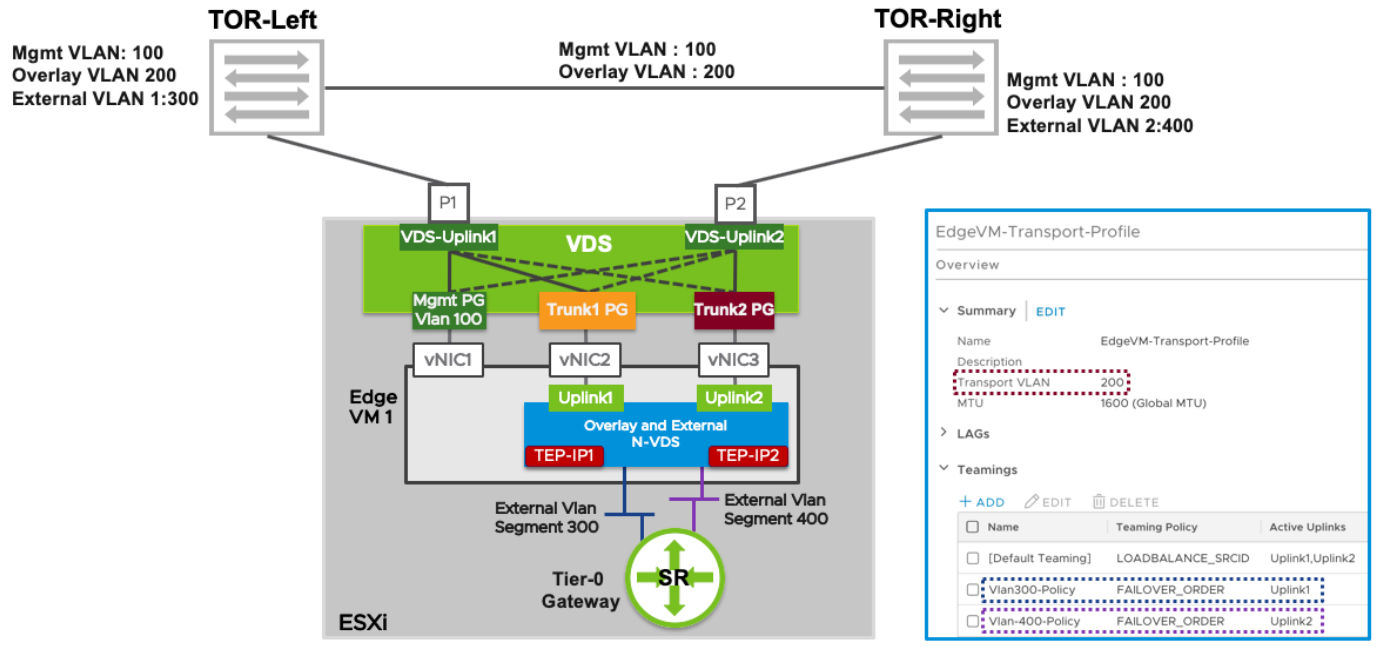
Figure 4-44: VLAN Tagging on Edge Node with Single N-VDS shows an Edge VM with one N-VDS i.e. "Overlay and External N-VDS", to carry both overlay and external traffic. Multi-TEP is configured to provide load balancing for overlay traffic on "Uplink1" and "Uplink2". "Uplink1" and "Uplink2" are mapped to use vNIC2 and vNIC3 respectively. Based on this teaming policy, overlay traffic will be sent and received on both vNIC2 and vNIC3 of the Edge VM. Notice that, both TEP IPs use same transport VLAN i.e. VLAN 200 which is configured on both top of rack switches.

Similar to *Figure 4-43: VLAN Tagging on Edge Mode*, Tier-0 Gateway for BGP peering connects to the physical infrastructure leveraging VLAN segments "External VLAN Segment 300" and "External VLAN Segment 400" respectively. In this example, "External VLAN Segment 300" and “External VLAN Segment 400” are configured with a VLAN tag, 300 and 400 respectively. External traffic received on VDS port groups “Trunk1 PG” and Trunk2 PG” is VLAN tagged and hence, these port groups should be configured in VGT (Virtual guest tagging) mode and allow those specific VLANs.

Named teaming policy is also configured to load balance external traffic. *Figure 4-44: VLAN Tagging on Edge Node with Single N-VDS* also shows named teaming policy configuration used for this topology. "External VLAN segment 300" is configured to use a named teaming policy “Vlan300-Policy” that sends traffic from this VLAN on “Uplink1” (vNIC2 of Edge VM). "External VLAN segment 400" is configured to use a named teaming policy “Vlan400-Policy” that sends traffic from this VLAN on “Uplink2” (vNIC3 of Edge VM). Based on this named teaming policy, North-South or external traffic from “External VLAN Segment 300” will always be sent and received on vNIC2 of the Edge VM. North-South or external traffic from “External VLAN Segment 400” will always be sent and received on vNIC3 of the Edge VM.

Overlay or external traffic from Edge VM is received by the VDS DVPGs “Trunk1 PG” and “Trunk2 PG”. Teaming policy used on the VDS port group level defines how this overlay and external traffic coming from Edge node VM exits the hypervisor. For instance, “Trunk1 PG” is configured to use active uplink as “VDS-Uplink1” and standby uplink as “VDS-Uplink2”. “Trunk2 PG” is configured to use active uplink as “VDS-Uplink2” and standby uplink as “VDS-Uplink1”.

This configuration ensures that the traffic sent on “External VLAN Segment 300” i.e. VLAN 300 always uses vNIC2 of Edge VM to exit Edge VM. This traffic then uses “VDS-Uplink1” (based on “Trunk1 PG” configuration) and is sent to the left TOR switch. Similarly, traffic sent on VLAN 400 uses “VDS-Uplink2” and is sent to the TOR switch on the right.



EdgeVM-Transport-Profile

Overview

Summary | EDIT

Name	EdgeVM-Transport-Profile
Description	
Transport VLAN	200
MTU	1600 (Global MTU)

LAGs

Teamings

Name	Teaming Policy	Active Uplinks
[Default Teaming]	LOADBALANCE_SRCID	Uplink1,Uplink2
Vlan300-Policy	FAILOVER_ORDER	Uplink1
Vlan-400-Policy	FAILOVER_ORDER	Uplink2

Figure 4-44: VLAN Tagging on Edge Node with Single N-VDS

Starting with NSX-T release 2.5, single N-VDS deployment mode is recommended for both bare metal and Edge VM. Key benefits of single N-VDS deployment are:

- Consistent deployment model for both Edge VM and bare metal Edge with one N-VDS carrying both overlay and external traffic.
- Load balancing of overlay traffic with Multi-TEP configuration.
- Ability to distribute external traffic to specific TORs for distinct point to point routing adjacencies.
- No change in DVPG configuration when new service interfaces (workload VLAN segments) are added.
- Deterministic North South traffic pattern.

Service interface were introduced earlier, following section focusses on how service interfaces work in the topology shown in *Figure 4-45: VLAN Tagging on Edge Node with Service Interface*.

4.8.2.4 VLAN Backed Service Interface on Tier-0 or Tier-1 Gateway

Service interface is an interface connecting VLAN backed segments/logical switch to provide connectivity to VLAN backed physical or virtual workloads. This interface acts as a gateway for these VLAN backed workloads and is supported both on Tier-0 and Tier-1 Gateways configured in active/standby HA configuration mode.

Service interface is realized on Tier-0 SR or Tier-1 SR. This implies that traffic from a VLAN workload needs to go to Tier-0 SR or Tier-1 SR to consume any centralized service or to communicate with any other VLAN or overlay segments. Tier-0 SR or Tier-1 SR is always hosted on Edge node (bare metal or Edge VM).

Figure 4-45: VLAN Tagging on Edge Node with Service Interface shows a VLAN segment “VLAN Seg-500” that is defined to provide connectivity to the VLAN workloads. “VLAN Seg-500” is configured with a VLAN tag of 500. Tier-0 gateway has a service interface “Service Interface-1” configured leveraging this VLAN segment and acts as a gateway for VLAN workloads connected to this VLAN segment. In this example, if the workload VM, VM1 needs to communicate with any other workload VM on overlay or VLAN segment, the traffic will be sent from the compute hypervisor (ESXi-2) to the Edge node (hosted on ESXi-1). This traffic is tagged with VLAN 500 and hence the DVPG receiving this traffic (“Trunk-1 PG” or “Trunk-2 PG”) must be configured in VST (Virtual Switch Tagging) mode. Adding more service interfaces on Tier-0 or Tier-1 is just a matter of making sure that the specific VLAN is allowed on DVPG (“Trunk-1 PG” or “Trunk-2 PG”).

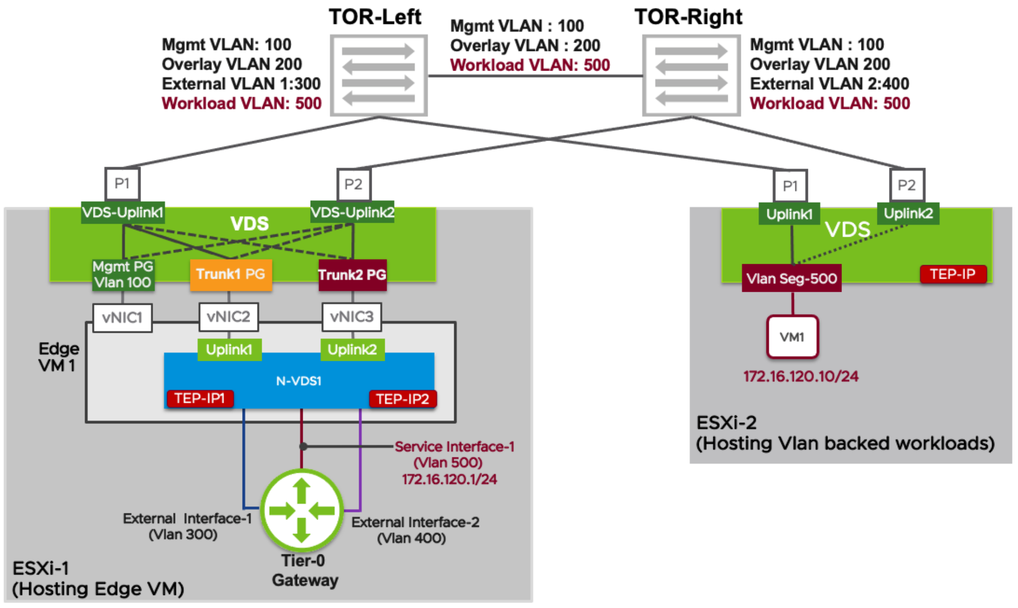


Figure 4-45: VLAN Tagging on Edge Node with Service Interface

Note: Service interface can also be connected to overlay segments for standalone load balancer use cases. This is explained in Load balancer Chapter 6.

4.8.3 Edge Cluster

An Edge cluster is a group of Edge transport nodes. It provides scale out, redundant, and high-throughput gateway functionality for logical networks. Scale out from the logical networks to the Edge nodes is achieved using ECMP. NSX-T 2.3 introduced the support for heterogeneous Edge nodes which facilitates easy migration from Edge node VM to bare metal Edge node without reconfiguring the logical routers on bare metal Edge nodes. There is a flexibility in assigning Tier-0 or Tier-1 gateways to Edge nodes and clusters. Tier-0 and Tier-1 gateways can be hosted on either same or different Edge clusters.

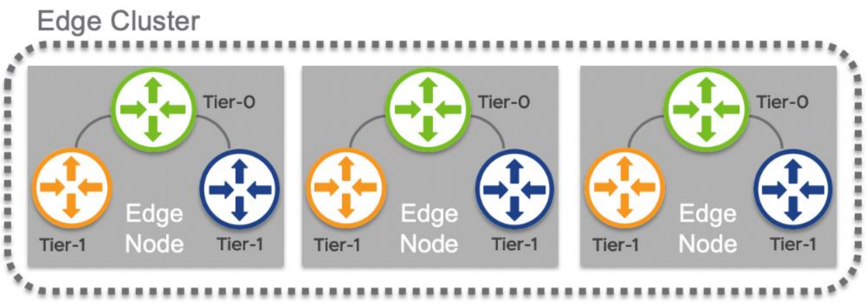


Figure 4-46: Edge Cluster with Tier-0 and Tier 1 Services

Depending upon the services hosted on the Edge node and their usage, an Edge cluster could be dedicated simply for running centralized services (e.g., NAT). *Figure 4-47: Multiple Edge Clusters with Dedicated Tier-0 and Tier-1 Services* shows two clusters of Edge nodes. Edge Cluster 1 is dedicated for Tier-0 gateways only and provides external connectivity to the physical infrastructure. Edge Cluster 2 is responsible for NAT functionality on Tier-1 gateways.

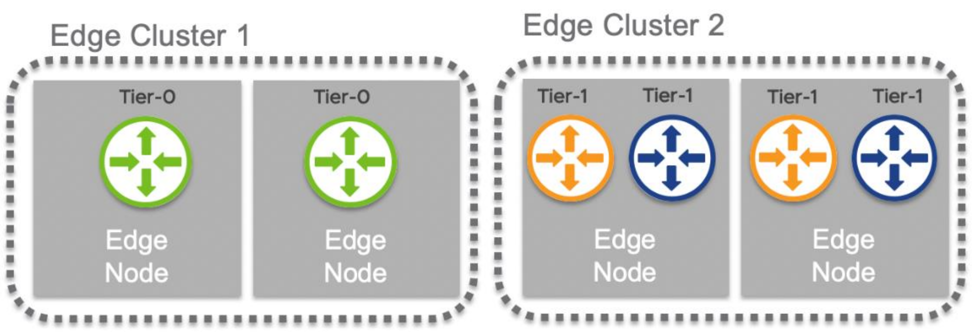


Figure 4-47: Multiple Edge Clusters with Dedicated Tier-0 and Tier-1 Services

There can be only one Tier-0 gateway per Edge node; however, multiple Tier-1 gateways can be hosted on one Edge node.

A maximum of 10 Edge nodes can be grouped in an Edge cluster. A Tier-0 gateway supports a maximum of eight equal cost paths, thus a maximum of eight Edge nodes are supported for ECMP. Edge nodes in an Edge cluster run Bidirectional Forwarding Detection (BFD) on both tunnel and management networks to detect Edge node failure. The BFD protocol provides fast detection of failure for forwarding paths or forwarding engines, improving convergence. Edge VMs support BFD with minimum BFD timer of 50ms with three retries, providing a 1.5 second failure detection time. Bare metal Edges support BFD with minimum BFD TX/RX timer of 50ms with three retries which implies 150ms failure detection time.

4.8.4 Failure Domain

Failure domain is a logical grouping of Edge nodes within an Edge Cluster. This feature is introduced in NSX-T 2.5 release and can be enabled on Edge cluster level via API configuration. Please refer to this API configuration available in Appendix 3.

As discussed in high availability section, a Tier-1 gateway with centralized services runs on Edge nodes in active/standby HA configuration mode. When a user assigns a Tier-1 gateway to an Edge cluster, NSX manager automatically chooses the Edge nodes in the cluster to run the active and standby Tier-1 SR. The auto placement of Tier-1 SRs on different Edge nodes considers several parameters like Edge capacity, active/standby HA state etc.

Failure domains compliment auto placement algorithm and guarantee service availability in case of a rack failure. Active and standby instance of a Tier-1 SR always run in different failure domains.

Figure 4-48: Failure Domains shows an edge cluster comprised of four Edge nodes, EN1, EN2, EN3 and EN4. EN1 and EN2 connected to two TOR switches in rack 1 and EN3 and EN4 connected to two TOR switches in rack 2. Without failure domain, a Tier-1 SR could be auto placed in EN1 and EN2. If rack1 fails, both active and standby instance of this Tier-1 SR fail as well.

EN1 and EN2 are configured to be a part of failure domain 1, while EN3 and EN4 are in failure domain 2. When a new Tier-1 SR is created and if active instance of that Tier-1 is hosted on EN1, then the standby Tier-1 SR will be instantiated in failure domain 2 (EN3 or EN4).

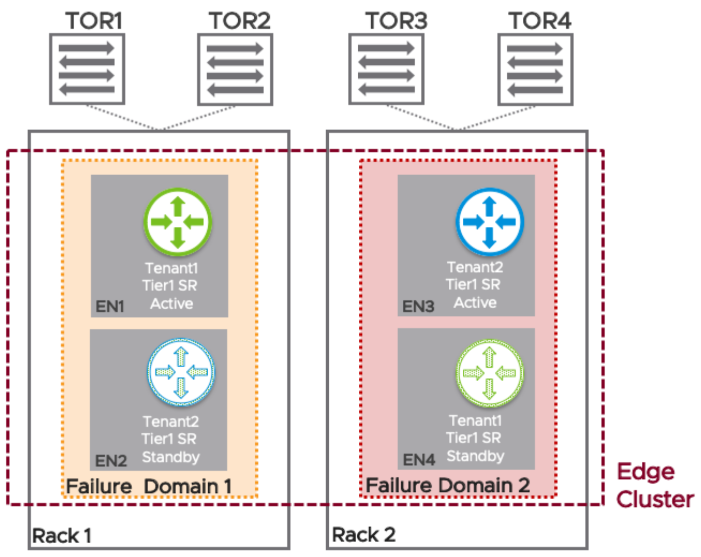


Figure 4-48: Failure Domains

To ensure that all Tier-1 services are active on a set of edge nodes, 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.

4.9 Other Network Services

4.9.1 Unicast Reverse Path Forwarding (uRPF)

A router forwards packets based on the value of the destination IP address field that is present in the IP header. The source IP address field is generally not used when forwarding a packet on a network (except when networks implement source-based routing). Unicast Reverse Path Forwarding is defined in RFC 2827 and 3704. It prevents packets with spoofed source IP address to be forwarded in the network. uRPF is generally enabled on a router per interface and not globally. A uRPF enabled router will inspect the source IP address of each packet received on an interface. When a packet arrives on an interface, the router will verify if the receiving that specific interface would be used to reach the source of the packet. It will discard the packets if the received and routing table interfaces are different. This protection prevents spoofed source IP address attacks that are commonly used by sending packets with random source IP addresses.

Figure 4-49 – uRPF diagrams a physical network with uRPF enabled on the core router.

1- The core router receives a packet with a source IP address of 10.1.1.1 on interface ethernet0/2.
2- The core router has the uRPF feature enabled on all its interfaces and will check in its routing table if the source IP address of the packet would be routed through interface ethernet 0/2. In this case, 10.1.1.1 is the source IP address present in the IP header. The core router has a longest prefix match for 10.1.1.0/24 via interface ethernet 0/0.
3- Since the packet does not come from the interface ethernet 0/0, the packet will be discarded.

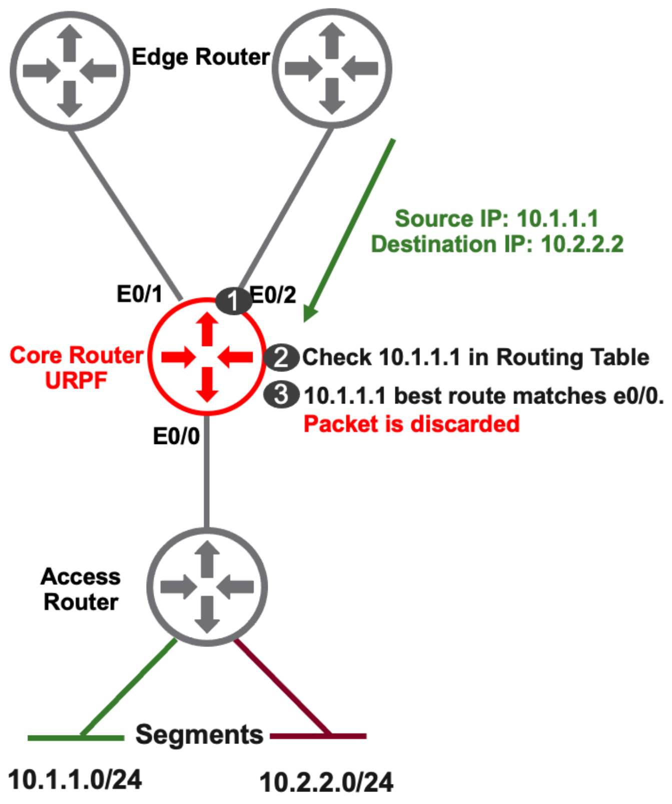


Figure 4-49 – uRPF

In NSX-T, uRPF is enabled by default on external, internal and service interfaces. From a security standpoint, it is a best practice to keep uRPF enabled on these interfaces. uRPF is also recommended in architectures that leverage ECMP. On intra-tier and router link interfaces, a simplified anti-spoofing mechanism is implemented. It is checking that a packet is never sent back to the interface the packet was received on.

It is possible to disable uRPF in complex routing architecture where asymmetric routing exists. As of NSX-T 3.0, it is possible to disable or enable uRPF on the Policy UI except for downlink interfaces where the administrator would need to use the Manager UI or Policy API.

4.9.2 Network Address Translation

Users can enable NAT as a network service on NSX-T. This is a centralized service which can be enabled on both Tier-0 and Tier-1 gateways.

Supported NAT rule types include:

- **Source NAT (SNAT)**: Source NAT translates the source IP of the outbound packets to a known public IP address so that the application can communicate with the outside world without using its private IP address. It also keeps track of the reply.
- **Destination NAT (DNAT)**: DNAT allows for access to internal private IP addresses from the outside world by translating the destination IP address when inbound communication is initiated. It also takes care of the reply. For both SNAT and DNAT, users can apply NAT rules based on 5 tuple match criteria.

- **Reflexive NAT:** Reflexive NAT rules are stateless ACLs which must be defined in both directions. These do not keep track of the connection. Reflexive NAT rules can be used in cases where stateful NAT cannot be used due to asymmetric paths (e.g., user needs to enable NAT on active/active ECMP routers).

Table 4-3: NAT Usage Guidelines summarizes NAT rules and usage restrictions.

NAT Rules Type	Type	Specific Usage Guidelines
Stateful	Source NAT (SNAT) Destination NAT (DNAT)	Can be enabled on both Tier-0 and Tier-1 gateways
Stateless	Reflexive NAT	Can be enabled on Tier-0 gateway; generally used when the Tier-0 is in active/active mode.

Table 4-3: NAT Usage Guidelines

Table 4-4: Tier-0 and Tier-1 NAT Use Cases summarizes the use cases and advantages of running NAT on Tier-0 and Tier-1 gateways.

Gateway Type	NAT Rule Type	Specific Usage Guidelines
Tier-0	Stateful	Recommended for TAS/TKGI deployments. E-W routing between different tenants remains completely distributed.
Tier-1	Stateful	Recommended for high throughput ECMP topologies. Recommended for topologies with overlapping IP address space.

Table 4-4: Tier-0 and Tier-1 NAT Use Cases

NAT Service Router Placement
As a centralized service, whenever NAT is enabled, a service component or SR must be instantiated on an Edge cluster. In order to configure NAT, specify the Edge cluster where the service should run; it is also possible the NAT service on a specific Edge node pair. If no specific Edge node is identified, the platform will perform auto placement of the services component on an Edge node in the cluster using a weighted round robin algorithm.

4.9.3 DHCP Services

NSX-T provides both DHCP relay and DHCP server functionality. DHCP relay can be enabled at the gateway level and can act as relay between non-NSX managed environment and DHCP servers. DHCP server functionality can be enabled to service DHCP requests from VMs connected to NSX-managed segments. DHCP server functionality is a stateful service and must be bound to an Edge cluster or a specific pair of Edge nodes as with NAT functionality.

4.9.4 Metadata Proxy Service

With a metadata proxy server, VM instances can retrieve instance-specific metadata from an OpenStack Nova API server. This functionality is specific to OpenStack use-cases only. Metadata proxy service runs as a service on an NSX Edge node. For high availability, configure metadata proxy to run on two or more NSX Edge nodes in an NSX Edge cluster.

4.9.5 Gateway Firewall Service

Gateway Firewall service can be enabled on the Tier-0 and Tier-1 gateway for North-South firewalling. Table 4-5 summarizes Gateway Firewalling usage criteria.

Gateway Firewall	**Specific Usage Guidelines**
Stateful	Can be enabled on both Tier-0 and Tier-1 gateways.
Stateless	Can be enabled on Tier-0 gateway; generally used when the Tier-0 is in active/active mode.

Table 4-5: Gateway Firewall Usage Guideline

Since Gateway Firewalling is a centralized service, it needs to run on an Edge cluster or a set of Edge nodes. This service is described in more detail in the NSX-T Security chapter.

4.9.6 Proxy ARP

Proxy ARP is a method that consist of answering an ARP request on behalf of another host. This method is performed by a layer 3 networking device (usually a router). The purpose is to provide connectivity between 2 hosts when routing wouldn't be possible for various reasons.

Proxy ARP in an NSX-T infrastructure can be considered in environments where IP subnets are limited. Proof of concepts and VMware Enterprise TKGI (PKS) environments are usually using Proxy-ARP to simplify the network topology.

For production environment, it is recommended to implement proper routing between a physical fabric and the NSX-T Tier-0 by using either static routes or Border Gateway Protocol with BFD. If proper routing is used between the Tier-0 gateway and the physical fabric, BFD with its sub-second timers will converge faster. In case of failover with proxy ARP, the convergence relies on gratuitous ARP (broadcast) to update all hosts on the VLAN segment with the new MAC Address to use. If the Tier-0 gateway has proxy ARP enabled for 100 IP addresses, the newly active Tier-0 SR needs to send 100 Gratuitous ARP packets.

Edge Node HA	**Specific Usage Guidelines**
Active / Standby	Supported

Active / Active	Not supported

Table 4-6: Proxy ARP Support

By enabling proxy-ARP, hosts on the overlay segments and hosts on a VLAN segment can exchange network traffic together without implementing any change in the physical networking fabric. Proxy ARP is automatically enabled when a NAT rule or a load balancer VIP uses an IP address from the subnet of the Tier-0 gateway uplink.

Figure 4-50: Proxy ARP Topology presents the logical packet flow between a virtual machine connected to an NSX-T overlay segment and a virtual machine or physical appliance connected to a VLAN segment shared with the NSX-T Tier-0 uplinks.

In this example, the virtual machine connected to the overlay segment initiates networking traffic toward 20.20.20.100.

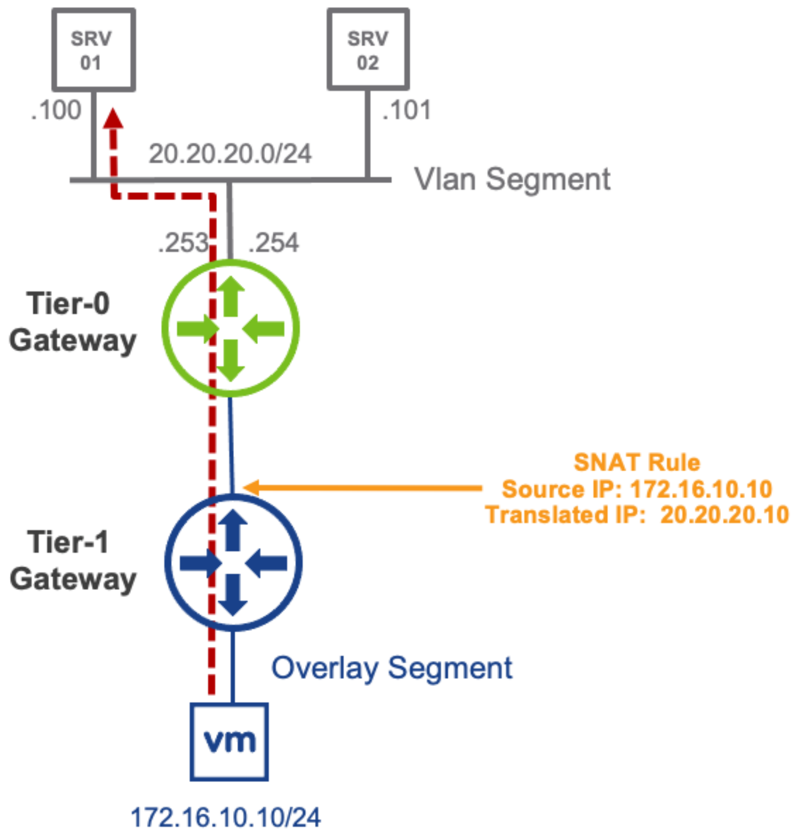


Figure 4-50: Proxy ARP Topology

1. The virtual machine connected to the overlay segment with an IP address of 172.16.10.10 sends a packet to the physical appliance "SRV01" with an IP address of 20.20.20.100. the local DR hosted on the local hypervisor performs a routing lookup and sends the traffic to the SR.

2. The SR hosted on an edge node translates the source IP of 172.16.10.10 with a value of 20.20.20.10 and sends the traffic to the Tier-0.
3. Tier-0 SR has proxy ARP enabled on its uplink interface and will send an ARP request (broadcast) on the vlan segment to map the IP address of 20.20.20.100 with the correct MAC address.
4. The physical appliance "SRV01" answers to that ARP request with an ARP reply.
5. Tier-0 SR sends the packet to the physical appliance with a source IP of 20.20.20.10 and a destination IP of 20.20.20.100.
6. The physical appliance "SRV01" receives the packet and sends an ARP broadcast on the VLAN segment to map the IP address of the virtual machine (20.20.20.10) to the corresponding MAC address.
7. Tier-0 receives the ARP request for 20.20.20.10 (broadcast) and has the proxy ARP feature enabled on its uplink interfaces. It replies to the ARP request with an ARP reply that contains the Tier-0 SR MAC address for the interface uplink.
8. The physical appliance "SRV01" receives the ARP request and sends a packet on the vlan segment with a source IP of 20.20.20.100 and a destination IP of 20.20.20.10.
9. The packet is being received by the Tier-0 SR and is being routed to the Tier-1 who does translate the Destination IP of 20.20.20.10 with a value of 172.16.10.10. Packet is sent to the overlay segment and the virtual machine receives it.

It is crucial to note that in this case, the traffic is initiated by the virtual machine which is connected to the overlay segment on the Tier-1. If the initial traffic was initiated by a server on the VLAN segment, a Destination NAT rule would have been required on the Tier-1/Tier-0 since the initial traffic would not match the SNAT rule that has been configured previously.

Figure 4-51: Edge Node Failover and Proxy ARP represents an outage on an active Tier-0 gateway with Proxy ARP enabled. The newly active Tier-0 gateway will send a gratuitous ARP to announce the new MAC address to be used by the hosts on the VLAN segment in order to reach the virtual machine connected to the overlay. It is critical to fathom that the newly active Tier-0 will send a Gratuitous ARP for each IP address that are configured for Proxy ARP.

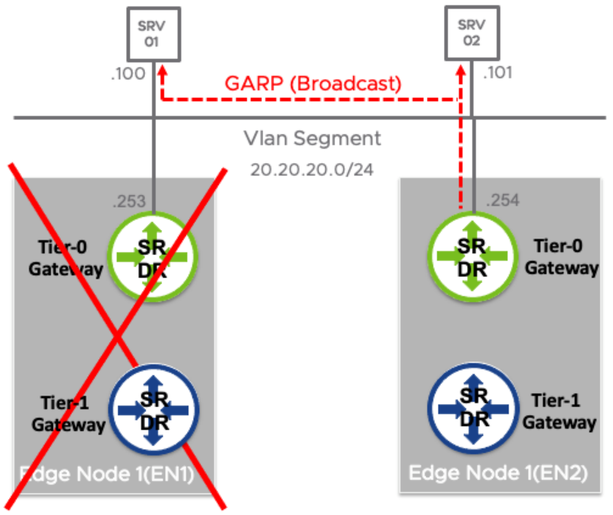


Figure 4-51: Edge Node Failover and Proxy ARP

4.10 Topology Consideration

This section covers a few of the many topologies that customers can build with NSX-T. NSX-T routing components - Tier-1 and Tier-0 gateways - enable flexible deployment of multi-tiered routing topologies. Topology design also depends on what services are enabled and where those services are provided at the provider or tenant level.

4.10.1 Supported Topologies

Figure 4-52: Single Tier and Multi-tier Routing Topologies shows three topologies with Tier-0 gateway providing N-S traffic connectivity via multiple Edge nodes. The first topology is single-tiered where Tier-0 gateway connects directly to the segments and provides E-W routing between subnets. Tier-0 gateway provides multiple active paths for N-S L3 forwarding using ECMP. The second topology shows the multi-tiered approach where Tier-0 gateway provides multiple active paths for L3 forwarding using ECMP and Tier-1 gateways as first hops for the segments connected to them. Routing is fully distributed in this multi-tier topology. The third topology shows a multi-tiered topology with Tier-0 gateway configured in Active/Standby HA mode to provide some centralized or stateful services like NAT, VPN etc.

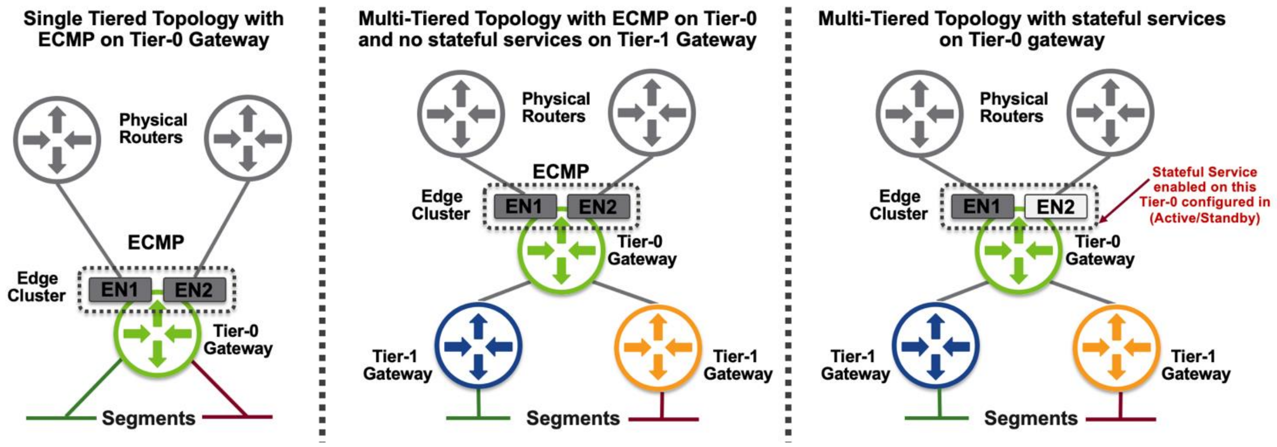

Single Tiered Topology with ECMP on Tier-0 Gateway
Physical Routers
ECMP
Edge Cluster
EN1
EN2
Tier-0 Gateway
Segments
Multi-Tiered Topology with ECMP on Tier-0 and no stateful services on Tier-1 Gateway
Physical Routers
ECMP
Edge Cluster
EN1
EN2
Tier-0 Gateway
Tier-1 Gateway
Tier-1 Gateway
Segments
Multi-Tiered Topology with stateful services on Tier-0 gateway
Physical Routers
Edge Cluster
EN1
EN2
Stateful Service enabled on this Tier-0 configured in (Active/Standby)
Tier-0 Gateway
Tier-1 Gateway
Tier-1 Gateway
Segments

Figure 4-52: Single Tier and Multi-tier Routing Topologies

As discussed in the two-tier routing section, centralized services can be enabled on Tier-1 or Tier-0 gateway level. *Figure 4-52: Single Tier and Multi-tier Routing Topologies* shows two multi-tiered topologies. The first topology shows centralized services like NAT, load balancer on Tier-1 gateways while Tier-0 gateway provides multiple active paths for L3 forwarding using ECMP. The second topology shows centralized services configured on a Tier-1 and Tier-0 gateway. In NSX-T 2.4 release or earlier, some centralized services are only available on Tier-1 like load balancer and other only on Tier-0 like VPN. Starting NSX-T 2.5 release, below topology can be used where requirement is to use both Load balancer and VPN service on NSX-T. Note that VPN is available on Tier-1 gateways starting NSX-T 2.5 release.

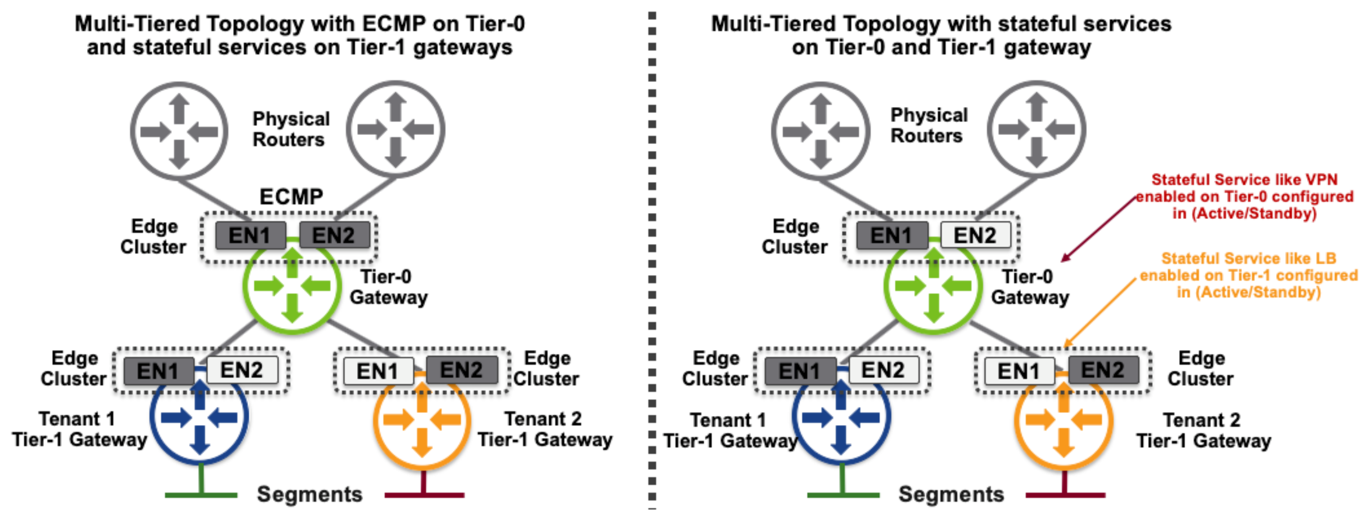

Multi-Tiered Topology with ECMP on Tier-0 and stateful services on Tier-1 gateways
Physical Routers
ECMP
Edge Cluster
EN1
EN2
Tier-0 Gateway
Edge Cluster
Tenant 1 Tier-1 Gateway
Tenant 2 Tier-1 Gateway
Segments
Multi-Tiered Topology with stateful services on Tier-0 and Tier-1 gateway
Stateful Service like VPN enabled on Tier-0 configured in (Active/Standby)
Stateful Service like LB enabled on Tier-1 configured in (Active/Standby)

Figure 4-53: Stateful and Stateless (ECMP) Services Topologies Choices at Each Tier

Figure 4-54: Multiple Tier-0 Topologies with Stateful and Stateless (ECMP) Services shows a topology with Tier-0 gateways connected back to back. “Tenant-1 Tier-0 Gateway” is configured for a stateful firewall while “Tenant-2 Tier-0 Gateway” has stateful NAT configured. Since stateful services are configured on both “Tenant-1 Tier-0 Gateway” and “Tenant-2 Tier-0 Gateway”, they are configured in Active/Standby high availability mode. The top layer of Tier-0 gateway, "Aggregate Tier-0 Gateway” provides ECMP for North-South traffic. Note that only external interfaces should be used to connect a Tier-0 gateway to another Tier-0 gateway. Static routing and BGP are supported to exchange routes between two Tier-0 gateways and full mesh connectivity is recommended for optimal traffic forwarding. This topology provides high N-S throughput with centralized stateful services running on different Tier-0 gateways. This topology also provides complete separation of routing tables on the tenant Tier-0 gateway level and allows services that are only available on Tier-0 gateways (like VPN until NSX-T 2.4 release) to leverage ECMP northbound. Note that VPN is available on Tier-1 gateways starting NSX-T 2.5 release. NSX-T 3.0 introduces new multi tenancy features such as EVPN and VRF-lite. These features are recommended and suitable for true multi-tenant architecture where stateful services need to be run on multiple layers or Tier-0

Full mesh connectivity is recommended for optimal traffic forwarding.

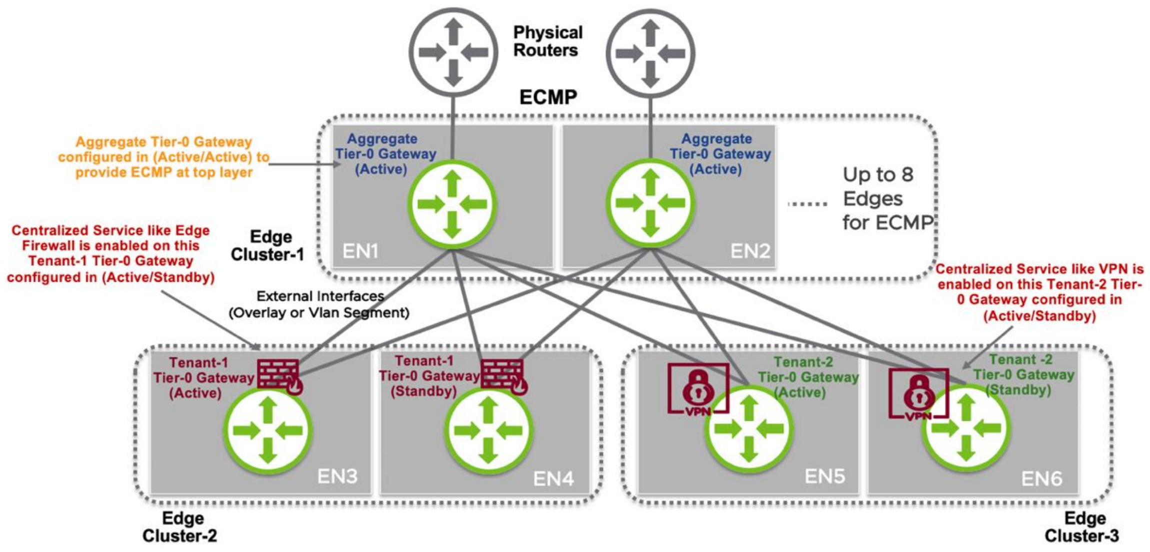

Physical Routers
ECMP
Aggregate Tier-0 Gateway configured in (Active/Active) to provide ECMP at top layer
Aggregate Tier-0 Gateway (Active)
Aggregate Tier-0 Gateway (Active)
Up to 8 Edges for ECMP
EN1
EN2
Edge Cluster-1
Centralized Service like Edge Firewall is enabled on this Tenant-1 Tier-0 Gateway configured in (Active/Standby)
External Interfaces (Overlay or Vlan Segment)
Centralized Service like VPN is enabled on this Tenant-2 Tier-0 Gateway configured in (Active/Standby)
Tenant-1 Tier-0 Gateway (Active)
Tenant-1 Tier-0 Gateway (Standby)
Tenant-2 Tier-0 Gateway (Active)
Tenant -2 Tier-0 Gateway (Standby)
VPN
VPN
EN3
EN4
EN5
EN6
Edge Cluster-2
Edge Cluster-3

Figure 4-54: Multiple Tier-0 Topologies with Stateful and Stateless (ECMP) Services

Figure 4-55: Multiple Tier-0 Topologies with Stateful and Stateless (ECMP) Services shows another topology with Tier-0 gateways connected back to back. “Corporate Tier-0 Gateway” on Edge cluster-1 provides connectivity to the corporate resources (172.16.0.0/16 subnet) learned via a pair of physical routers on the left. This Tier-0 has stateful Gateway Firewall enabled to allow access to restricted users only.

“WAN Tier-0 Gateway” on Edge-Cluster-2 provides WAN connectivity via WAN routers and is also configured for stateful NAT.

“Aggregate Tier-0 gateway” on the Edge cluster-3 learns specific routes for corporate subnet (172.16.0.0/16) from “Corporate Tier-0 Gateway” and a default route from “WAN Tier-0 Gateway”. “Aggregate Tier-0 Gateway” provides ECMP for both corporate and WAN traffic originating from any segments connected to it or connected to a Tier-1 southbound. Full mesh connectivity is recommended for optimal traffic forwarding.

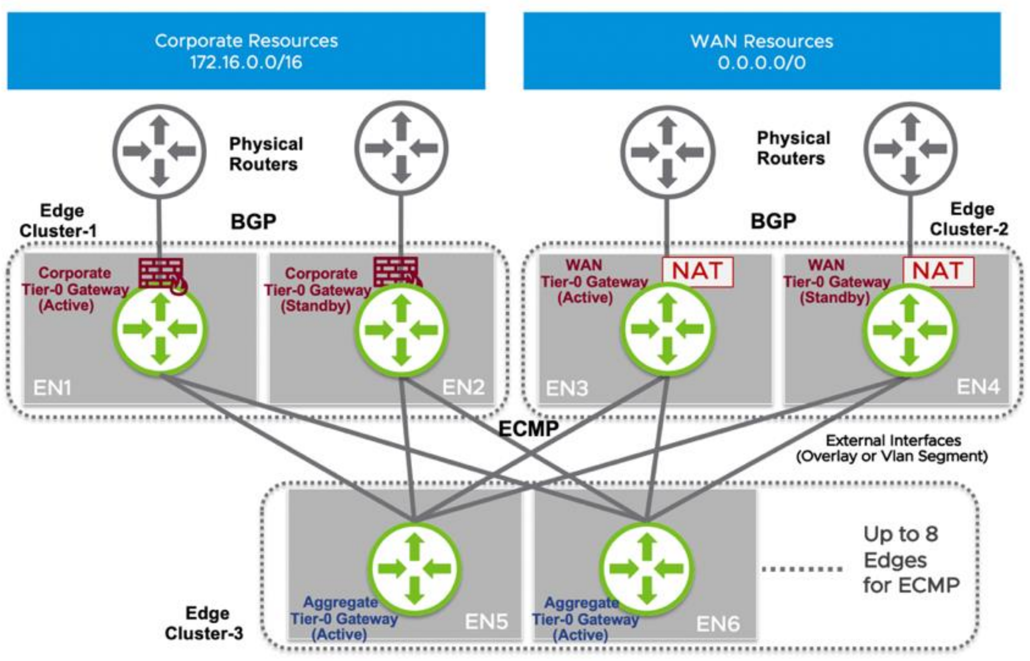

Corporate Resources
172.16.0.0/16
WAN Resources
0.0.0.0/0
Physical Routers
Physical Routers
Edge Cluster-1
BGP
BGP
Edge Cluster-2
Corporate Tier-0 Gateway (Active)
Corporate Tier-0 Gateway (Standby)
WAN Tier-0 Gateway (Active)
NAT
WAN Tier-0 Gateway (Standby)
NAT
EN1
EN2
EN3
EN4
ECMP
External Interfaces (Overlay or Vlan Segment)
Up to 8 Edges for ECMP
Edge Cluster-3
Aggregate Tier-0 Gateway (Active)
EN5
Aggregate Tier-0 Gateway (Active)
EN6

Figure 4-55: Multiple Tier-0 Topologies with Stateful and Stateless (ECMP) Services

4.10.2 Unsupported Topologies

While the deployment of logical routing components enables customers to deploy flexible multi-tiered routing topologies, *Figure 4-56: Unsupported Topologies* presents topologies that are not supported. The topology on the left shows that a tenant Tier-1 gateway cannot be connected directly to another tenant Tier-1 gateway. If the tenants need to communicate, route exchanges between two tenants Tier-1 gateway must be facilitated by the Tier-0 gateway. The rightmost topology highlights that a Tier-1 gateway cannot be connected to two different upstream Tier-0 gateways.

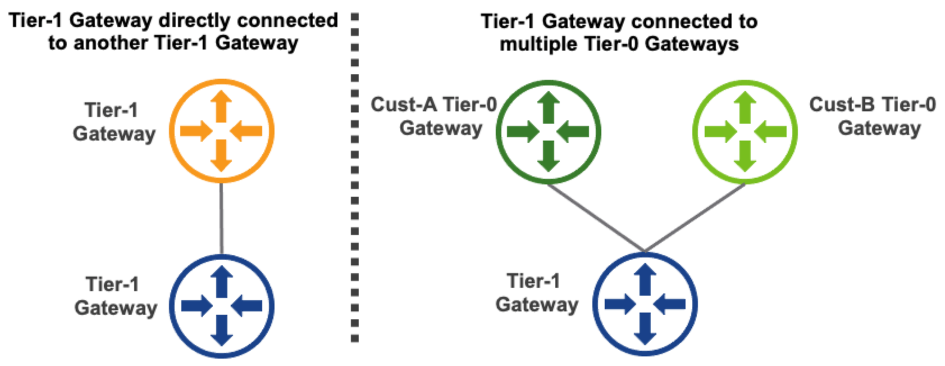

Tier-1 Gateway directly connected to another Tier-1 Gateway
Tier-1 Gateway
Tier-1 Gateway
Tier-1 Gateway connected to multiple Tier-0 Gateways
Cust-A Tier-0 Gateway
Cust-B Tier-0 Gateway
Tier-1 Gateway

Figure 4-56: Unsupported Topologies

5 NSX-T Security

In addition to providing network virtualization, NSX-T also serves as an advanced security platform, providing a rich set of features to streamline the deployment of security solutions. This chapter focuses on NSX-T security capabilities, architecture, components, and implementation. Key concepts for examination include:

- NSX-T distributed firewall (DFW) provides stateful protection of the workload at the vNIC level. For ESXi, the DFW enforcement occurs in the hypervisor kernel, helping deliver micro-segmentation. However, the DFW extends to physical servers, KVM hypervisors, containers, and public clouds providing distributed policy enforcement.
- Uniform security policy model for on-premises and cloud deployment, supporting multi-hypervisor (i.e., ESXi and KVM) and multi-workload, with a level of granularity down to VM/containers/bare metal attributes.
- Agnostic to compute domain - supporting hypervisors managed by different compute-managers while allowing any defined micro-segmentation policy to be applied across hypervisors spanning multiple vCenter environments.
- Support for Layer 3, Layer 4, Layer-7 APP-ID, & Identity based firewall policies provide security via protocol, port, and or deeper packet/session intelligence to suit diverse needs.
- NSX-T Gateway firewall serves as a centralized stateful firewall service for N-S traffic. Gateway firewall is implemented per gateway and supported at both Tier-0 and Tier-1. Gateway firewall is independent of NSX-T DFW from policy configuration and enforcement perspective, providing a means for defining perimeter security control in addition to distributed security control.
- Gateway & Distributed Firewall Service insertion capability to integrate existing security investments using integration with partner ecosystem products on a granular basis without the need for interrupting natural traffic flows.
- Distributed IDS extends IDS capabilities to every host in the environment.
- Dynamic grouping of objects into logical constructs called Groups based on various criteria including tag, virtual machine name or operating system, subnet, and segments which automates policy application.
- The scope of policy enforcement can be selective, with application or workload-level granularity.
- Firewall Flood Protection capability to protect the workload & hypervisor resources.
- IP discovery mechanism dynamically identifies workload addressing.
- SpoofGuard blocks IP spoofing at vNIC level.
- Switch Security provides storm control and security against unauthorized traffic.

5.1 NSX-T Security Use Cases

The NSX-T security platform is designed to address the security challenges faced by IT admins. Although it started with firewalling, the NSX-T security feature set has since grown to encompass Identity Firewalling, IPS, and many more. The NSX-T firewall is delivered as part of a distributed platform that offers ubiquitous enforcement, scalability, line rate performance, multi-hypervisor support, and API-driven orchestration. These fundamental pillars of the NSX-T firewall allow it to address many different use cases for production deployment.

One of the leading use cases NSX-T supports is micro-segmentation. Micro-segmentation enables an organization to logically divide its data center into distinct security segments down to the individual workload level, then define distinct security controls for and deliver services to each unique segment. This is all possible without the need to change underlying network architecture or addressing. A central benefit of micro-segmentation is its ability to deny attackers the opportunity to pivot laterally within the internal network, even after the perimeter has been breached.

VMware NSX-T supports micro-segmentation as it allows for a centrally controlled, operationally distributed firewall to be attached directly to workloads within an organization's network. The distribution of the firewall for the application of security policy to protect individual workloads is highly efficient; rules can be applied that are specific to the requirements of each workload. Of additional value is that NSX's capabilities are not limited to homogeneous vSphere environments. NSX supports the heterogeneity of platforms and infrastructure that is common in organizations today.

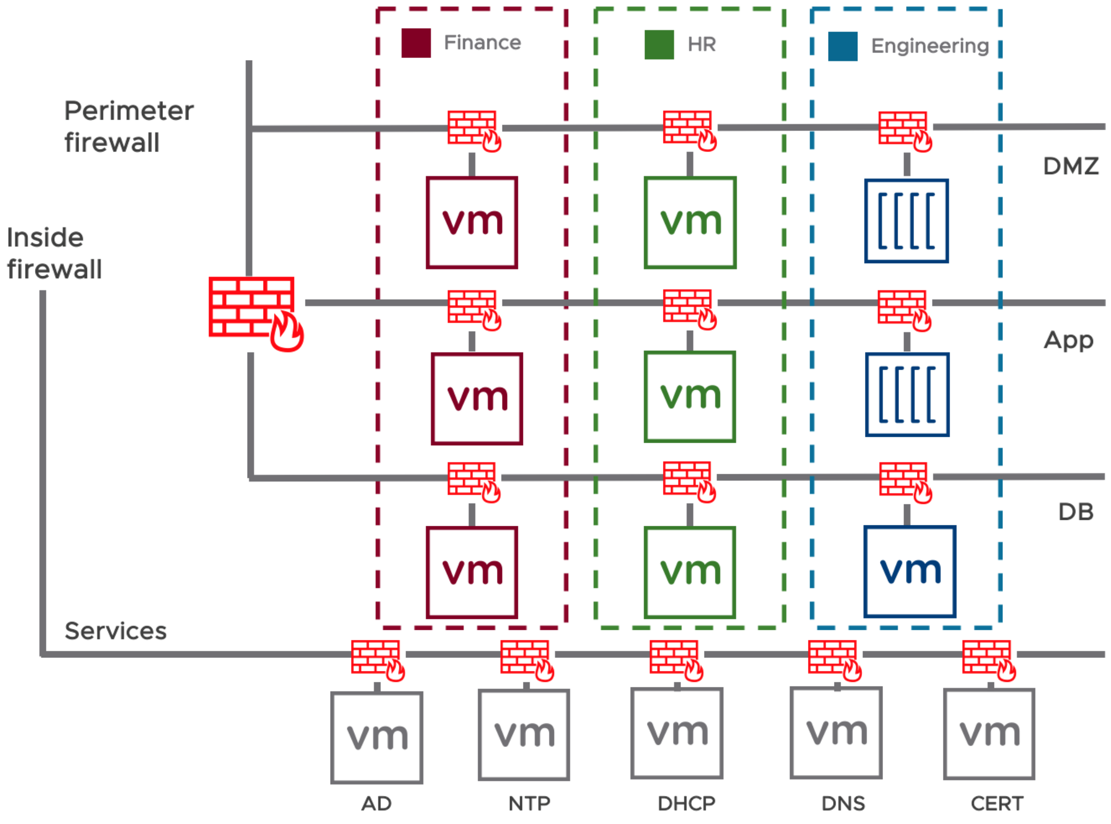


Figure 5-1: Example of Micro-segmentation with NSX

Micro-segmentation provided by NSX-T is an essential element of zero trust, specifically it embodies "making the *access control enforcement as granular as possible*." (NIST ZTA publication). It establishes a security perimeter around each VM or container workload with a dynamically defined policy which can be down to the user level of granularity. Legacy security models assume that everything on the inside of an organization's network can be trusted; zero-trust assumes the opposite - trust nothing and verify everything. This addresses the increased sophistication of networks attacks and insider threats that frequently exploit the conventional perimeter-controlled approach. For each system in an organization's network, trust of the underlying network is removed. A perimeter is defined per system within the network to limit the possibility of lateral (i.e., East-West) movement of an attacker.

Implementation of a zero-trust architecture with traditional network security solutions can be costly, complex, and come with a high management burden. Moreover, the lack of visibility for organization's internal networks can slow down implementation of a zero-trust architecture and leave gaps that may only be discovered after they have been exploited. Additionally, conventional internal perimeters may have granularity only down to a VLAN or subnet – as is common with many traditional DMZs – rather than down to the individual system.

5.2 NSX-T DFW Architecture and Components

The NSX-T DFW architecture management plane, control plane, and data plane work together to enable a centralized policy configuration model with distributed firewalling. This section will examine the role of each plane and its associated components, detailing how they interact with each other to provide a scalable, topology agnostic distributed firewall solution.

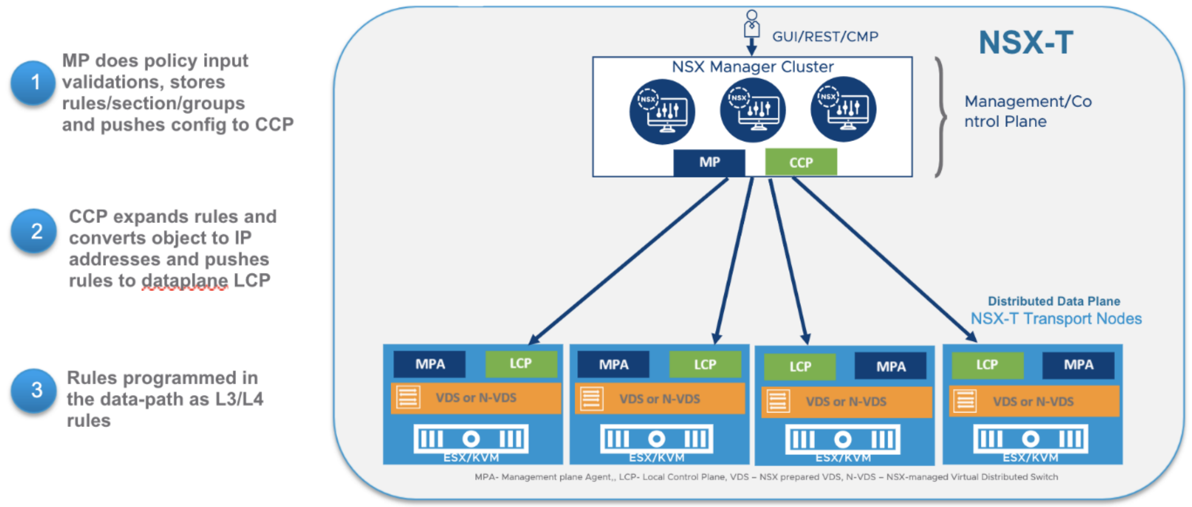

1
MP does policy input validations, stores rules/section/groups and pushes config to CCP
2
CCP expands rules and converts object to IP addresses and pushes rules to dataplane LCP
3
Rules programmed in the data-path as L3/L4 rules
GUI/REST/CMP
NSX-T
NSX Manager Cluster
Management/Control Plane
MP
CCP
Distributed Data Plane
NSX-T Transport Nodes
MPA
LCP
VDS or N-VDS
ESX/KVM
MPA- Management plane Agent,, LCP- Local Control Plane, VDS – NSX prepared VDS, N-VDS – NSX-managed Virtual Distributed Switch

Figure 5-2: NSX-T DFW Architecture and Components

5.2.1 Management Plane

The NSX-T management plane is implemented through NSX-T Managers. NSX-T Managers are deployed as a cluster of 3 manager nodes. Access to the NSX-T Manager is available through a GUI or REST API framework. When a firewall policy rule is configured, the NSX-T management plane service validates the configuration and locally stores a persistent copy. Then the NSX-T Manager pushes user-published policies to the control plane service within Manager Cluster which in turn pushes to the data plane. A typical DFW policy configuration consists of one or more sections with a set of rules using objects like Groups, Segments, and application level gateway (ALGs). For monitoring and troubleshooting, the NSX-T Manager interacts with a host-based management plane agent (MPA) to retrieve DFW status along with rule and flow statistics. The NSX-T Manager also collects an inventory of all hosted virtualized workloads on NSX-T transport nodes. This is dynamically collected and updated from all NSX-T transport nodes.

5.2.2 Control Plane

The NSX-T control plane consists of two components - the central control plane (CCP) and the Local Control Plane (LCP). The CCP is implemented on NSX-T Manager Cluster, while the LCP includes the user space module on all of the NSX-T transport nodes. This module interacts with the CCP to exchange configuration and state information.

From a DFW policy configuration perspective, NSX-T Control plane will receive policy rules pushed by the NSX-T Management plane. If the policy contains objects including segments or Groups, it converts them into IP addresses using an object-to-IP mapping table. This table is maintained by the control plane and updated using an IP discovery mechanism. Once the policy is converted into a set of rules based on IP addresses, the CCP pushes the rules to the LCP on all the NSX-T transport nodes.

The CCP utilizes a hierarchy system to distribute the load of CCP-to-LCP communication. The responsibility for transport node notification is distributed across the managers in the manager clusters based on an internal hashing mechanism. For example, for 30 transport nodes with three managers, each manager will be responsible for roughly ten transport nodes.

5.2.3 Data Plane

The NSX-T transport nodes comprise the distributed data plane with DFW enforcement done at the hypervisor kernel level. Each of the transport nodes, at any given time, connects to only one of the CCP managers, based on mastership for that node. On each of the transport nodes, once the local control plane (LCP) has received policy configuration from CCP, it pushes the firewall policy and rules to the data plane filters (in kernel) for each of the virtual NICs. With the "Applied To" field in the rule or section which defines scope of enforcement, the LCP makes sure only relevant DFW rules are programmed on relevant virtual NICs instead of every rule everywhere, which would be a suboptimal use of hypervisor resources. Additional details on data plane components for both ESXi and KVM hosts explained in following sections.

5.3 NSX-T Data Plane Implementation - ESXi vs. KVM Hosts

NSX-T provides network virtualization and security services in a heterogeneous hypervisor environment, managing ESXi and KVM hosts as part of the same NSX-T cluster. The DFW is functionally identical in both environments; however, there are architectural and implementation differences depending on the hypervisor specifics.

Management and control plane components are identical for both ESXi and KVM hosts. For the data plane, they use a different implementation for packet handling. NSX-T uses either the VDS in ESXi 7.0 and later or the N-VDS (which is derived from the VDS) on earlier ESXi hosts, along with the VMware Internetworking Service Insertion Platform (vSIP) kernel module for firewalling. (For details on the differences between the N-VDS and the VDS, see NSX-T Logical

Switching. For KVM, the N-VDS leverages Open vSwitch (OVS) and its utilities. The following sections highlight data plane implementation details and differences between these two options.

5.3.1 ESXi Hosts- Data Plane Components

NSX-T uses VDS or N-VDS on ESXi hosts for connecting virtual workloads, managing it with the NSX-T Manager application. The NSX-T DFW kernel space implementation for ESXi is same as the implementation of NSX for vSphere – it uses the VMware Internetworking Service Insertion Platform (vSIP) kernel module and kernel IO chains filters. NSX-T does not require vCenter to be present. *Figure 5-3: NSX-T Management Plane Components on KVM* provides details on the data plane components for the ESX host.

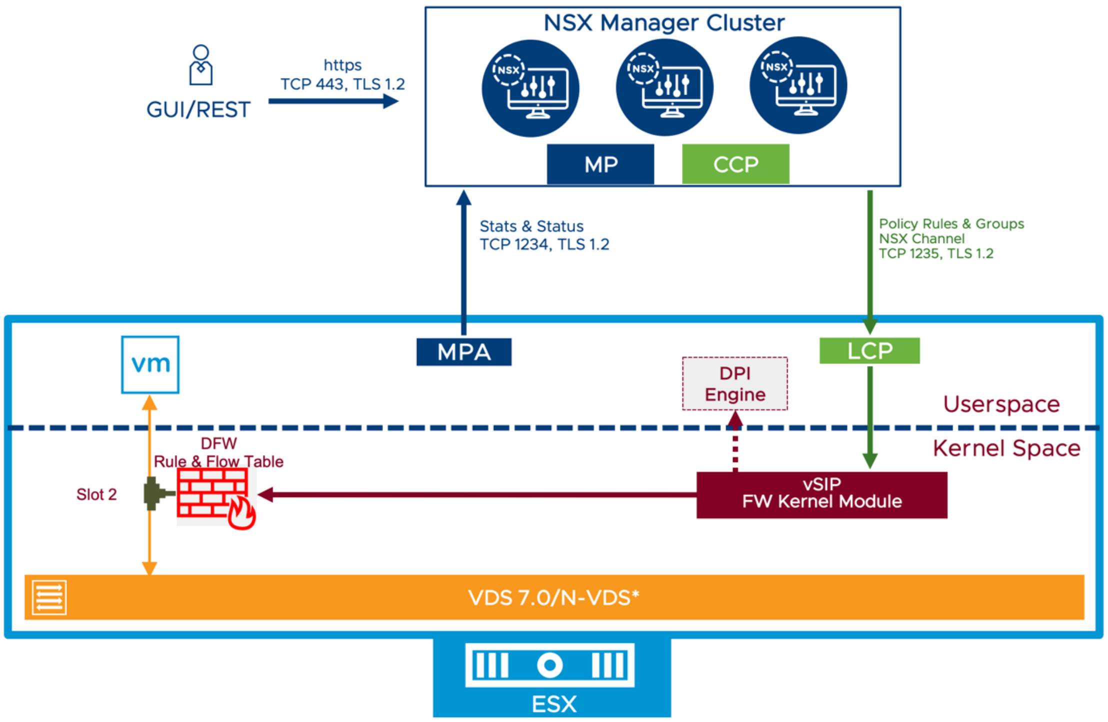


Figure 5-3: NSX-T Management Plane Components on KVM

NSX-T uses OVS and its utilities on KVM to provide DFW functionality, thus the LCP agent implementation differs from an ESXi host. For KVM, there is an additional component called the NSX agent in addition to LCP, with both running as user space agents. When LCP receives DFW policy from the CCP, it sends it to the NSX-agent. The NSX-agent will process and convert policy messages received to a format appropriate for the OVS data path. Then, the NSX agent programs the policy rules onto the OVS data path using OpenFlow messages. For stateful DFW rules, NSX-T uses the Linux conntrack utilities to keep track of the state of permitted flow connections allowed by a stateful firewall rule. For DFW policy rule logging, NSX-T uses the ovs-fwd module.

The MPA interacts with NSX-T Manager to export status, rules, and flow statistics. The MPA module gets the rules and flows statistics from data path tables using the stats exporter module.

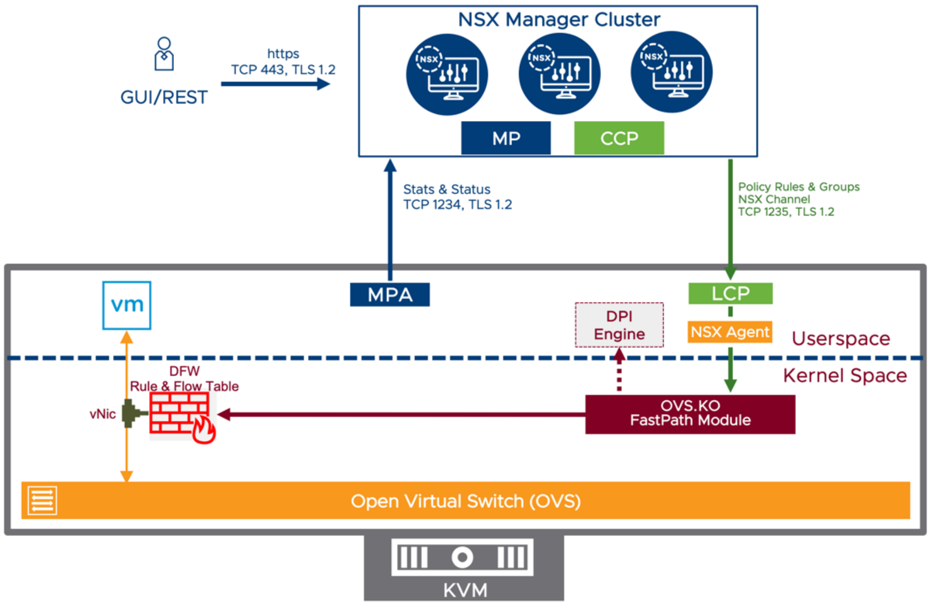


Figure 5-4: NSX-T DFW Data Plane Components on KVM

5.3.2 NSX-T DFW Policy Lookup and Packet Flow

In the data path, the DFW maintains two tables: a rule table and a connection tracker table. The LCP populates the rule table with the configured policy rules, while the connection tracker table is updated dynamically to cache flows permitted by rule table. NSX-T DFW can allow for a policy to be stateful or stateless with section-level granularity in the DFW rule table. The connection tracker table is populated only for stateful policy rules; it contains no information on stateless policies. This applies to both ESXi and KVM environments.

NSX-T DFW rules are enforced as follows:

- Rules are processed in top-to-bottom order.
- Each packet is checked against the top rule in the rule table before moving down the subsequent rules in the table.
- The first rule in the table that matches the traffic parameters is enforced. The search is then terminated, so no subsequent rules will be examined or enforced.

Because of this behavior, it is always recommended to put the most granular policies at the top of the rule table. This will ensure more specific policies are enforced first. The DFW default policy rule, located at the bottom of the rule table, is a catchall rule; packets not matching any other rule will be enforced by the default rule - which is set to “allow” by default. This ensures that VM-to-VM communication is not broken during staging or migration phases. It is a best practice to then change this default rule to a “drop” action and enforce access control through an explicit allow model (i.e., only traffic defined in the firewall policy is allowed onto the network). *Figure 5-5: NSX-T DFW Policy Lookup* diagrams the policy rule lookup and packet flow.

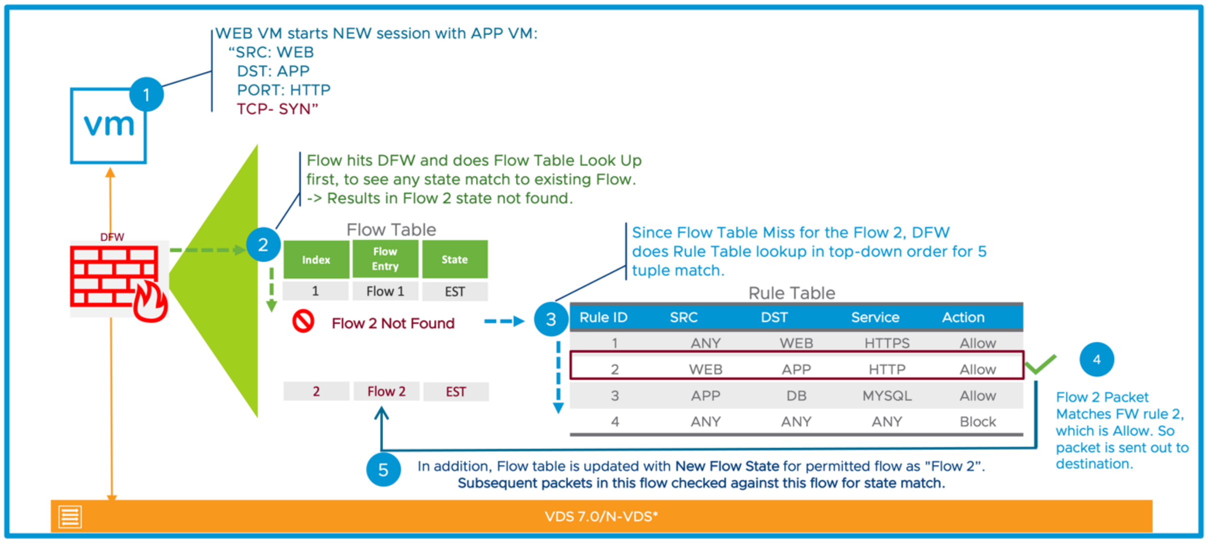

WEB VM starts NEW session with APP VM:
"SRC: WEB
DST: APP
PORT: HTTP
TCP- SYN"
vm
DFW
Flow hits DFW and does Flow Table Look Up first, to see any state match to existing Flow.
-> Results in Flow 2 state not found.
Flow Table
Index
Flow Entry
State
Flow 1
EST
Flow 2 Not Found
Flow 2
Since Flow Table Miss for the Flow 2, DFW does Rule Table lookup in top-down order for 5 tuple match.
Rule Table
Rule ID
SRC
DST
Service
Action
ANY
WEB
HTTPS
Allow
APP
HTTP
DB
MYSQL
HTTP
Block
Flow 2 Packet Matches FW rule 2, which is Allow. So packet is sent out to destination.
In addition, Flow table is updated with New Flow State for permitted flow as "Flow 2".
Subsequent packets in this flow checked against this flow for state match.
VDS 7.0/N-VDS*

Figure 5-5: NSX-T DFW Policy Lookup

In the example shown above,

1. WEB VM initiates a session to APP VM by sending TCP SYN packet.
2. The TCP SYN packets hit the DFW on vNIC and does a Flow Table lookup first, to see if any state matches the existing Flow. Given it's the first packet of the new session, lookup results in “Flow state not found”.
3. Since the Flow Table missed, the DFW does a Rule Table lookup in top-down order for 5-Tuple match.
4. Flow Matches FW rule 2, which is Allow so the packet is sent out to the destination.
5. In addition, the Flow table is updated with New Flow State for permitted flow as "Flow 2”.

Subsequent packets in this TCP session checked against this flow in the flow table for the state match. Once the session terminates, the flow information is removed from the flow table.

5.4 NSX-T Security Policy - Plan, Design and Implement

Planning, designing, and implementing NSX-T security policy is a three-step process:
1. Policy Methodology – Decide on the policy approach - application-centric, infrastructure-centric, or network-centric
2. Policy Rule Model – Select grouping and management strategy for policy rules by the NSX-T DFW policy categories and sections.
3. Policy Consumption – Implement the policy rules using the abstraction through grouping constructs and options provided by NSX-T.

5.4.1 Security Policy Methodology

This section details the considerations behind policy creation strategies to help determine which capabilities of the NSX-T platform should be utilized as well as how various grouping methodologies and policy strategies can be adopted for a specific design.

The three general methodologies reviewed in *Figure 5-6: Micro-segmentation Methodologies* can be utilized for grouping application workloads and building security rule sets within the NSX-T DFW. This section will look at each methodology and highlight appropriate usage.

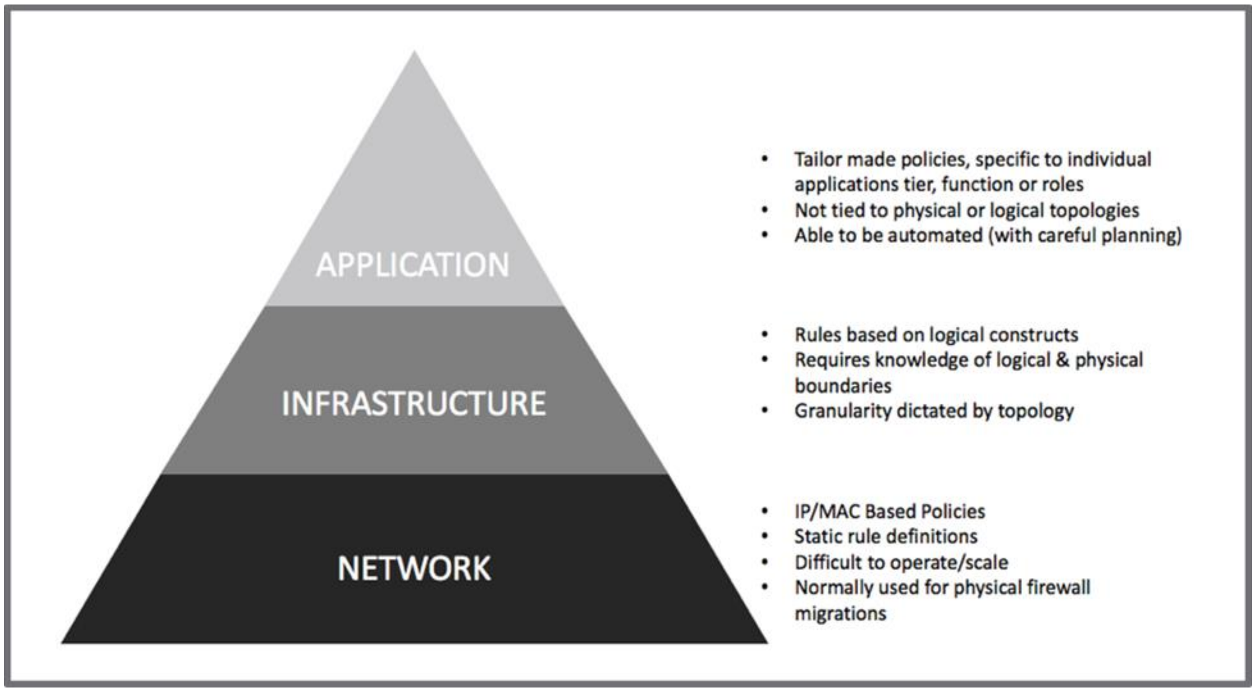

APPLICATION
INFRASTRUCTURE
NETWORK
Tailor made policies, specific to individual applications tier, function or roles
Not tied to physical or logical topologies
Able to be automated (with careful planning)
Rules based on logical constructs
Requires knowledge of logical & physical boundaries
Granularity dictated by topology
IP/MAC Based Policies
Static rule definitions
Difficult to operate/scale
Normally used for physical firewall migrations

Figure 5-6: Micro-segmentation Methodologies

5.4.1.1 Ethernet

The Ethernet Section of the policy is a Layer 2 firewalling section. All rules in this section must use MAC Addresses for their source or destination objects. Any rule defined with any other object type will be ignored.

5.4.1.2 Application

In an application-centric approach, grouping is based on the application type (e.g., VMs tagged as “Web-Servers”), application environment (e.g., all resources tagged as “Production-Zone”) and application security posture. An advantage of this approach is the security posture of the application is not tied to network constructs or infrastructure. Security policies can move with the application irrespective of network or infrastructure boundaries, allowing security teams to focus on the policy rather than the architecture. Policies can be templated and reused across instances of the same types of applications and workloads while following the application lifecycle; they will be applied when the application is deployed and is destroyed when the application is decommissioned. An application-based policy approach will significantly aid in moving towards a self-service IT model. In an environment where there is strong adherence to a strict naming convention, the VM substring grouping option allows for simple policy definition.

An application-centric model does not provide significant benefits in an environment that is static, lacks mobility, and has infrastructure functions that are properly demarcated.

5.4.1.3 Infrastructure

Infrastructure-centric grouping is based on infrastructure components such as segments or segment ports, identifying where application VMs are connected. Security teams must work closely with the network administrators to understand logical and physical boundaries.

If there are no physical or logical boundaries in the environment, then an infrastructure-centric approach is not suitable.

5.4.1.4 Network

Network-centric is the traditional approach of grouping based on L2 or L3 elements. Grouping can be done based on MAC addresses, IP addresses, or a combination of both. NSX-T supports this approach of grouping objects. A security team needs to aware of networking infrastructure to deploy network-based policies. There is a high probability of security rule sprawl as grouping based on dynamic attributes is not used. This method of grouping works well for migrating existing rules from an existing firewall.

A network-centric approach is not recommended in dynamic environments where there is a rapid rate of infrastructure change or VM addition/deletion.

5.4.2 Security Rule Model

Policy rule models in a data center are essential to achieve optimal micro-segmentation strategies. The first criteria in developing a policy model is to align with the natural boundaries in the data center, such as tiers of application, SLAs, isolation requirements, and zonal access restrictions. Associating a top-level zone or boundary to a policy helps apply consistent, yet flexible control.

Global changes for a zone can be applied via single policy; however, within the zone there could be a secondary policy with sub-grouping mapping to a specific sub-zone. An example production zone might itself be carved into sub-zones like PCI or HIPAA. There are also zones for each department as well as shared services. Zoning creates relationships between various groups, providing basic segmentation and policy strategies.

A second criterion in developing policy models is identifying reactions to security events and workflows. If a vulnerability is discovered, what are the mitigation strategies? Where is the source of the exposure – internal or external? Is the exposure limited to a specific application or operating system version?

When east-west security is first implemented in a brownfield environment, there are two common approaches, depending on corporate culture: either an incremental zonal approach where one application is secured before moving to the next, or a top-down iterative approach where first prod and non-prod are divided then each of those areas are further subdivided. Regardless of the chosen approach, there will likely be a variety of security postures taken within each zone. A lab zone, for example may merely be ring-fenced with a policy that allows any traffic type from lab device to lab device and only allows basic common services such as LDAP, NTP, and DNS to penetrate the perimeter in. On the other end of the spectrum, any zone containing regulated or sensitive data (such as customer info) will often be tightly defined traffic between entities, many types being further inspected by partner L7 firewall offerings using Service Insertion.

The answers to these questions help shape a policy rule model. Policy models should be flexible enough to address ever-changing deployment scenarios, rather than simply be part of the initial setup. Concepts such as intelligent grouping, tags and hierarchy provide flexible yet agile response capability for steady state protection as well as during instantaneous threat response. The model shown in *Figure 5-7: Security Rule Model* represents an overview of the different classifications of security rules that can be placed into the NSX-T DFW rule table. Each of the classification shown represents a category on NSX-T firewall table layout. The Firewall table category aligns with the best practice around organizing rules to help admin with grouping Policy based on the category. Each firewall category can have one or more policy within it to organize firewall rules under that category.

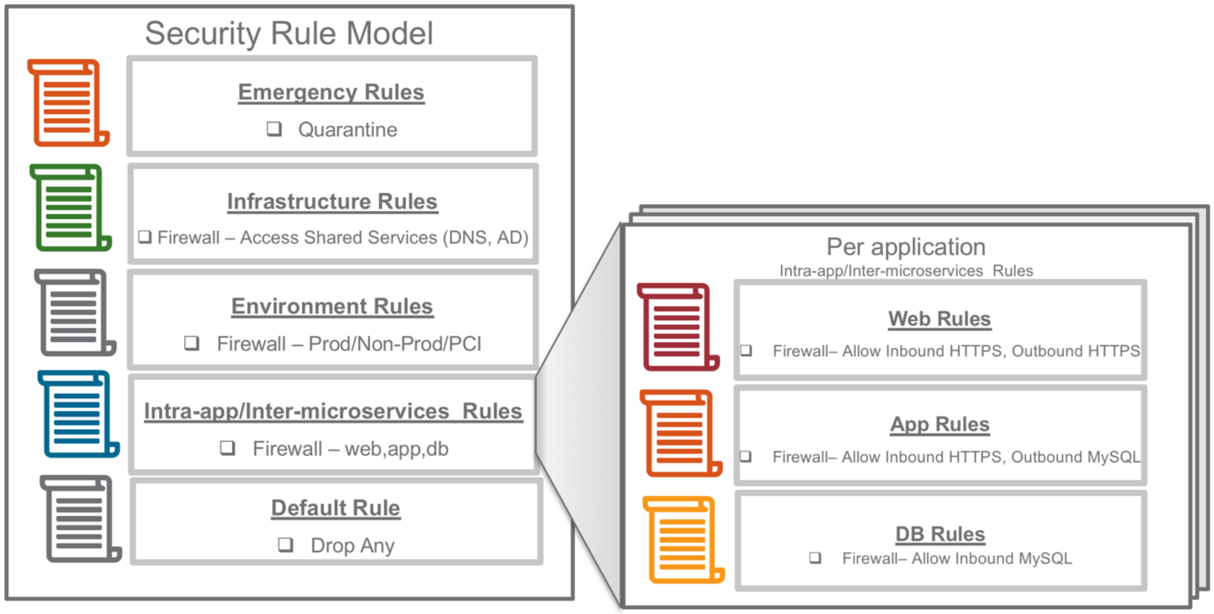

Security Rule Model
Emergency Rules
Quarantine
Infrastructure Rules
Firewall – Access Shared Services (DNS, AD)
Environment Rules
Firewall – Prod/Non-Prod/PCI
Intra-app/Inter-microservices Rules
Firewall – web,app,db
Default Rule
Drop Any
Per application
Intra-app/Inter-microservices Rules
Web Rules
Firewall– Allow Inbound HTTPS, Outbound HTTPS
App Rules
Firewall– Allow Inbound HTTPS, Outbound MySQL
DB Rules
Firewall– Allow Inbound MySQL

Figure 5-7: Security Rule Model

5.4.3 Security Policy - Consumption Model

NSX-T Security policy is consumed by the firewall rule table, which is using NSX-T Manager GUI or REST API framework. When defining security policy rules for the firewall table, it is recommended to follow these high-level steps:

- **VM Inventory Collection** – Identify and organize a list of all hosted virtualized workloads on NSX-T transport nodes. This is dynamically collected and saved by NSX-T Manager as the nodes – ESXi or KVM – are added as NSX-T transport nodes.
- **Tag Workload** – Use VM inventory collection to organize VMs with one or more tags. Each designation consists of scope and tag association of the workload to an application, environment, or tenant. For example, a VM tag could be “Scope = Prod, Tag = web” or “Scope=tenant-1, Tag = app-1”. Often, these categories will dive several layers deep including BU, project, environment, and regulatory flags. When following the iterative approach of segmentation, categories and tags can be added to entities with existing tags. In the application centric approach, new categories can be added with each application.
- **Group Workloads** – Use the NSX-T logical grouping construct with dynamic or static membership criteria based on VM name, tags, segment, segment port, IP’s, or other attributes. NSX-T allows for thousands of groups based on tags, although rarely are more than a dozen or so needed.
- **Define Security Policy** – Using the firewall rule table, define the security policy. Have categories and policies to separate and identify emergency, infrastructure, environment, and application-specific policy rules based on the rule model.

The methodology and rule model mentioned earlier would influence how to tag and group the workloads as well as affect policy definition. The following sections offer more details on grouping and firewall rule table construction with an example of grouping objects and defining NSX-T DFW policy.

5.4.3.1 Group Creation Strategies

The most basic grouping strategy is creation of a group around every application which is hosted in the NSX-T environment. Each 3-tier, 2-tier, or single-tier applications should have its own security group to enable faster operationalization of micro-segmentation. When combined with a basic rule restricting inter-application communication to only essential shared services (e.g., DNS, AD, DHCP server) this enforces granular security inside the perimeter. Once this basic micro-segmentation is in place, the writing of per-application rules can begin.

Groups

NSX-T provides collection of referenceable objects represented in a construct called Groups. The selection of a specific policy methodology approach – application, infrastructure, or network – will help dictate how grouping construct is used. Groups allow abstraction of workload grouping from the underlying infrastructure topology. This allows a security policy to be written for either a workload or zone (e.g., PCI zone, DMZ, or production environment).

A Group is a logical construct that allows grouping into a common container of static (e.g., IPSet/NSX objects) and dynamic (e.g., VM names/VM tags) elements. This is a generic construct which can be leveraged across a variety of NSX-T features where applicable.

Static criteria provide capability to manually include particular objects into the Group. For dynamic inclusion criteria, Boolean logic can be used to create groups between various criteria.

A Group creates a logical grouping of VMs based on static and dynamic criteria. *Table 5-1: NSX-T Objects used for Groups* shows one type of grouping criteria based on NSX-T Objects.

NSX-T Object	Description
IP Address	Grouping of IP addresses and subnets.
Segment	All VMs/vNICs connected to this segment/logical switch segment will be selected.
Group	Nested (Sub-group) of collection of referenceable objects - all VMs/vNICs defined within the Group will be selected
Segment Port	This particular vNIC instance will be selected.
MAC Address	Selected MAC sets container will be used. MAC sets contain a list of individual MAC addresses.
AD Groups	Grouping based on Active Directory groups for Identity Firewall (VDI/RDSH) use case.

Table 5-1: NSX-T Objects used for Groups

Table 5-2: VM Properties used for Groups list the selection criteria based on VM properties.

VM Property	Description
VM Name	All VMs that contain/equal/starts/not-equals with the string as part of their name.
Tags	All VMs that are applied with specified NSX-T security tags
OS Name	All VM with specific operating System type and version
Computer name	All VMs that contain/equal/starts/not-equals with the string as part of their hostname.

Table 5-2: VM Properties used for Groups

The use of Groups gives more flexibility as an environment changes over time. This approach has three major advantages:

- Rules stay more constant for a given policy model, even as the data center environment changes. The addition or deletion of workloads will affect group membership alone, not the rules.
- Publishing a change of group membership to the underlying hosts is more efficient than publishing a rule change. It is faster to send down to all the affected hosts and cheaper in terms of memory and CPU utilization.
- As NSX-T adds more grouping object criteria, the group criteria can be edited to better reflect the data center environment.

Using Nested Groups

Groups can be nested. A Group may contain multiple groups or a combination of groups and other grouping objects. A security rule applied to the parent Group is automatically applied to the child Groups. Nesting should be limited to 3 levels, although more are supported. This is to ease troubleshooting, minimize unintentional policy results, and to optimize the computational burden of publishing policy. Nothing prolongs downtime like trying to follow the logic of a grouping nested 5 levels deep.

In the example shown in *Figure 5-8: Group and Nested Group Example*, three Groups have been defined with different inclusion criteria to demonstrate the flexibility and the power of grouping construct.

- Using dynamic inclusion criteria, all VMs with name starting by "WEB" are included in Group named "SG-WEB".
- Using dynamic inclusion criteria, all VMs containing the name "APP" and having a tag "Scope=PCI" are included in Group named "SG-PCI-APP".
- Using static inclusion criteria, all VMs that are connected to a segment "SEG-DB" are included in Group named "SG-DB".

Nesting of Group is also possible; all three of the Groups in the list above could be children of a parent Group named "SG-APP-1-AllTier". This organization is also shown in *Figure 5-8: Group and Nested Group Example*.

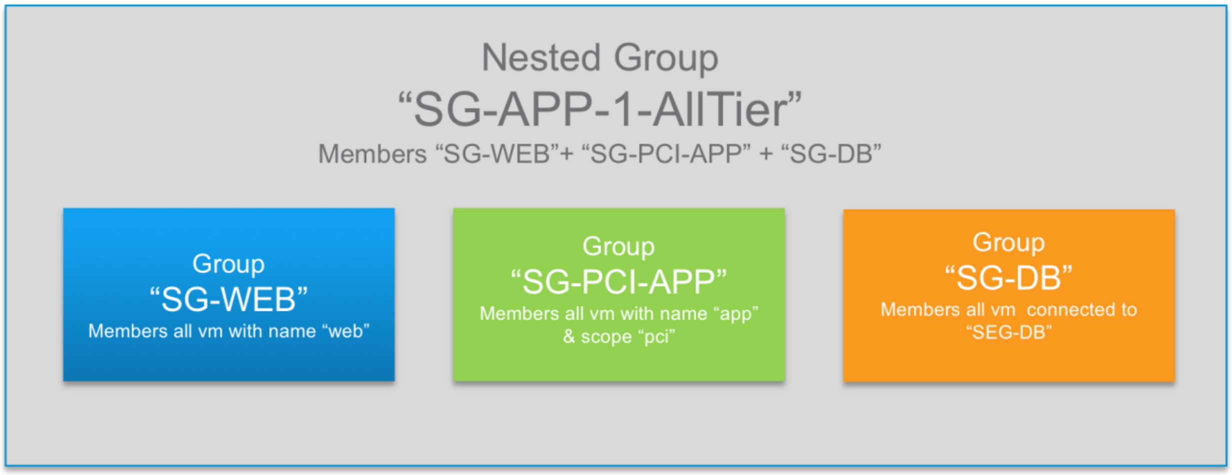

Nested Group
"SG-APP-1-AllTier"
Members "SG-WEB"+ "SG-PCI-APP" + "SG-DB"
Group
"SG-WEB"
Members all vm with name "web"
Group
"SG-PCI-APP"
Members all vm with name "app" & scope "pci"
Group
"SG-DB"
Members all vm connected to "SEG-DB"

Figure 5-8: Group and Nested Group Example

Efficient Grouping Considerations
Calculation of groups adds a processing load to the NSX-T management and control planes. Different grouping mechanisms add different types of loads. Static groupings are more efficient than dynamic groupings in terms of calculation. At scale, grouping considerations should consider the frequency of group changes for associated VMs. A large number of group changes applied frequently means the grouping criteria is suboptimal.

5.4.3.2 Define Policy using DFW Rule Table

The NSX-T DFW rule table starts with a default rule to allow any traffic. An administrator can add multiple policies on top of default rule under different categories based on the specific policy model. NSX-T distributed firewall table layout consists of Categories like Ethernet, Emergency, Infrastructure, Environment, and Application to help users to organize security policies. Each category can have one or more policy/section with one or more firewall rules. Please refer to Security Rule Model section above to understand the best practices around organizing the policies.

In the data path, the packet lookup will be performed from top to bottom order, starting with policies from category Ethernet, Emergency, Infrastructure, Environment and Application. Any packet not matching an explicit rule will be enforced by the last rule in the table (i.e., default rule). This final rule is set to the "allow" action by default, but it can be changed to "block" if desired.

The NSX-T DFW enables policy to be stateful or stateless with policy-level granularity. By default, NSX-T DFW is a stateful firewall; this is a requirement for most deployments. In some scenarios where an application has less network activity, the stateless section may be appropriate to avoid connection reset due to inactive timeout of the DFW stateful connection table.
NSX-T Firewall policy can also be locked by a user to avoid losing any update to policy with multiple people editing same policy at the same time.

Name	ID	Source	Destination	Service	Profiles	Applied To	Action	Advanced Setting	Stats

Table 5-3: Policy Rule Fields

A rule within a policy is composed of field shown in *Table 5-3: Policy Rule Fields* and its meaning is described below

Rule Name: User field; supports up to 30 characters.
ID: Unique rule ID auto generated by System. The rule id helps in monitoring and troubleshooting. Firewall Log carries this Rule ID when rule logging is enabled.
Source and Destination: Source and destination fields of the packet. This will be a GROUP which could be static or dynamic groups as mentioned under Group section.
Service: Predefined services, predefined services groups, or raw protocols can be selected. When selecting raw protocols like TCP or UDP, it is possible to define individual port numbers or a range. There are four options for the services field:

- **Pre-defined Service** – A pre-defined Service from the list of available objects.
- **Add Custom Services** – Define custom services by clicking on the "Create New Service" option. Custom services can be created based on L4 Port Set, application level gateways (ALGs), IP protocols, and other criteria. This is done using the "service type" option in the configuration menu. When selecting an L4 port set with TCP or UDP, it is possible to define individual destination ports or a range of destination ports. When selecting ALG, select supported protocols for ALG from the list. ALGs are only supported in stateful mode; if the section is marked as stateless, the ALGs will not be implemented. Additionally, some ALGs may be supported only on ESXi hosts, not KVM. Please review release-specific documentation for supported ALGs and hosts.
- **Custom Services Group** – Define a custom Services group, selecting from single or multiple services. Workflow is similar to adding Custom services, except you would be adding multiple service entries.

Profiles: This is used to select & define Layer 7 Application ID & FQDN profile. This is used for Layer 7 based security rules.
Applied To: Define the scope of rule publishing. The policy rule could be published all workloads (default value) or restricted to a specific GROUP. When GROUP is used in Applied-To it needs to be based on NON-IP members like VM object, Segments etc. Not using the Applied To field can result in very large firewall tables being loaded on vNICs, which will negatively affect performance.

Action: Define enforcement method for this policy rule; available options are listed in *Table 5-4: Firewall Rule Table – "Action" Values*

Action	Description
Drop	Block silently the traffic.
Allow	Allow the traffic.
Reject	Reject action will send back to initiator: • RST packets for TCP connections. • ICMP unreachable with network administratively prohibited code for UDP, ICMP and other IP connections.

Table 5-4: Firewall Rule Table – "Action" Values

Advanced Settings: Following settings are under advanced settings options:

Logging: Enable or disable packet logging. When enabled, each DFW enabled host will send DFW packet logs in a syslog file called "dfwpktlog.log" to the configured syslog server. This information from the default rule will provide insight to traffic not currently being caught by existing policy. Best practice for deploying east-west traffic in a brownfield environment is to define policy with a default allow rule with logging. This allows for the verification of traffic not currently caught by policy.
Direction: This field matches the direction of the packet, default both In-Out. It can be set to match packet exiting the VM, entering the VM, or both directions.
IP Protocol: By default, both IPv4 & IPv6 protocols. Option to choose IPv4 or IPv6.
Log Label: You can Label the rule; this will be sent as part of DFW packet log when traffic hits this rule**.**
Notes: This field can be used for any free-flowing string and is useful to store comments. Best practice is to use this field for change control by pointing to a ticket ID.
Stats: Provides packets/bytes/sessions statistics along with popularity index associated with that rule entry. The Also provides Popularity Index for the given rule. Stats per rule are Polled Aggregated every 15 minutes from all the transport nodes.

Examples of Policy Rules for 3-Tier Application

Figure 5-9: 3-Tier Application Network Topology shows a standard 3-Tier application topology used to define NSX-T DFW policy. Three web servers are connected to "SEG Web", two applications servers are connected to "SEG App", and 2 DB servers connected to "SEG DB". A distributed

Gateway is used to interconnect the three tiers by providing inter-tier routing. NSX-T DFW has been enabled, so each VM has a dedicated instance of DFW attached to its vNIC/segment port.

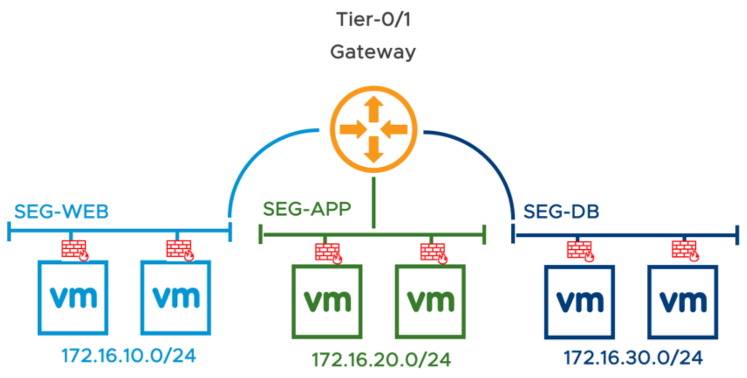


Figure 5-9: 3-Tier Application Network Topology

In order to define micro-segmentation policy for this application use the category Application on DFW rule table and add a new policy session and rules within it for each application.

The following use cases employ present policy rules based on the different methodologies introduced earlier.

Example 1: Static IP addresses/subnets Group in security policy rule.

This example shows use of the network methodology to define policy rule. Groups in this example are identified in *Table 5-5: Firewall Rule Table - Example 1 – Group Definition* while the firewall policy configuration is shown in *Table 5-6: Firewall Rule Table - Example 1- Policy*.

Group name	Group definition
Group-WEB-IP	IP Members: 172.16.10.0/24
Group-APP-IP	IP Members: 172.16.20.0/24
Group-DB-IP	IP Members: 172.16.30.0/24

Table 5-5: Firewall Rule Table - Example 1 – Group Definition

Name	Source	Destination	Service	Action	Applied To
Any to Web	Any	Group-WEB-IP	https	Allow	All

Web to App	Group-WEB-IP	Group-APP-IP	<Enterprise Service Bus>	Allow	All
App to DB	Group-APP-IP	Group-DB-IP	SQL	Allow	All
Block-Other	Any	Any	Any	Drop	All

Table 5-6: Firewall Rule Table - Example 1- Policy

The DFW engine is able to enforce network traffic access control based on the provided information. To use this type of construct, exact IP information is required for the policy rule. This construct is quite static and does not fully leverage dynamic capabilities with modern cloud systems.

Example 2: Using Segment object Group in Security Policy rule.
This example uses the infrastructure methodology to define policy rule. Groups in this example are identified in *Table 5-7: Firewall Rule Table - Example 2 – Group Definition* while the firewall policy configuration is shown in *Table 5-8: Firewall Rule Table - Example 2 – Policy*.

Group name	**Group definition**
Group-SEG-WEB	Static inclusion: SEG-WEB
Group-SEG-APP	Static inclusion: SEG-APP
Group-SEG-DB	Static inclusion: SEG-DB

Table 5-7: Firewall Rule Table - Example 2 – Group Definition

Name	**Source**	**Destination**	**Service**	**Action**	**Applied To**
Any to Web	Any	Group-SEG-WEB	https	Allow	Group-SEG-WEB
Web to App	Group-SEG-WEB	Group-SEG-APP	<Enterprise Service Bus>	Allow	Group-SEG-WEB Group-SEG-APP
App to DB	Group-SEG-APP	Group-SEG-DB	SQL	Allow	Group-SEG-APP Group-SEG-DB
Block-Other	Any	Any	Any	Drop	Group-SEG-WEB Group-SEG-APP Group-SEG-DB

Table 5-8: Firewall Rule Table - Example 2 – Policy

Reading this policy rule table would be easier for all teams in the organization, ranging from security auditors to architects to operations. Any new VM connected on any segment will be automatically secured with the corresponding security posture. For instance, a newly installed web server will be seamlessly protected by the first policy rule with no human intervention, while VM disconnected from a segment will no longer have a security policy applied to it. This type of construct fully leverages the dynamic nature of NSX-T. It will monitor VM connectivity at any given point in time, and if a VM is no longer connected to a particular segment, any associated security policies are removed.

This policy rule also uses the “Applied To” option to apply the policy to only relevant objects rather than populating the rule everywhere. In this example, the first rule is applied to the vNIC associated with “SEG-Web”. Use of “Applied To” is recommended to define the enforcement point for the given rule for better resource usage.

Security policy and IP Discovery
Both NSX-T DFW and Gateway Firewall (GFW) has a dependency on VM-to-IP discovery which is used to translate objects to IP before rules are pushed to data path. This is mainly required when the policy is defined using grouped objects. This VM-to-IP table is maintained by NSX-T Control plane and populated by the IP discovery mechanism. IP discovery used as a central mechanism to ascertain the IP address of a VM. By default, this is done using DHCP and ARP snooping, with VMware Tools available as another mechanism with ESXi hosts. These discovered VM-to-IP mappings can be overridden by manual input if needed, and multiple IP addresses are possible on a single vNIC. The IP and MAC addresses learned are added to the VM-to-IP table. This table is used internally by NSX-T for SpoofGuard, ARP suppression, and firewall object-to-IP translation.

5.5 Intrusion Detection

Much like distributed firewalling changed the game on firewalling by providing a distributed, ubiquitous enforcement plane, NSX distributed IPS/IPS changes the game on IPS by providing a distributed, ubiquitous enforcement plane. However, there are additional benefits that the NSX distributed IPS model brings beyond ubiquity (which in itself is a game changer). NSX IPS is IPS distributed across all the hosts. Much like with DFW, the distributed nature allows the IPS capacity to grow linearly with compute capacity. Beyond that, however, there is an added benefit to distributing IPS. This is the added context. Legacy network Intrusion Detection and Prevention systems are deployed centrally in the network and rely either on traffic to be hairpinned through them or a copy of the traffic to be sent to them via techniques like SPAN or TAPs. These sensors typically match all traffic against all or a broad set of signatures and have very little context about the assets they are protecting. Applying all signatures to all traffic is very inefficient, as IDS/IPS unlike firewalling needs to look at the packet payload, not just the network headers. Each signature that needs to be matched against the traffic adds inspection overhead and potential latency introduced. Also, because legacy network IDS/IPS appliances just see packets without having context about the protected workloads, it’s very difficult for security teams to determine the appropriate priority for each incident. Obviously, a successful intrusion against a vulnerable database server in production which holds mission-critical data needs more attention than someone in the IT staff triggering an IDS event by running a vulnerability scan. Because the NSX distributed IDS/IPS is applied to the vNIC of every workload, traffic does not need to hairpinned to a centralized appliance, and we can be very selective as to what signatures are applied. Signatures related to a windows vulnerability don’t need to be applied to Linux workloads, or servers running Apache don’t need signatures that detect an exploit of a database service. Through the Guest Introspection Framework, and in-guest drivers, NSX has access to context about each guest, including the operating system version, users logged in or any running process. This context can be leveraged to selectively apply only the relevant signatures, not only reducing the processing impact, but more importantly reducing the noise and quantity of false positives compared to what would be seen if all signatures are applied to all traffic with a traditional appliance. For a detailed description of IDS configuration, see the NSX Product Documentation.

5.6 Service Insertion

The value of NSX security extends beyond NSX to your pre-existing security infrastructure; NSX is the mortar that ties your security bricks to build a stronger wall. Legacy security strategies were intolerant of pre-existing security infrastructure. Anyone who had a Checkpoint firewall and wanted to move to a Palo Alto Networks firewall would run the 2 managers, side by side until the transition was complete. Troubleshooting during this transition period required a lot of chair swiveling. NSX brings a new model, complementing pre-existing infrastructure. Service Insertion is the feature which allows NSX firewalls (both gateway and DFW) to send traffic to legacy firewall infrastructure for processing. This can be done as granularly as a port level, without any modification to existing network architecture. Service Insertion not only sends the traffic to other services for processing, Service Insertion offers and a deep integration which allows the exchange of NSX Manager objects to SI service managers. So, a group in NSX which is comprised on VMs which a substring of “web” (for example) would get shared to the SI service manager. Thus, when a new VM is spun up which becomes a member of the new group, the NSX Manager will send that update to the SI Service Manager so that policy can be consistently applied across platforms.

5.7 Additional Security Features

NSX-T extends the security solution beyond DFW with additional features to enhance data center security posture on top of micro-segmentation. These features include:

- **SpoofGuard** - Provides protection against spoofing with MAC+IP+VLAN bindings. This can be enforced at a per logical port level. The SpoofGuard feature requires static or dynamic bindings (e.g., DHCP/ARP snooping) of IP+MAC for enforcement.
- **Segment Security** - Provides stateless L2 and L3 security to protect segment integrity by filtering out malicious attacks (e.g., denial of service using broadcast/multicast storms) and unauthorized traffic entering segment from VMs. This is accomplished by attaching the segment security profile to a segment for enforcement. The segment security profile has options to allow/block bridge protocol data unit (BPDU), DHCP server/client traffic, non-IP traffic. It allows for rate limiting of broadcast and multicast traffic, both transmitted and received.

5.8 NSX-T Security Enforcement – Agnostic to Network Isolation

The NSX-T security solution is agnostic to network isolation and topology requirements. Below are the different possible deployment options for adapting NSX-T micro-segmentation policies based on different network isolation requirements.

The consumption of security policies requires no changes from policy planning, design, and implementation perspective. This applies to all of the deployment options mentioned below. However, the following initial provisioning steps required to enforce NSX security policies:
a) Preparation of compute hosts for NSX-T.
b) Create VLAN or overlay segments on NSX-T based on network isolation and
c) Move relevant workloads to relevant VLAN or overlay segments/networks on compute hosts for policy enforcement.

5.8.1 NSX-T Distributed Firewall for VLAN Backed workloads

This is a very common use case for our customer who is looking at NSX-T as a platform only for micro-segmentation security use case without changing existing network isolation, which is VLAN backed. This is the ideal use case for a brownfield deployment where customer wants to enhance the security posture for existing applications without changing network design.

The following diagram depicts this use case with logical and physical topology.

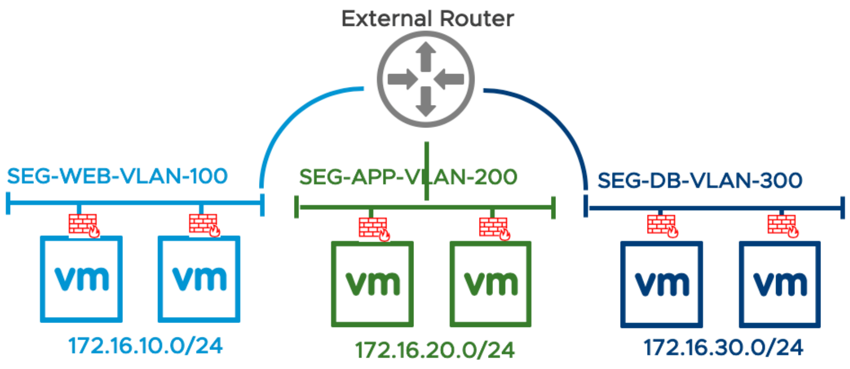


Figure 5-10: NSX-T DFW Logical topology – VLAN Backed Workloads

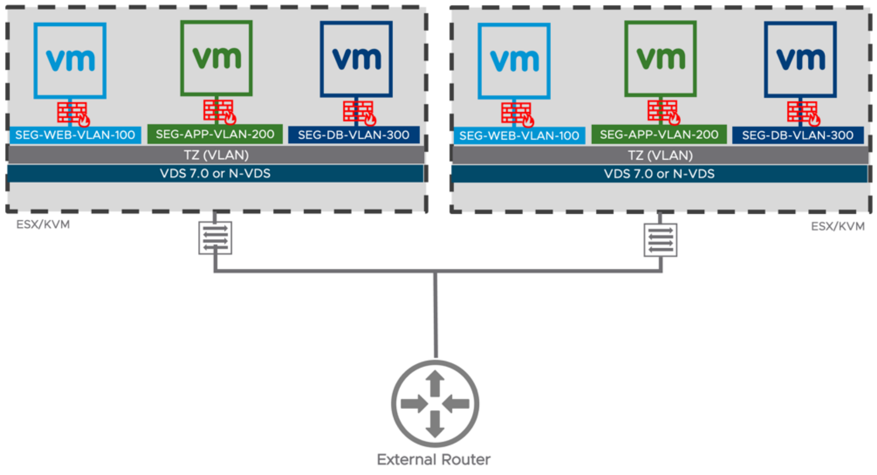


Figure 5-11: NSX-T DFW Physical Topology – VLAN Backed Workloads

5.8.2 NSX-T Distributed Firewall for Mix of VLAN and Overlay backed workloads

This use case mainly applies to customer who wants to adapt NSX-T micro-segmentation policies to all of their workloads and looking at adapting NSX-T network virtualization (overlay) for their application networking needs in phases. This scenario may arise when customer starts to either deploy new application with network virtualization or migrating existing applications in phases from VLAN to overlay backed networking to avail the advantages of NSX-T network virtualization. This scenario is also common where there are applications which prevent overlay backed networking from being adopted fully (as described in section <BRIDGING> above). The order of operations in this environment is as follows: on egress, DFW processing happens first, then overlay network processing happens second. On traffic arrival at a remote host, overlay network processing happens first, then DFW processing happens before traffic arrives at the VM.

The following diagram depicts this use case with logical and physical topology.

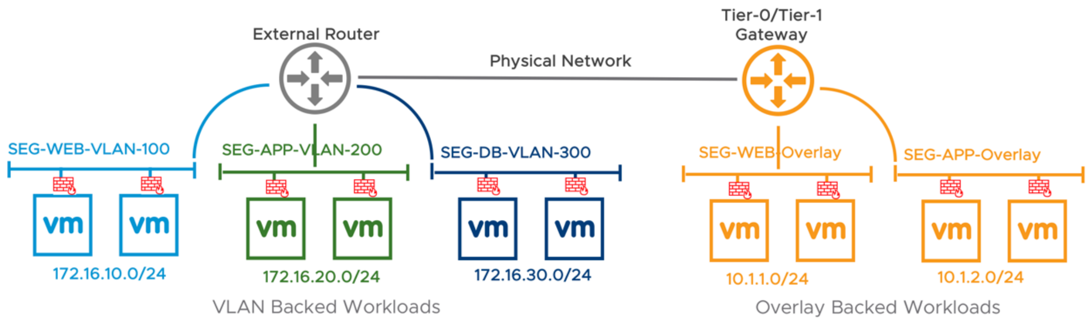


Figure 5-12: NSX-T DFW Logical Topology – Mix of VLAN & Overlay Backed Workloads

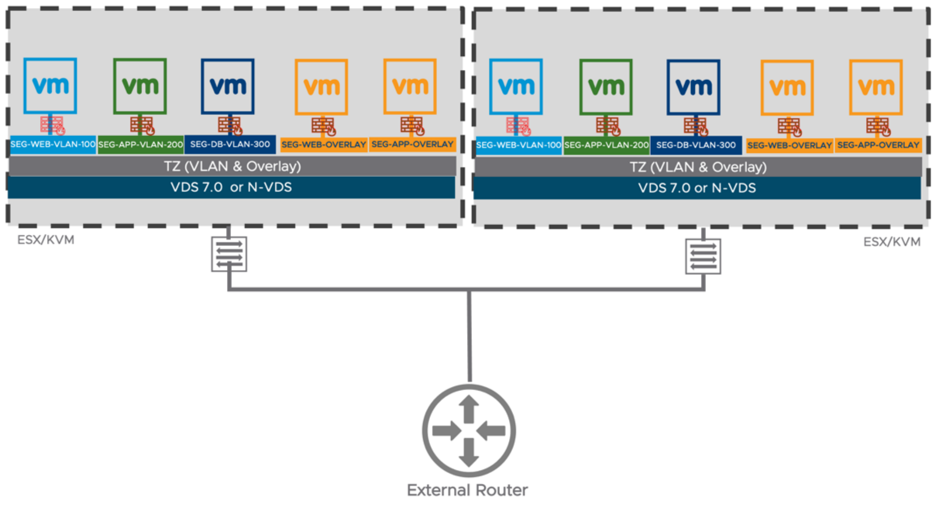


Figure 5-13: NSX-T DFW Physical Topology – Mix of VLAN & Overlay Backed Workloads

5.8.3 NSX-T Distributed Firewall for Overlay Backed workloads

In this use case where all the virtualized applications are hosted or moved from VLAN to NSX-T overlay backed networking from the network isolation perspective. This could apply to green field deployment or final phase of brownfield deployments where all virtualized applications have been moved from VLAN to NSX-T overlay backed networking.

In summary, NSX-T Platform enforces micro-segmentation policies irrespective of network isolation, VLAN or overlay or Mix, without having to change policy planning, design, and implementation. A user can define NSX-T micro-segmentation policy once for the application, and it will continue to work as you migrate application from VLAN based networking to NSX-T overlay backed networking.

5.9 Gateway Firewall

The NSX-T Gateway firewall provides essential perimeter firewall protection which can be used in addition to a physical perimeter firewall. Gateway firewall service is part of the NSX-T Edge node for both bare metal and VM form factors. The Gateway firewall is useful in developing PCI zones, multi-tenant environments, or DevOps style connectivity without forcing the inter-tenant or inter-zone traffic onto the physical network. The Gateway firewall data path uses DPDK framework supported on Edge to provide better throughput.

Optionally, Gateway Firewall service insertion capability can be leveraged with the partner ecosystem to provide integrated security which leverages existing security investments. This enhances the security posture by providing next-generation firewall (NGFW) services on top of native firewall capability NSX-T provides. This is applicable for the design where security compliance requirements mandate zone or group of workloads need to be secured using NGFW, for example, DMZ or PCI zones or Multi-Tenant environments. Service insertion leverages existing security infrastructure investments and extends NSX dynamic security groups to them.

5.9.1 Consumption

NSX-T Gateway firewall is instantiated per gateway and supported at both Tier-0 and Tier-1. Gateway firewall works independently of NSX-T DFW from a policy configuration and enforcement perspective, although objects can be shared from the DFW. A user can consume the Gateway firewall using either the GUI or REST API framework provided by NSX-T Manager. The Gateway firewall configuration is similar to DFW firewall policy; it is defined as a set of individual rules within a section. Like the DFW, the Gateway firewall rules can use logical objects, tagging and grouping constructs (e.g., Groups) to build policies. Similarly, regarding L4 services in a rule, it is valid to use predefined Services, custom Services, predefined service groups, custom service groups, or TCP/UDP protocols with the ports. NSX-T Gateway firewall also supports multiple Application Level Gateways (ALGs). The user can select an ALG and supported protocols by using the other setting for type of service. Gateway FW supports only FTP and TFTP as part of ALG. ALGs are only supported in stateful mode; if the section is marked as stateless, the ALGs will not be implemented.

When partner services are leveraged through service insertion, the implementation requires registering the NSX Manager on the partner management console and the registration of the partner management console in the NSX-T manager. Once the two managers are integrated, they will share relevant objects, which will improve security policy consistency across the board.

5.9.2 Implementation

Gateway firewall is an optional centralized firewall implemented on NSX-T Tier-0 gateway uplinks and Tier-1 gateway links. This is implemented on a Tier-0/1 SR component which is hosted on NSX-T Edge. Tier-0 Gateway firewall supports stateful firewalling only with active/standby HA mode. It can also be enabled in an active/active mode, though it will be only working in stateless mode. Gateway firewall uses a similar model as DFW for defining policy, and NSX-T grouping construct can be used as well. Gateway firewall policy rules are organized using one or more policy sections in the firewall table for each Tier-0 and Tier-1 Gateway. Firewalling at the perimeter allows for a coarse grain policy definition which can greatly reduce the security policy size inside.

5.9.3 Deployment Scenarios

This section provides two examples for possible deployment and data path implementation.

Gateway FW as Perimeter FW at Virtual and Physical Boundary
The Tier-0 Gateway firewall is used as perimeter firewall between physical and virtual domains. This is mainly used for N-S traffic from the virtualized environment to physical world. In this case, the Tier-0 SR component which resides on the Edge node enforces the firewall policy before traffic enters or leaves the NSX-T virtual environment. The E-W traffic continues to leverage the distributed routing and firewalling capability which NSX-T natively provides in the hypervisor.   In addition to firewalling, the T1 Gateway can perform per tenant NAT. This is highly desirable in containerized environments to reduce the consumption of IP addresses.

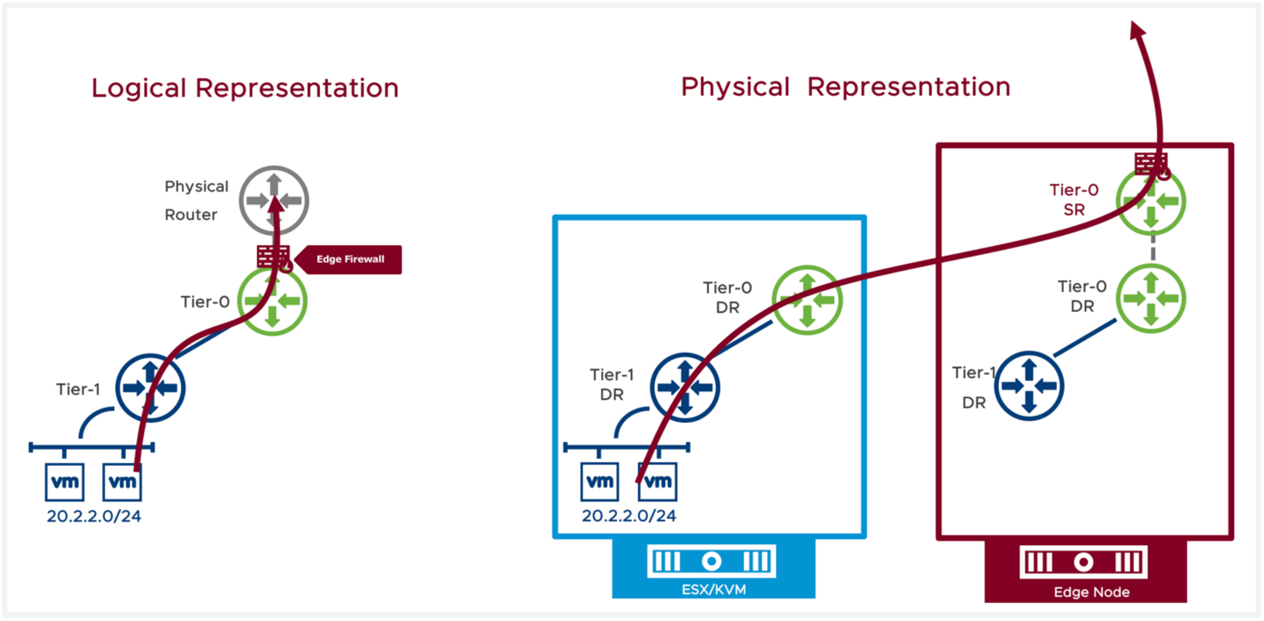


Figure 5-14: Tier-0 Gateway Firewall – Virtual-to-Physical Boundary

Gateway FW as Inter-tenant FW

The Tier-1 Gateway firewall is used as inter-tenant firewall within an NSX-T virtual domain. This is used to define policies between different tenants who resides within an NSX-T environment. This firewall is enforced for the traffic leaving the Tier-1 router and uses the Tier-0 SR component which resides on the Edge node to enforce the firewall policy before sending to the Tier-0 Gateway for further processing of the traffic. The intra-tenant traffic continues to leverage distributed routing and firewalling capabilities native to the NSX-T.

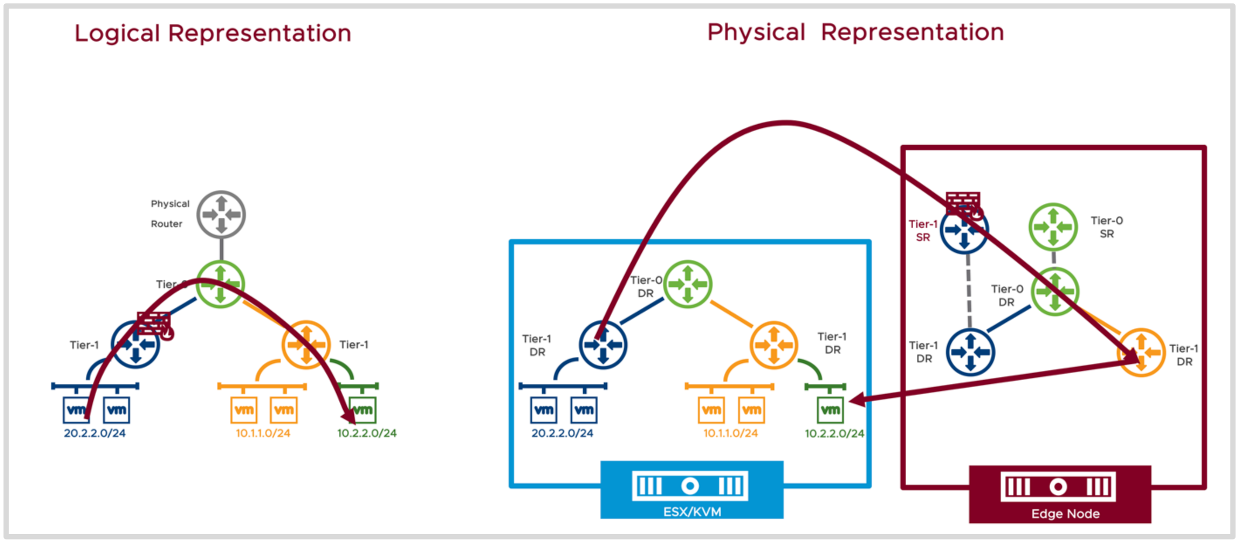


Figure 5-15: Tier-1 Gateway Firewall - Inter-tenant

Gateway FW with NGFW Service Insertion – As perimeter or Inter Tenant Service

This deployment scenario extends the Gateway Firewall scenarios depicted above with additional capability to insert the NGFW on top of native firewall capability NSX-T Gateway Firewall provides. This is applicable for the design where security compliance requirements mandate zones or groups of workloads be secured using NGFW, for example, DMZ or PCI zones or Multi-Tenant environments. The service insertion can be enabled per Gateway for both Tier-0 and Tier-1 Gateways depending on the scenario. Because traffic is redirected to partner services in a policy model, traffic can be redirected by protocol only for relevant traffic. This allows the insertion of partner firewalls in a surgical manner, without disruption to underlying network topology. As a best practice, Gateway firewall policy can be leveraged as the first level of defense to allow traffic based on L3/L4 policy and partner services as the second level defense. To do this, define policy on Gateway firewall to redirect the traffic which needs to be inspected by NGFW. This will optimize the NGFW performance and throughput, as well as reduce the capacity required of the partner service (which often impacts license cost).
The following diagram provides the logical representation of overall deployment scenario. Please refer to NSX-T interoperability matrix to check certified partners for the given use case.

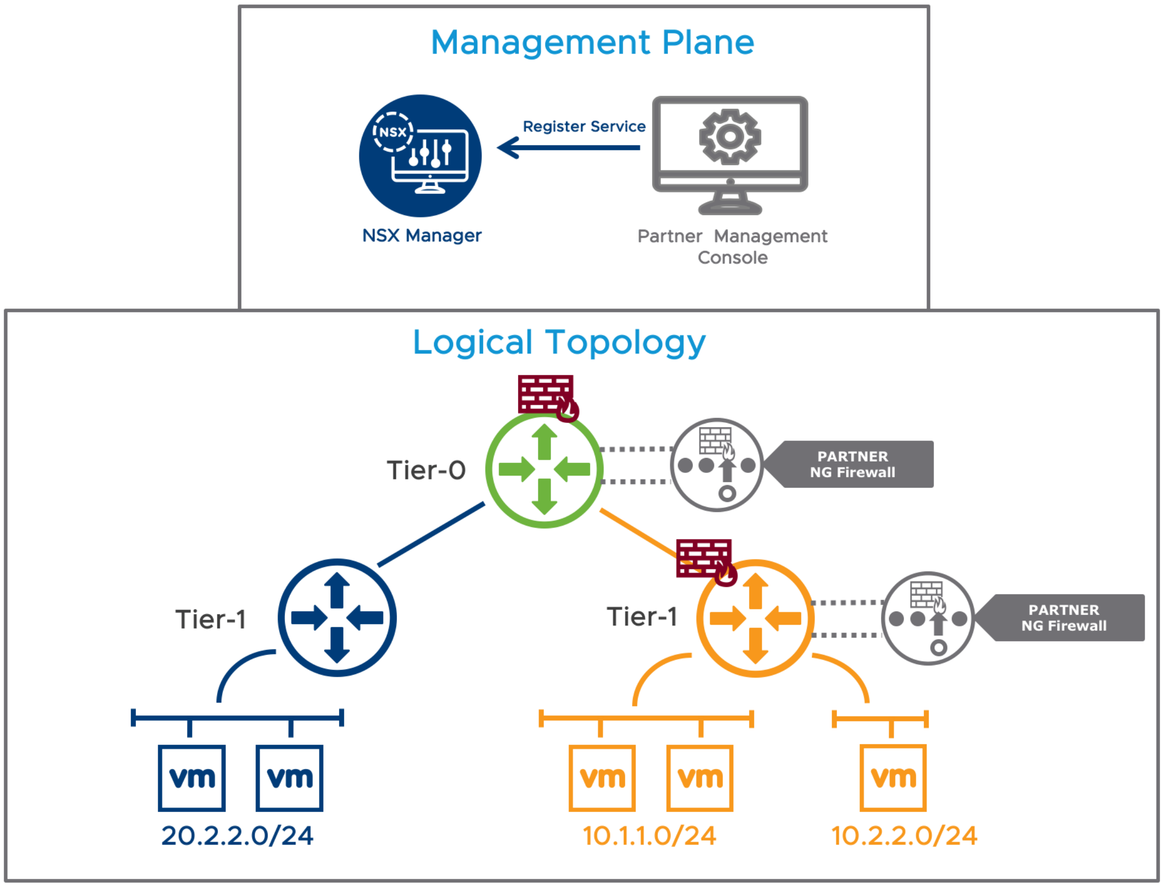


Figure 5-16: Gateway Firewall – Service Insertion

5.10 Endpoint Protection with NSX-T

NSX-T provides the Endpoint Protection platform to allow 3rd party partners to run agentless Anti-Virus/Anti-Malware (AV/AM) capabilities for virtualized workloads on ESXi. Traditional AV/AM services require agents be run inside the guest operating system of a virtual workload.

These agents can consume small amounts of resources for each workload on an ESXi host. In the case of Horizon, VDI desktop hosts typically attempt to achieve high consolidation ratios on the ESXi host, providing 10s to 100s of desktops per ESXi host. With each AV/AM agent inside the virtualized workload consuming a small amount of virtual CPU and memory, the resource costs can be noticeable and possibly reduce the overall number of virtual desktops an ESXi host can accommodate, thus increasing the size and cost of the overall VDI deployment. The Guest Introspection platform allows the AV/AM partner to remove their agent from the virtual workload and provide the same services using a Service Virtual Machine (SVM) that is installed on each host. These SVMs consume much less virtual CPU and memory overall than running agents on every workload on the ESXi host. Removing the agent also removes that processing tax from the VDI, resulting in greater individual VDI performance. Many AV/AM partner solutions have the ability to add tags to the workloads based on the result of the AV/AM scan. This allows for an automated immediate quarantine policy based on the result of the AV/AM scan with the definition of DFW security rules based on the partner tags.

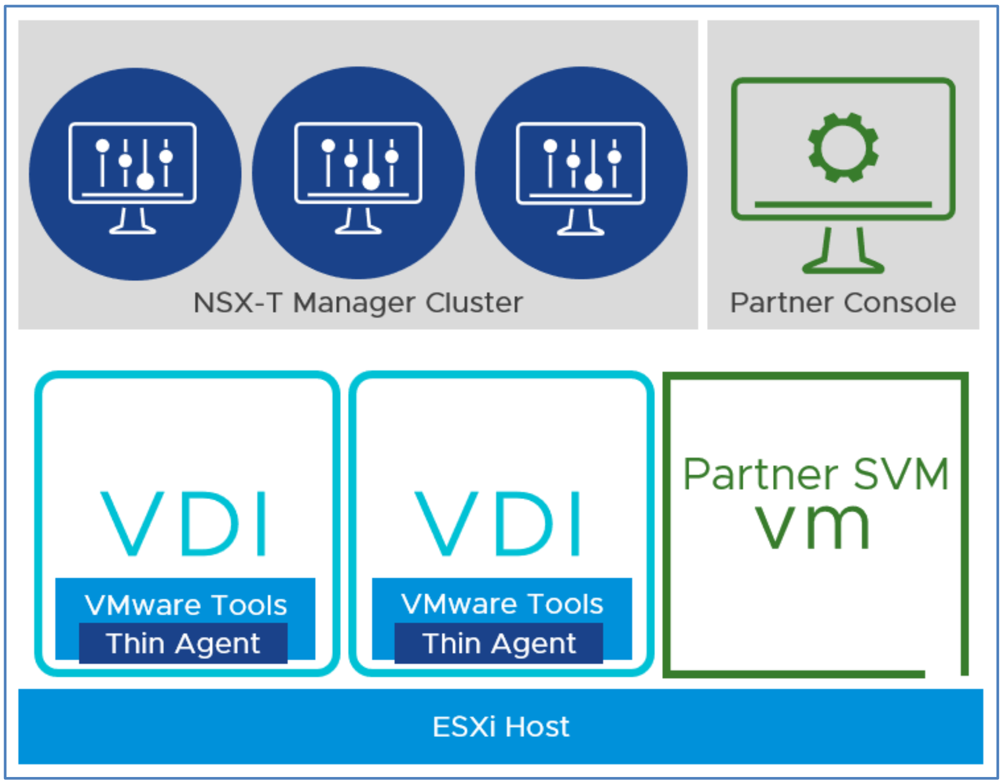


Figure 5-17: Endpoint Protection Components

The Endpoint Protection platform for NSX-T following a simple 3 step process to use.

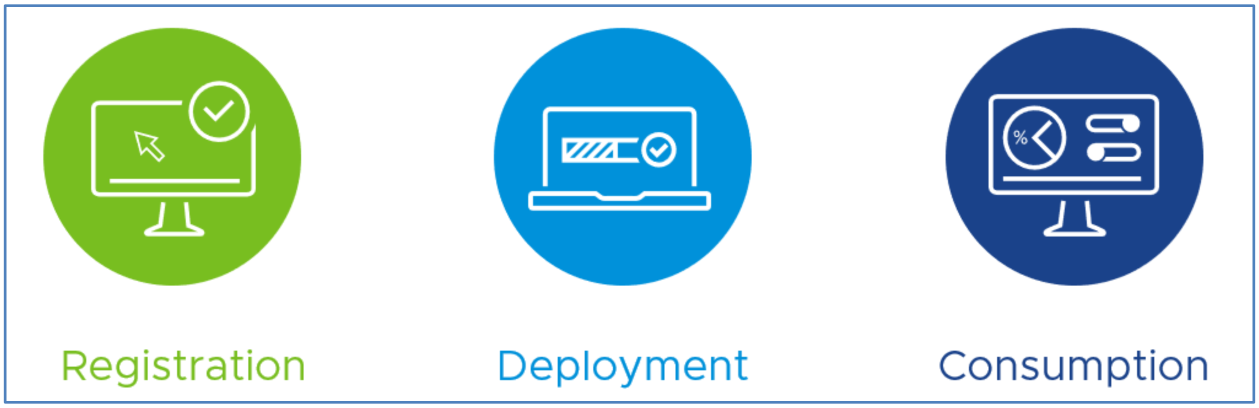


Figure 5-18: Endpoint Protection Steps

Registration
Registration of the VMware Partner console with NSX-T and vCenter.

Deployment
Creating a Service Deployment of the VMware Partner SVM and deployment to the ESXi Clusters. The SVMs require a Management network with which to talk to the Partner Management Console. This can be handled by IP Pool in NSX-T or by DHCP from the network. Management networks must be on a VSS or VDS switch.

Consumption
Consumption of the Endpoint Protection platform consists of creating a Service Profile of which references the Service Deployment and then creating Service Endpoint Protection Policy with Endpoint Rule that specifies which Service Profile should be applied to what NSX-T Group of Virtual Machines.

5.11 Recommendation for Security Deployments

This list provides best practices and recommendation for the NSX-T DFW. These can be used as guidelines while deploying an NSX-T security solution.

- For individual NSX-T software releases, always refer to release notes, compatibility guides, hardening guide and recommended configuration maximums..
- Exclude management components like vCenter Server, and security tools from the DFW policy to avoid lockout, at least in the early days of DFW use. Once there is a level of comfort and proficiency, the management components can be added back in with the appropriate policy. This can be done by adding those VMs to the exclusion list.
- Use the Applied To field in the DFW to limit the rule growth on individual vNICs.
- Choose the policy methodology and rule model to enable optimum groupings and policies for micro-segmentation.
- Use NSX-T tagging and grouping constructs to group an application or environment to its natural boundaries. This will enable simpler policy management.

- Consider the flexibility and simplicity of a policy model for Day-2 operations. It should address ever-changing deployment scenarios rather than simply be part of the initial setup.
- Leverage DFW category and policies to group and manage policies based on the chosen rule model. (e.g., emergency, infrastructure, environment, application...)
- Use an explicit allow model; create explicit rules for allowed traffic and change DFW the default rule from “allow” to “drop”.

5.11.1 A Practical Approach to Building Micro-Segmentation Policy

The ideal way to have least privilege security model is to define security policies explicitly allowing all the applications within your data center and denying all other traffic by default. However, it is a big challenge to profile tens/hundreds of applications and build security policies for each. Often times, application owners don’t know very much about their application’s details, which further complicates the process. This may take some time to profile your application and come up with a port defined security policy. Instead of waiting for profiling of an application to be complete, one can start with basic outside-in fencing approach to start defining broader security policies to enhancing the security posture and then move gradually to the desired explicit allow model over time as you complete the application profiling. The tag model of NSX allows this to be done quite easily as one can start with just Prod and Non-prod tags, then add more detailed tags as appropriate (PCI, HR, Finance, etc) to applicable VMs. (Note: Regardless of approach, experience has shown that the best starting point is common services such as DNS, NTP, AD, SNMP, etc. A great second step is the backup infrastructure.)

In this section we will walk you through a practical approach to start securing the data center workloads in a phased outside-in fencing approach as you are working on profiling your application to provide zero trust model.

First, we layout the data center topology and requirements. Then we will walk you through an approach to micro-segmentation policies in phases. This approach can be applied to both brownfield and green field deployment.

5.11.1.1 Data Center Topology and Requirements:

The following data center topology used which matches with most of our customer data center. This approach can be applied to both brownfield and greenfield deployment.

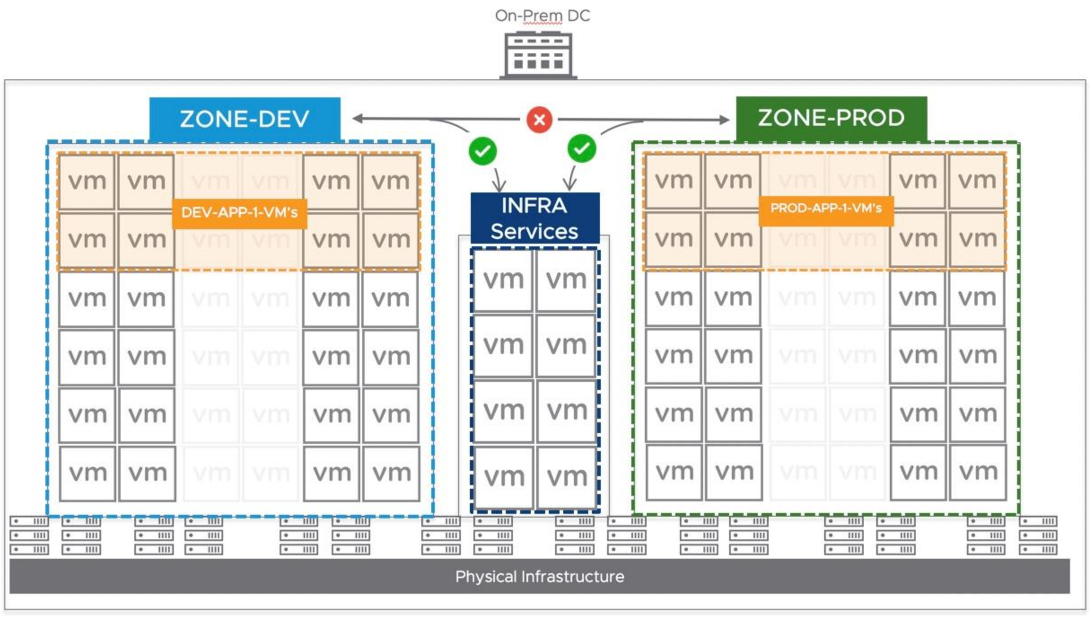


Figure 5-19: Data Center Topology Example

The data center has following characteristics:

1) Application deployment is split into two zones - production & development
2) Multiple applications hosted in both DEV and PROD ZONE
3) All application access same set of common services such as AD, DNS and NTP

The data center network has following characteristics:

1. The Zones have been assigned with dedicated IP CIDR block.
   1.1. Development zone has 10.1.16.0/20 and 10.1.32.0/20 IP CIDR block assigned
   1.2. Production zone has 10.2.16.0/20 and 10.2.32.0/20 IP CIDR block assigned.
   1.3. Infrastructure Services have 10.3.16.0/24 subnet assigned.
2. The application within the ZONE would be given IP subnets within that ZONE specific CIDR block.
3. In most cases application VM's belonging to same application share same L2 segments. In some cases, they have separate L2 segments, especially for Database's. (In brownfield environments where L2 segments may be mixed populations of workloads, one can easily create static groups of workloads.)

The data center security has following Requirements:

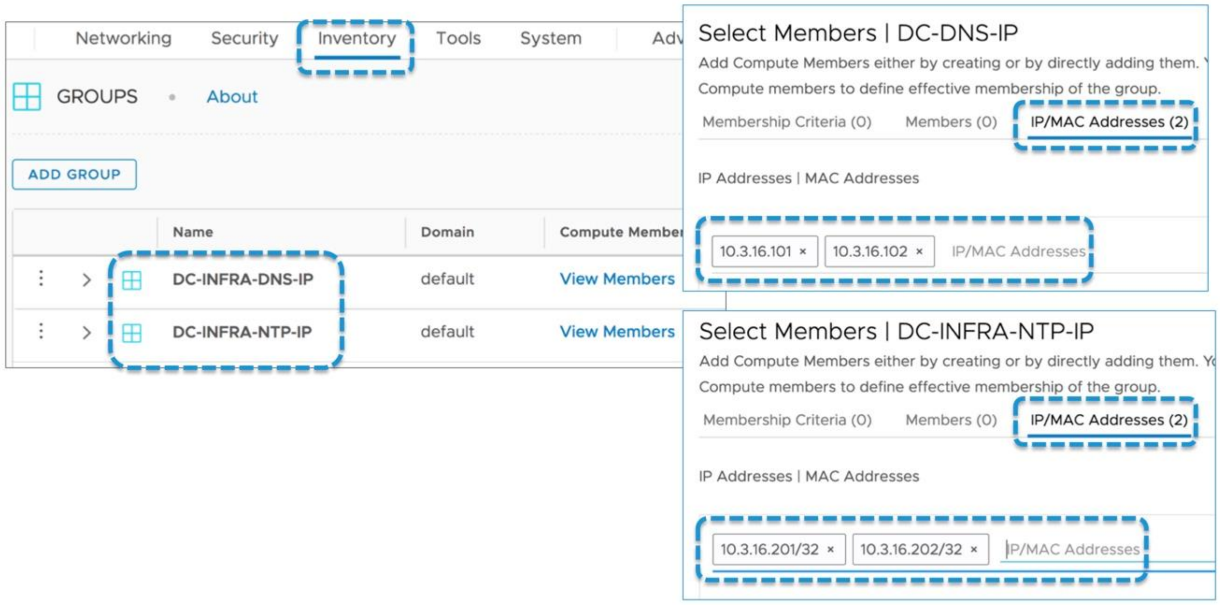
1) All applications need to be allowed communicate with common Infrastructure services.
2) Between the ZONE - Workloads should not be allowed to communicate with each other.
3) Within the ZONE - Applications VM's belonging to a certain application should not be talking to other application VM's.
4) Some application within a ZONE have common Database services which runs within that ZONE.
5) Log all unauthorized communication between workloads for monitoring and for compliance.

5.11.1.2 Phased approach for NSX-T micro-segmentation policies:

Phase-1: Define common-services policy.

Here are the suggested steps:

1. Define NSX-T Groups for each of the Infrastructure Services. Following example shows the group for DNS and NTP servers with IP addresses of the respective servers as group members.



Name	Domain	Compute Membe
DC-INFRA-DNS-IP	default	View Members
DC-INFRA-NTP-IP	default	View Members

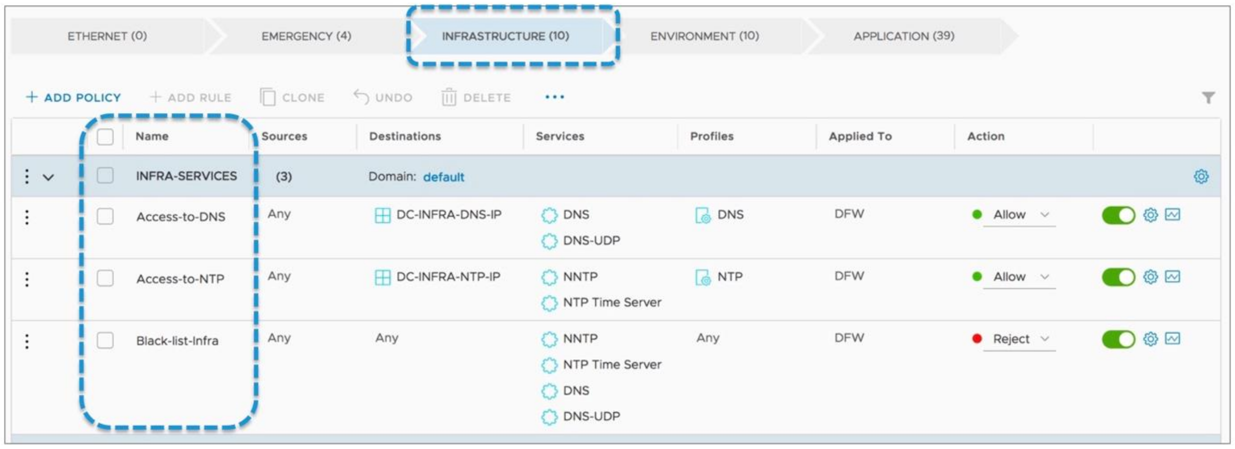
Select Members | DC-DNS-IP
Add Compute Members either by creating or by directly adding them.
Compute members to define effective membership of the group.
Membership Criteria (0) Members (0) IP/MAC Addresses (2)
IP Addresses | MAC Addresses
10.3.16.101 × 10.3.16.102 × IP/MAC Addresses

Select Members | DC-INFRA-NTP-IP
Add Compute Members either by creating or by directly adding them.
Compute members to define effective membership of the group.
Membership Criteria (0) Members (0) IP/MAC Addresses (2)
IP Addresses | MAC Addresses
10.3.16.201/32 × 10.3.16.202/32 × IP/MAC Addresses

Figure 5-20: NSX-T Groups Example

2. Define policy for common services; like DNS, NTP as in the figure below.
   a) Define this policy under Infrastructure tab as shown below.
   b) Have two rules allows all workloads to access the common services using GROUPS created in step 1 above.
   c) Use Layer 7 context profile, DNS and NTP, in the rule to further enhance the security posture.
   d) Have catch-all deny rule to deny any other destination for the common services with logging enabled, for compliance and monitoring any unauthorized communication.

Note: If the management entities are not in an exclusion list, this section would need to have rules to allow the required protocols between the appropriate entities. See https://ports.vmware.com/home/vSphere for the ports for all VMware products.



Name	Sources	Destinations	Services	Profiles	Applied To	Action
INFRA-SERVICES	(3)	Domain: default				
Access-to-DNS	Any	DC-INFRA-DNS-IP	DNS DNS-UDP	DNS	DFW	● Allow
Access-to-NTP	Any	DC-INFRA-NTP-IP	NNTP NTP Time Server	NTP	DFW	● Allow
Black-list-Infra	Any	Any	NNTP NTP Time Server DNS DNS-UDP	Any	DFW	● Reject

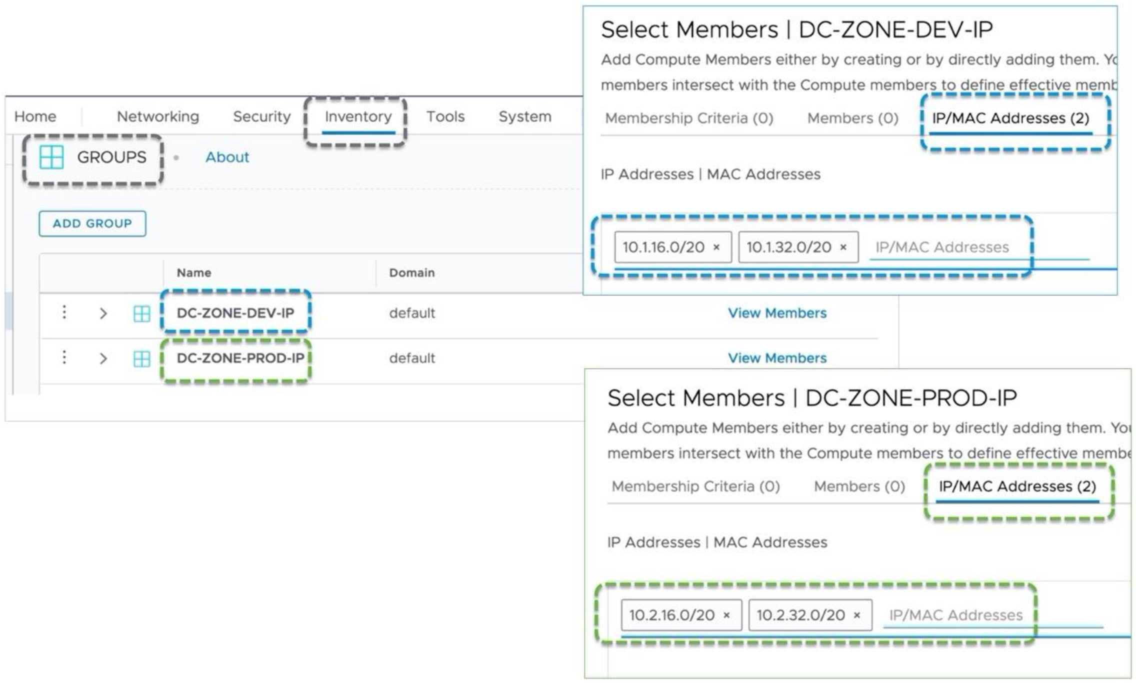
Figure 5-21: Common Services Policy Example

Phase-2: Define Segmentation around ZONES - by having an explicit allow policy between ZONES

As per the requirement, define policy between zones to deny any traffic between zones. This can be done using IP CIDR block as data center zones have pre-assigned IP CIDR block. Alternatively, this can be done using workload tags and other approach. However, IP-GROUP based approach is simpler (as admin has pre-assigned IP CIDR Block per zone), no additional workflow to tag workload and also less toll, compare to tagged approach, on NSX-T Manager and control plane. Tagged approach may add additional burden on NSX-T Manager to compute polices and update, in an environment with scale and churn. As a rule of thumb, the larger the IP block that can be defined in a rule, the more the policy can be optimized using CIDR blocks. In cases where there is no convenient CIDR block to group workloads, static groupings may be used to create entities without churn on the NSX Manager.

Here are the suggested steps:

1- Define 2 NSX-T Groups for each of the ZONE, Development and Production, say DC-ZONE-DEV-IP & DC-ZONE-PROD-IP with respective IP CIDR BLOCKs associated with the respective zones as members.


Home | Networking | Security | Inventory | Tools | System

GROUPS • About

ADD GROUP

	Name	Domain	
⋮ >	DC-ZONE-DEV-IP	default	View Members
⋮ >	DC-ZONE-PROD-IP	default	View Members

Select Members | DC-ZONE-DEV-IP

Add Compute Members either by creating or by directly adding them. Yo
members intersect with the Compute members to define effective memb

Membership Criteria (0) | Members (0) | IP/MAC Addresses (2)

IP Addresses | MAC Addresses

10.1.16.0/20 × | 10.1.32.0/20 × | IP/MAC Addresses

Select Members | DC-ZONE-PROD-IP

Add Compute Members either by creating or by directly adding them. You
members intersect with the Compute members to define effective membe

Membership Criteria (0) | Members (0) | IP/MAC Addresses (2)

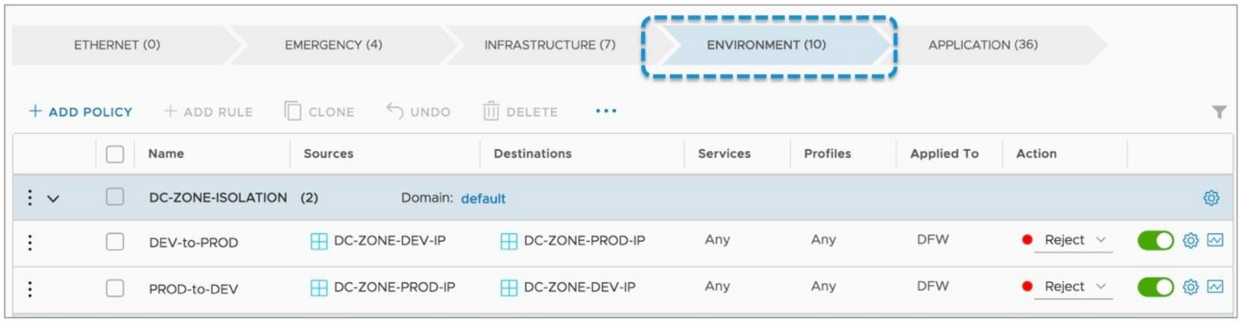
IP Addresses | MAC Addresses

10.2.16.0/20 × | 10.2.32.0/20 × | IP/MAC Addresses

Figure 5-22: Policies Between Zones Example

2- Define policy in environment category using the IP GROUPS created in step-1 to restrict all communication between Development and Production ZONE's.

3- Have logging enabled for this policy to track all unauthorized communication attempts. (Note: In many industries, it is sufficient to log only the default action for troubleshooting purposes. In others, there may be a compliance mandate to log every action. Logging requirements are driven by the balance between storage costs and compliance requirements.)


ETHERNET (0) | EMERGENCY (4) | INFRASTRUCTURE (7) | ENVIRONMENT (10) | APPLICATION (36)

+ ADD POLICY | + ADD RULE | CLONE | UNDO | DELETE | ...

Name	Sources	Destinations	Services	Profiles	Applied To	Action
DC-ZONE-ISOLATION (2)	Domain: default					
DEV-to-PROD	DC-ZONE-DEV-IP	DC-ZONE-PROD-IP	Any	Any	DFW	● Reject
PROD-to-DEV	DC-ZONE-PROD-IP	DC-ZONE-DEV-IP	Any	Any	DFW	● Reject

Figure 5-23: Policy Example

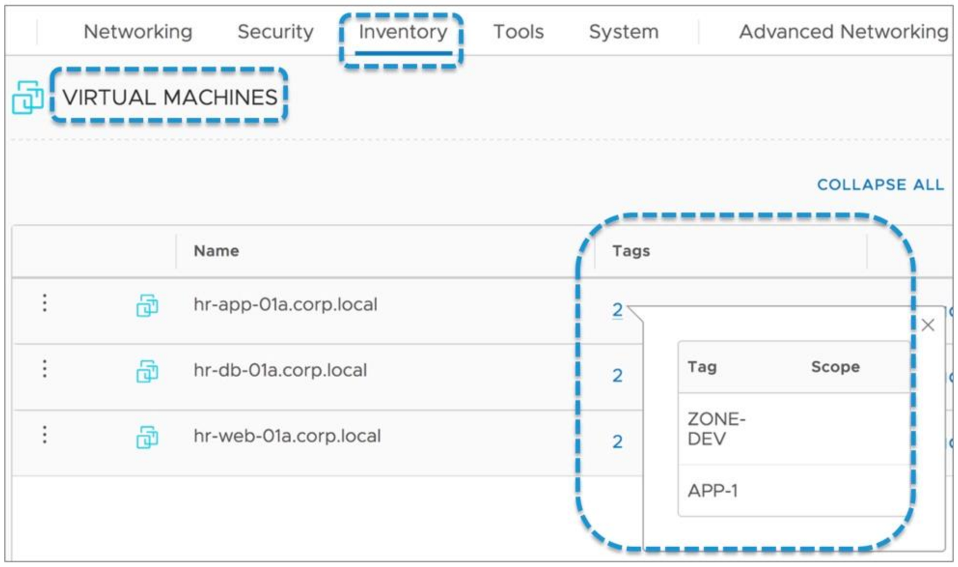
Phase-3: Define Segmentation around every Application, one at a time

This is two step approach to build a policy for the application. First step is to start with fence around application to build security boundary. Then as a second step profile the application further to plan and build more granular port-defined security policies between tiers.

- Start with DEV zone first and identify an application to be micro-segmented, say DEV-ZONE-APP-1.
- Identify all VM's associated with the Application within the zone.
- Check application has its own dedicated network Segments or IP Subnets.
    - If yes, you can leverage Segment or IP-based Group.
    - If no, tag application VM's with uniquely zone and application specific tags, say ZONE-DEV & APP-1.
- Check this application requires any other communication other than infra services and communication within group. For example, APP is accessed from outside on HTTPS.

Once you have above information about DEV-ZONE-APP-1, create segmentation around application by following steps:

1- Apply two tags to all the VM's belonging to APP-1 in the ZONE DEV, ZONE-DEV & APP-1.

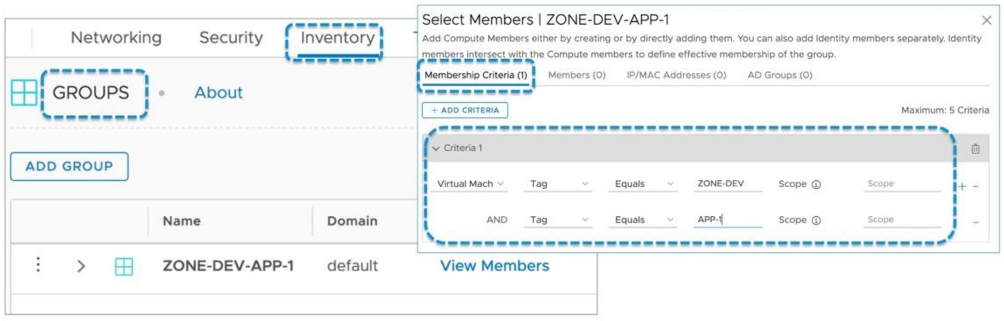


Name	Tags
hr-app-01a.corp.local	2
hr-db-01a.corp.local	2
hr-web-01a.corp.local	2

Tag	Scope
ZONE-DEV	
APP-1	

Figure 5-24: Segmentation Example

2- Create a GROUP, say "ZONE-DEV-APP-1" with criteria to match on tag equal to "ZONE-DEV & APP-1".



Add Compute Members either by creating or by directly adding them. You can also add Identity members separately. Identity members intersect with the Compute members to define effective membership of the group.

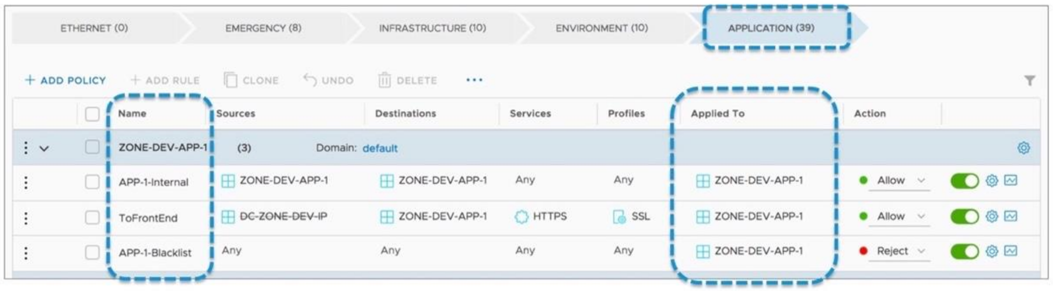
Virtual Mach	Tag	Equals	ZONE-DEV	Scope	Scope
AND	Tag	Equals	APP-1	Scope	Scope

Name	Domain	
ZONE-DEV-APP-1	default	View Members

Figure 5-25: Group Example

3- Define a policy under Application category with 3 rules as in the *Figure 5-26: Application Policy Example*.

a. Have "Applied To" set to "ZONE-DEV-APP-1" to limit the scope of policy only to the application VM's.
b. The first rule allows all internal communications between the application VM's. Enable logging for this rule to profile the application tiers and protocols. (Each log entry will contain 5 tuple details about every connection.)
c. The second rule allows access to front end of the application from outside. Use the L7 context profile to allow only SSL traffic. The below example uses Exclude Source from within ZONE, so that application is only accessible from outside, not from within except APP's other VM's, as per rule one.
d. Default deny all other communication to these "ZONE-DEV-APP-1" VM's. Enable log for compliance and monitoring any unauthorized communication.



Name	Sources	Destinations	Services	Profiles	Applied To	Action
ZONE-DEV-APP-1 (3) Domain: default						
APP-1-Internal	ZONE-DEV-APP-1	ZONE-DEV-APP-1	Any	Any	ZONE-DEV-APP-1	Allow
ToFrontEnd	DC-ZONE-DEV-IP	ZONE-DEV-APP-1	HTTPS	SSL	ZONE-DEV-APP-1	Allow
APP-1-Blacklist	Any	Any	Any	Any	ZONE-DEV-APP-1	Reject

Figure 5-26: Application Policy Example

Phase-4: Review Logs for Application Profile.

Log entries will identify the direction (In/Out) as well as the protocol and source IP address/port and destination IP addresses/port for each flow. If using the log file for policy definition, it is often advisable to process the log files using excel to sort traffic. Typically, 2 sheets are created, one for IN traffic and one for OUT traffic. Then, each sheet is sorted by port first then IP address. (In the case of IN traffic by destination IP address and in the case of OUT traffic by source address. This sorting methodology allows for the grouping of multiple servers serving/accessing the same traffic.) For each of these groupings, a rule can be inserted above rule 1 for the application. This will prevent the known traffic from appearing in the log. Once sufficient confidence is gained that the application is completely understood (this is typically when the logs are empty), the original rule ZONE-DEV-APP-1 can be removed. At this point, the security model has transitioned from zone-based to micro segmentation. (Note: Certain environments - such as labs - may be best served by ring fencing, whereas other environments may wish to add service insertion for certain traffic types on top of micro segmentation – such as sensitive financial information. The value of NSX is that a customer provides the means to implement appropriate security in one environment without impacting the other.)

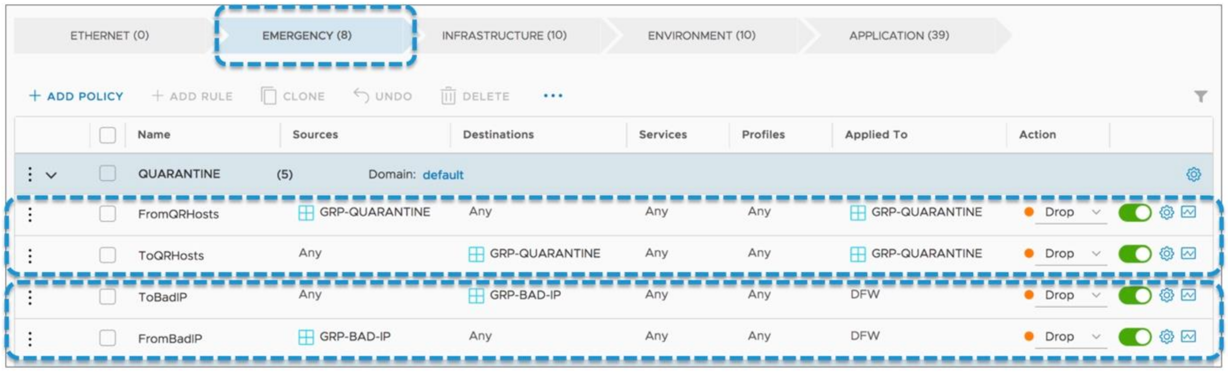
Phase-5: Repeat Phase-3 for other applications and ZONES.
Repeat the same approach as in Phase-3 for other applications, to have security boundary for every application within the ZONE-DEV and ZONE-PROD. Note that the securing of each of these applications can happen asynchronously, without impact to the others. This accommodates application-specific maintenance windows, where required.

Phase-6: Define Emergency policy, Kill Switch, in case of Security Event
An emergency policy mainly leveraged for following use case and enforced on top of the firewall table:

1- To quarantine vulnerable or compromised workloads in order to protect other workloads.
2- May want to explicitly deny known bad actors by their IP Subnet based on GEO location or reputation.

This policy is defined in Emergency Category as shown:

1- First two rules quarantine all traffic from workloads belonging to group GRP-QUARANTINE.
    a. "GRP-QUARANTINE" is a group which matches all VM with tag equal to "QUARANTINE". (If guest introspection is implemented, the AV/AM tags can be used to define different quarantine levels.)
    b. In order to enforce this policy to vulnerable VM's, add tag "QUARANTINE" to isolate the VM's and allow only admin to access the hosts to fix the vulnerability.
2- Other two rule uses Group with known bad IP's to stop any communication with those IP's.



Name	Sources	Destinations	Services	Profiles	Applied To	Action
QUARANTINE (5) Domain: default						
FromQRHosts	GRP-QUARANTINE	Any	Any	Any	GRP-QUARANTINE	Drop
ToQRHosts	Any	GRP-QUARANTINE	Any	Any	GRP-QUARANTINE	Drop
ToBadIP	Any	GRP-BAD-IP	Any	Any	DFW	Drop
FromBadIP	GRP-BAD-IP	Any	Any	Any	DFW	Drop

Figure 5-27: Emergency Category Example

In creating these policies, the iterative addition of rules to the policy is something that can be done at any time. It is only when the action of the default rule changes from allow to deny/drop that a maintenance window is advised. As logging has been on throughout the process, it is highly unusual to see an application break during the window. What is most frequently the case is that something within the next week or month may emerge as an unforeseen rule that was missed. For this reason, it is advised that even in environments where compliance does not dictate the collection of logs, the Deny All rule be set to logging. Aside from the security value of understanding the traffic that is being blocked, the Deny All rule logs are very useful when troubleshooting applications.

At this point you have basic level of micro-segmentation policy applied to all the workloads to shrink the attack surface. As a next step you further break the application into application tiers and its communication by profiling application flows using firewall logs or exporting IPFIX flows to Network Insight platform. This will help to group the application workload based on the function within the application and define policy based on associated port & protocols used. Once you have these groupings and protocols identified for a given application, update the policy for that application by creating additional groups and rules with right protocols to have granularly defined rules one at a time.

With this approach you start with outside-in fencing to start with micro-segmentation policies and finally come up with a granular port-based micro-segmentation policy for all the application.

5.12 NSX Firewall- For All Deployment Scenario

NSX firewall provides different security controls: Distribute Firewall, Distributed IDS, Gateway Firewall & Bridge Firewall, as an option to provide firewalling to different deployment scenarios.

A typical data center would have different workloads: VM's, Containers, Physical Server, and a mix of NSX managed and non-managed workloads. These workloads may also have a combination of a VLAN-based network or an NSX based overlay network.

The following *Figure 5-28: NSX Firewall For all Deployment Scenario* summarizes different datacenter deployment scenarios and associated NSX firewall security controls, which best fits the design. You can use same NSX manager as a single pane of glass to define Security policies to all of these different scenarios using different security controls.

1- NSX Managed Workloads with standard VLAN based networking.
- NSX Distributed Firewall can be used to protect NSX managed VM's, Containers & Physical Server workloads.

2- NSX Managed Workloads with NSX Overlay for networking:
- NSX Distributed Firewall can be used to protect NSX managed VM's, Containers & Physical Server workloads.

3- Non-NSX Managed workloads on traditional VLAN based network.
- NSX Gateway Firewall can provide the Inter VLAN routing and Firewalling. The Service Interface on NSX Gateway is used as a gateway & firewall for all non-NSX managed VLAN workloads.

4- NSX managed Overlay workload bridged to Non-NSX managed VLAN.
- This is the bridge scenario where an Overlay network is extended at Laye-2 into a VLAN network using NSX Bridge. In this case, NSX managed Overlay workloads can use

DFW/D-IDS, and Bridge Firewall can secure traffic at the boundary between VLAN and overlay network.

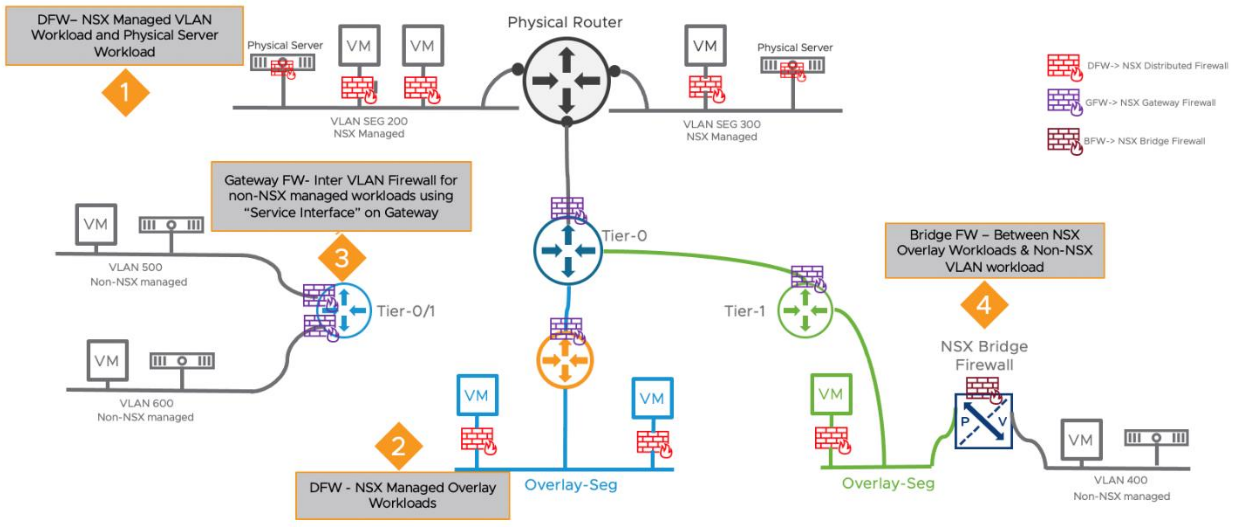

DFW– NSX Managed VLAN Workload and Physical Server Workload
1
Physical Server
VM
VM
Physical Router
VM
Physical Server
VLAN SEG 200 NSX Managed
VLAN SEG 300 NSX Managed
DFW-> NSX Distributed Firewall
GFW-> NSX Gateway Firewall
BFW-> NSX Bridge Firewall
Gateway FW- Inter VLAN Firewall for non-NSX managed workloads using "Service Interface" on Gateway
3
VM
VLAN 500 Non-NSX managed
Tier-0
Tier-0/1
VM
VLAN 600 Non-NSX managed
Bridge FW – Between NSX Overlay Workloads & Non-NSX VLAN workload
4
Tier-1
NSX Bridge Firewall
VM
VM
VM
P
V
VM
2
DFW - NSX Managed Overlay Workloads
Overlay-Seg
Overlay-Seg
VLAN 400 Non-NSX managed

Figure 5-28: NSX Firewall For all Deployment Scenario

6 NSX-T Load Balancer

A load-balancer defines a virtual service, or virtual server, identified by a virtual IP address (VIP) and a UDP/TCP port. This virtual server offers an external representation of an application while decoupling it from its physical implementation: traffic received by the load balancer can be distributed to other network-attached devices that will perform the service as if it was handled by the virtual server itself. This model is popular as it provides benefits for application scale-out and high-availability:

- **Application scale-out**:
  The following diagram represents traffic sent by users to the VIP of a virtual server, running on a load balancer. This traffic is distributed across the members of a pre-defined pool of capacity.

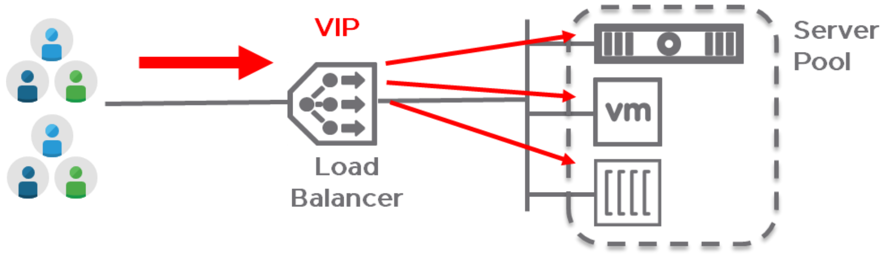


Figure 6-1: Load Balancing Offers Application Scale-out

  The server pool can include an arbitrary mix of physical servers, VMs or containers that together, allow scaling out the application.

- **Application high-availability**:
  The load balancer is also tracking the health of the servers and can transparently remove a failing server from the pool, redistributing the traffic it was handling to the other members:

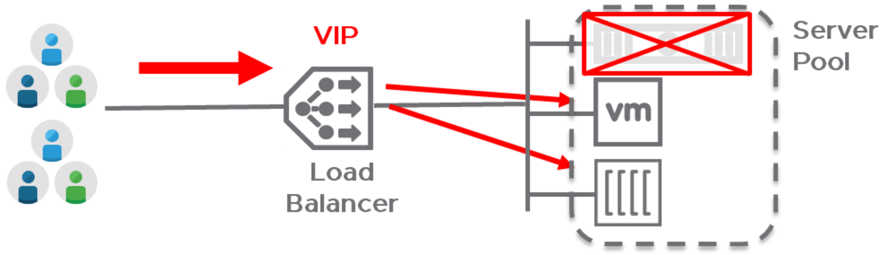


Figure 6-2: Load Balancing Offers Application High-availability

Modern applications are often built around **advanced load balancing** capabilities, which go far beyond the initial benefits of scale and availability. In the example below, the load balancer selects different target servers based on the URL of the requests received at the VIP:

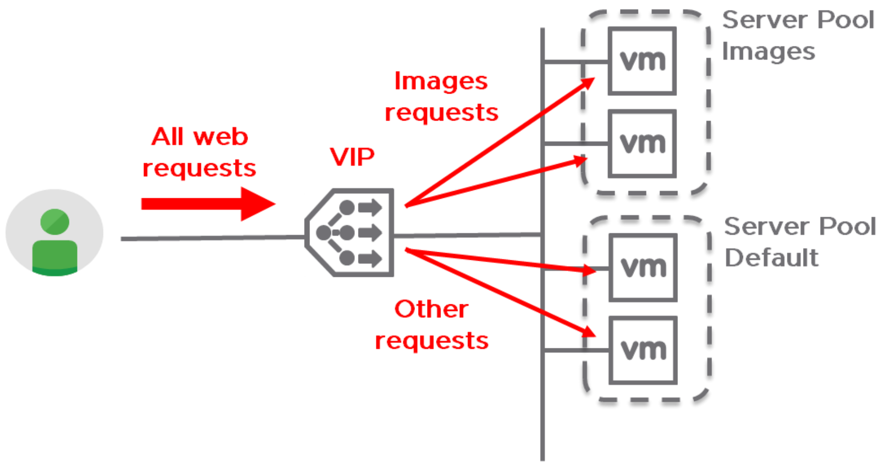


Figure 6-3: Load Balancing Offers Advanced Application Load Balancing

Thanks to its native capabilities, modern applications can be deployed in NSX-T without requiring any third party physical or virtual load balancer. The next sections in this part describe the architecture of the NSX-T load balancer and its deployment modes.

6.1 NSX-T Load Balancing Architecture

In order to make its adoption straightforward, the different constructs associated to the NSX-T load balancer have been kept similar to those of a physical load balancer. The following diagram show a logical view of those components.

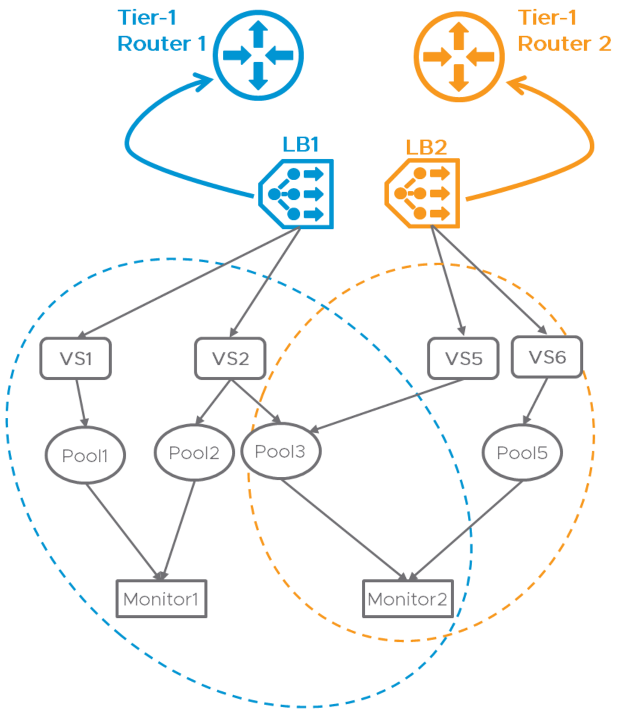


Figure 6-4: NSX-T Load Balancing Main Components

Load Balancer
The NSX-T load balancer is running on a Tier-1 gateway. The arrows in the above diagram represent a dependency: the two load balancers LB1 and LB2 are respectively attached to the Tier-1 gateways 1 and 2. Load balancers can only be attached to Tier-1 gateways (not Tier-0 gateways), and one Tier-1 gateway can only have one load balancer attached to it.

Virtual Server
On a load balancer, the user can define one or more virtual server (the maximum number depends on the load balancer form factor – See NSX-T Administrator Guide for load balancer scale information). As mentioned earlier, a virtual server is defined by a VIP and a TCP/UDP port number, for example IP: 20.20.20.20 TCP port 80. The diagram represents four virtual servers VS1, VS2, VS5 and VS6. A virtual server can have basic or advanced load balancing options such as forward specific client requests to specific pools (see below), or redirect them to external sites, or even block them.

Pool
A pool is a construct grouping servers hosting the same application. Grouping can be configured using server IP addresses or for more flexibility using Groups. NSX-T provides advanced load balancing rules that allow a virtual server to forward traffic to multiple pools. In the above diagram for example, virtual server VS2 could load balance image requests to Pool2, while directing other requests to Pool3.

Monitor
A monitor defines how the load balancer tests application availability. Those tests can range from basic ICMP requests to matching patterns in complex HTTPS queries. The health of the individual pool members is then validated according to a simple check (server replied), or more advanced ones, like checking whether a web page response contains a specific string.
Monitors are specified by pools: a single pool can use only 1 monitor, but the same monitor can be used by different Pools.

6.2 NSX-T Load Balancing deployment modes

NSX-T load balancer is flexible and can be installed in either traditional in-line or one-arm topologies. This section goes over each of those options and examine their traffic patterns.

6.2.1 In-line load balancing

In in-line load balancing mode, the clients and the pool servers are on different side of the load balancer. In the design below, the clients are on the Tier-1 uplink side, and servers are on the Tier-1 downlink side:

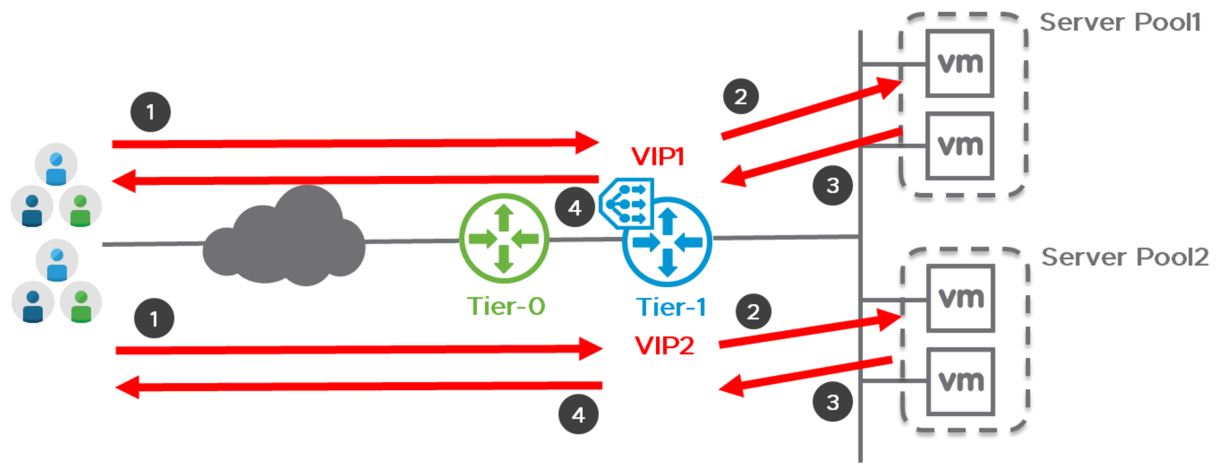


Figure 6-5: In-Line Load Balancing

Because the traffic between client and servers necessarily go through the load-balancer, there is no need to perform any LB Source-NAT (Load Balancer Network Address Translation at virtual server VIP).

The in-line mode is the simplest load-balancer deployment model. Its main benefit is that the pool members can directly identify the clients from the source IP address, which is passed unchanged (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 are 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.

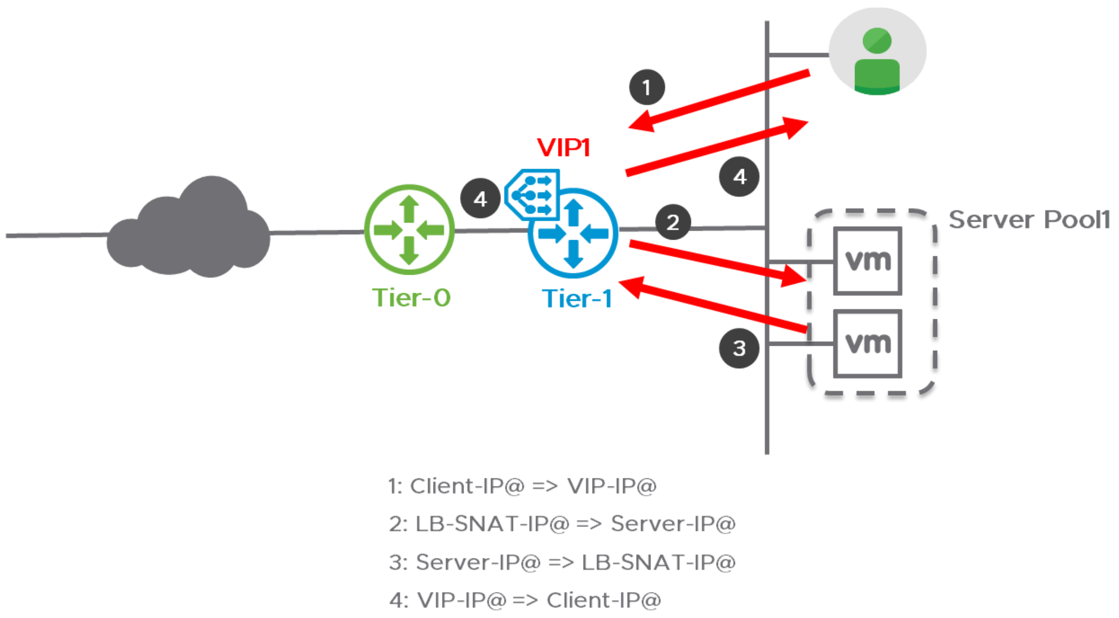
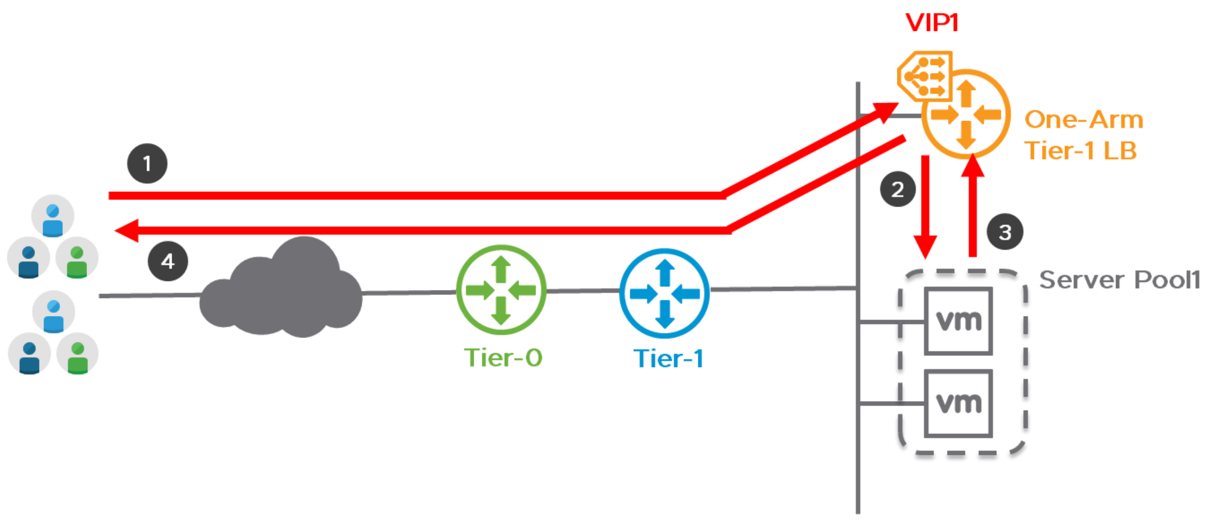


Figure 6-6: One-Arm Load Balancing with Clients and Servers on the same segment

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

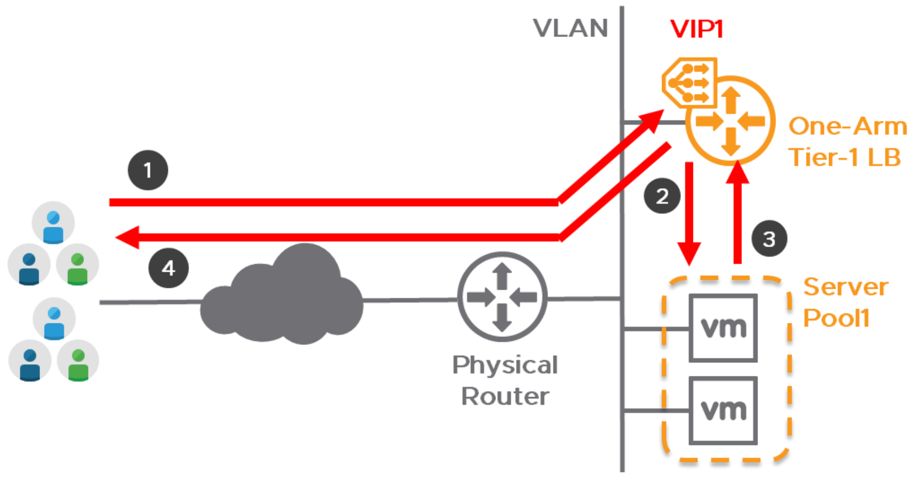
In the design below, the blue Tier-1 gateway does not run any load-balancer service. Instead, the load-balancer has been deployed as a standalone Tier-1 gateway (represented in orange in the diagram), with a single Service Interface. This gateway is acting as an appliance instantiating a load-balancer. This way, several segments below the blue Tier-1 gateway can have their own dedicated load-balancer.



1: Client-IP@ => VIP-IP@
2: LB-SNAT-IP@ => Server-IP@
3: Server-IP@ => LB-SNAT-IP@
4: VIP-IP@ => Client-IP@

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.



1: Client-IP@ => VIP-IP@
2: LB-SNAT-IP@ => Server-IP@
3: Server-IP@ => LB-SNAT-IP@
4: VIP-IP@ => Client-IP@

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.

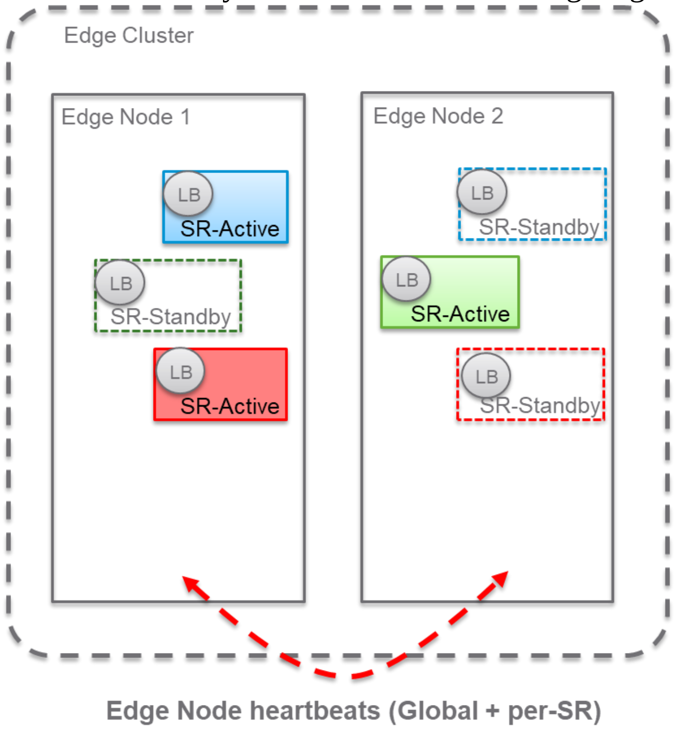


Figure 6-9: Load Balancing High-Availability

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.

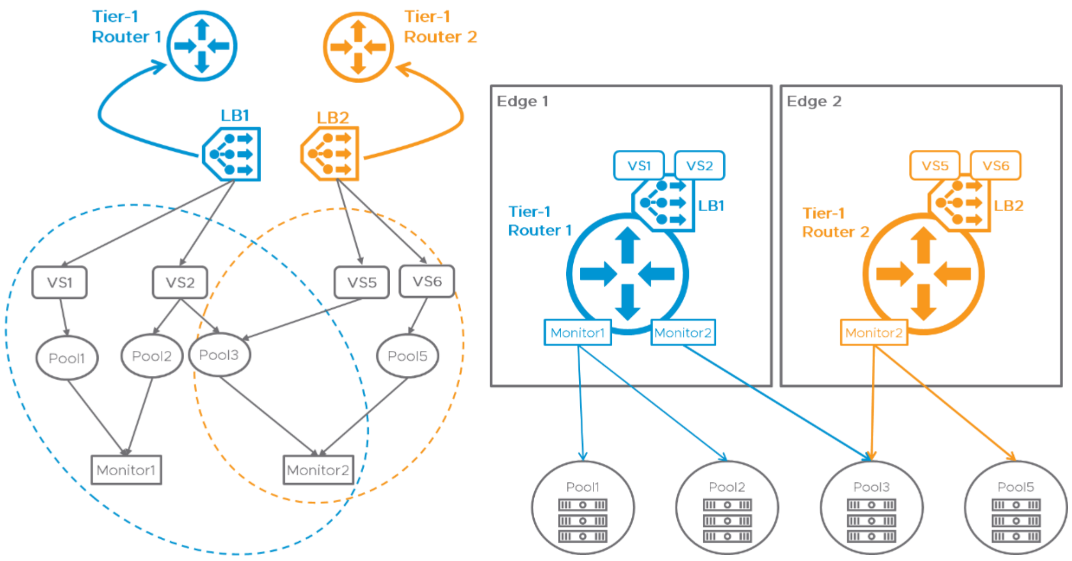


Figure 6-10: NSX-T Load Balancer Monitor

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 VS5 and VS6.
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.

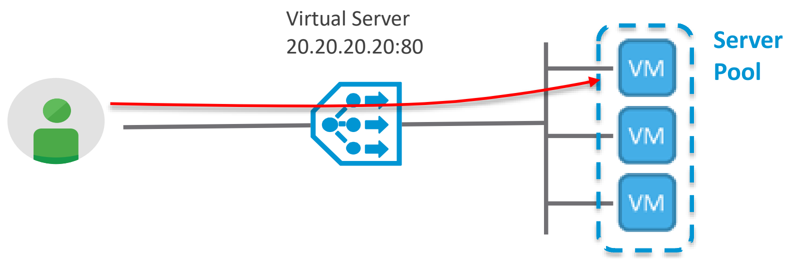


Figure 6-11: NSX-T L4 VIP

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.

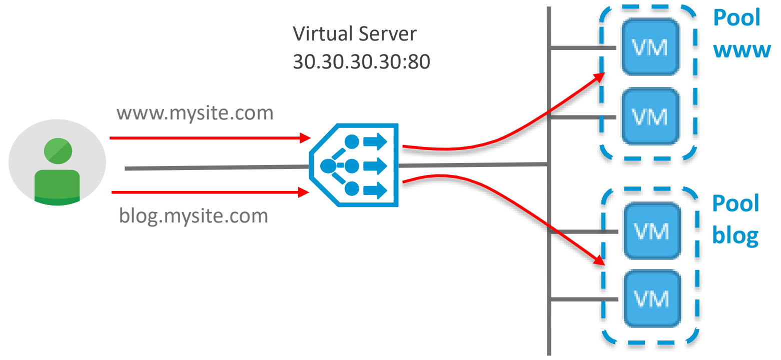


Figure 6-12: NSX-T L7 VIP

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.

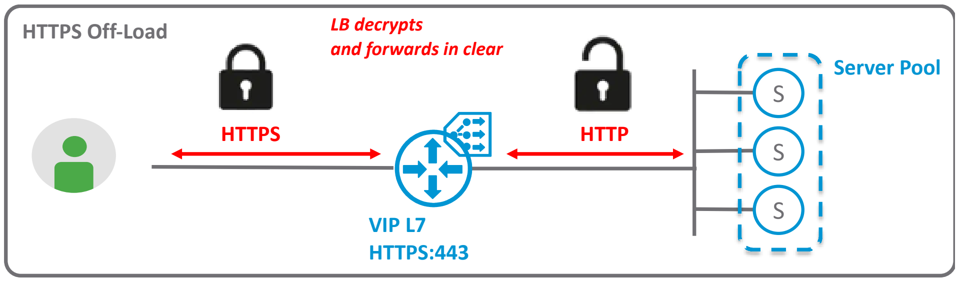


Figure 6-13: NSX-T L7 HTTPS Off-Load VIP

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.

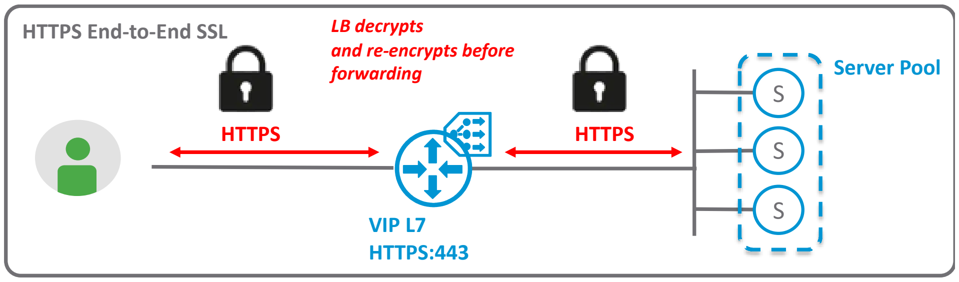


Figure 6-14: NSX-T L7 HTTPS End-to-End VIP

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.

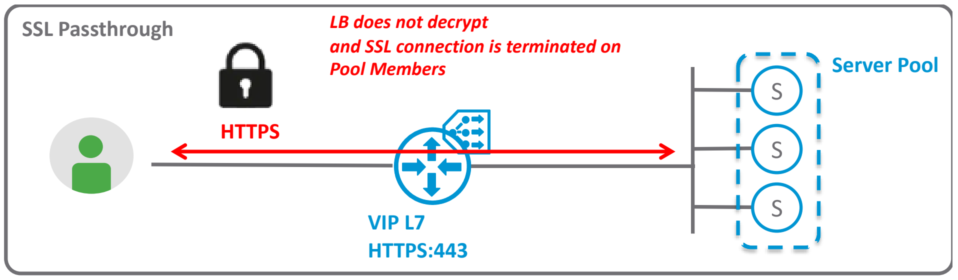


Figure 6-15: NSX-T L7 SSL Passthrough VIP

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.

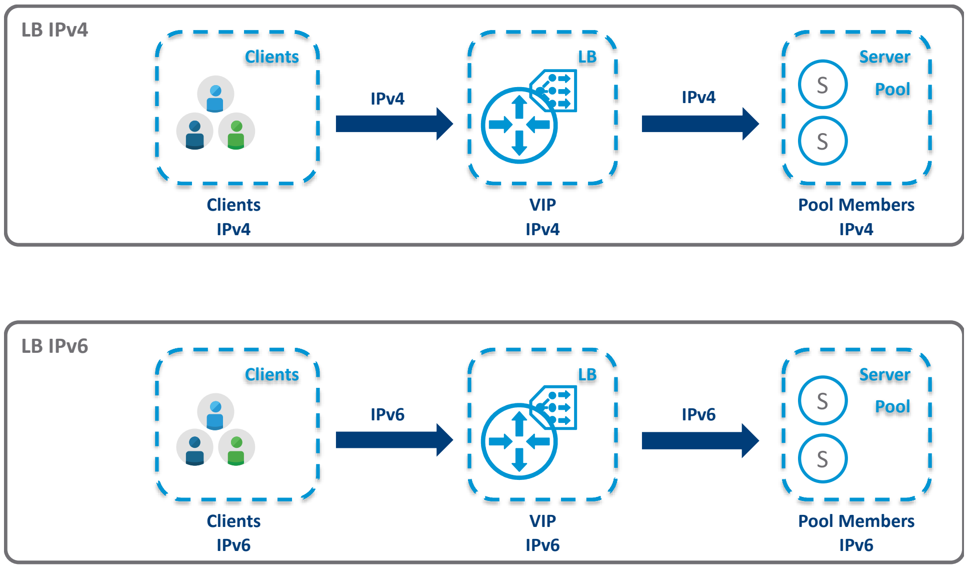


Figure 6-16: NSX-T LB IPv4 and IPv6

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:

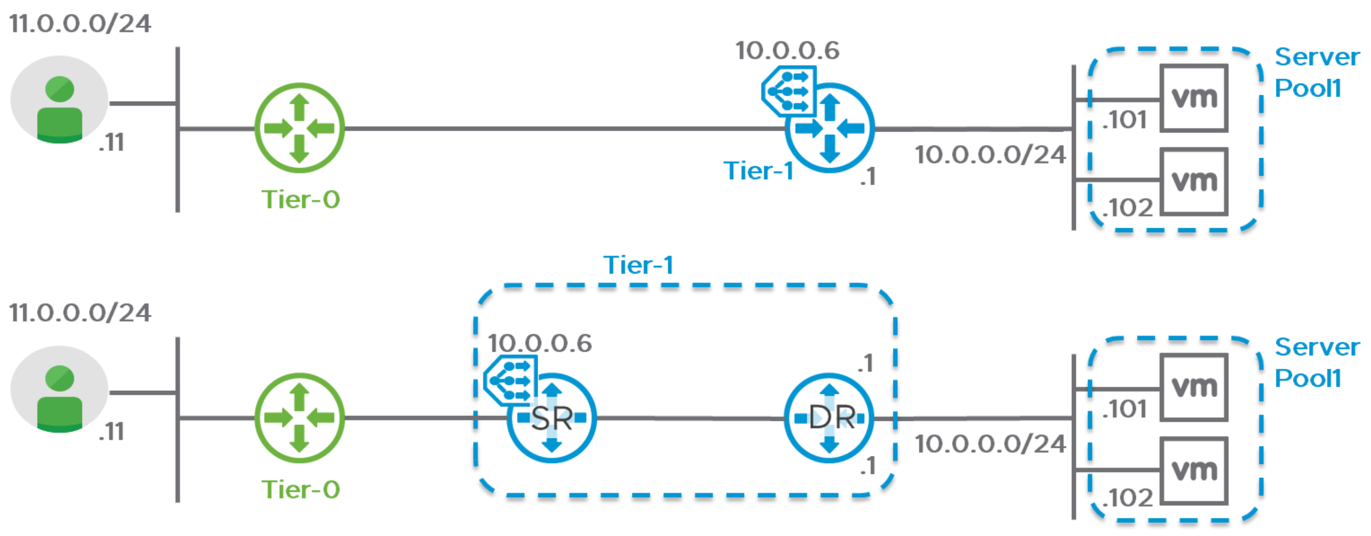


Figure 6-17: In-Line Model: Logical and Expanded View

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.

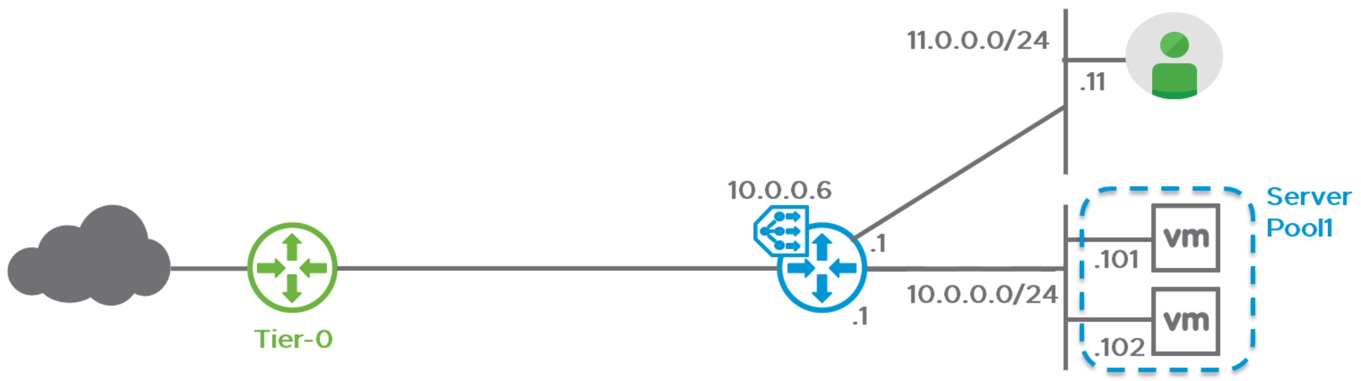


Figure 6-18: Load Balancing VIP IP@ in Tier-1 Downlink Subnet – Tier-1 Expanded View

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:

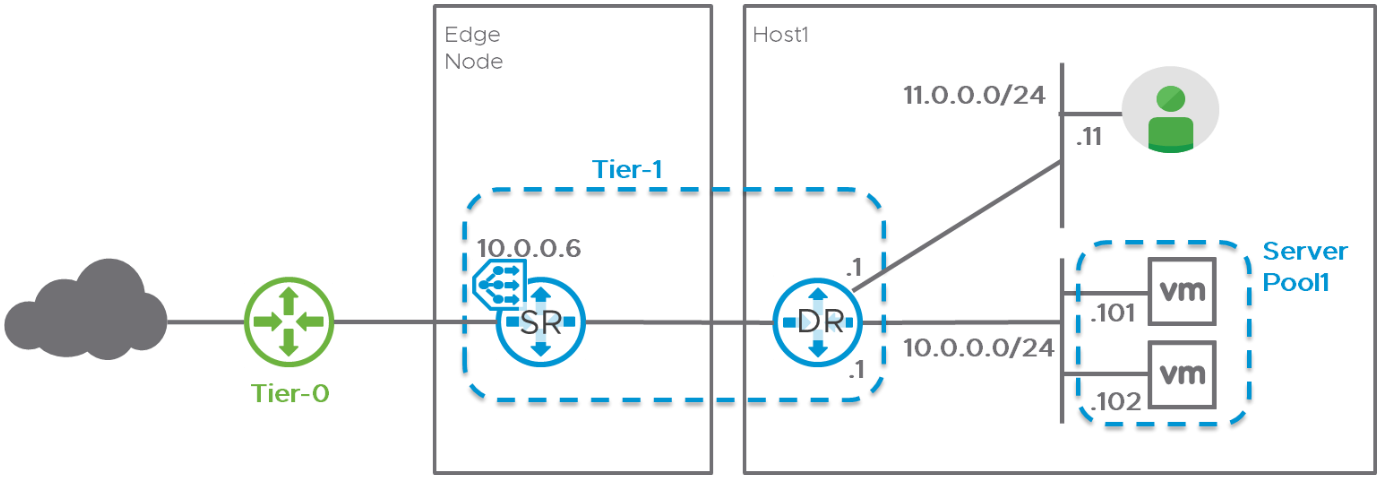


Figure 6-19: Load Balancing VIP IP@ in Tier-1 Downlink Subnet – Tier-1 Expanded View

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.

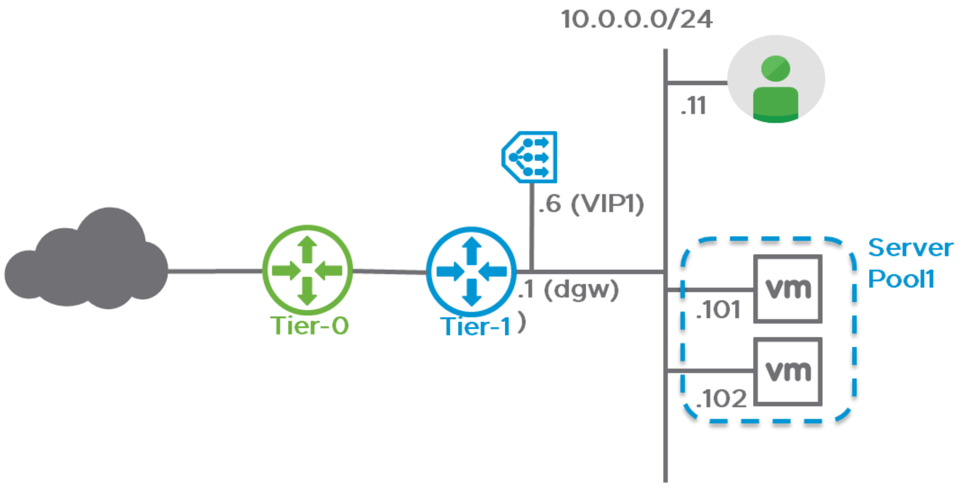
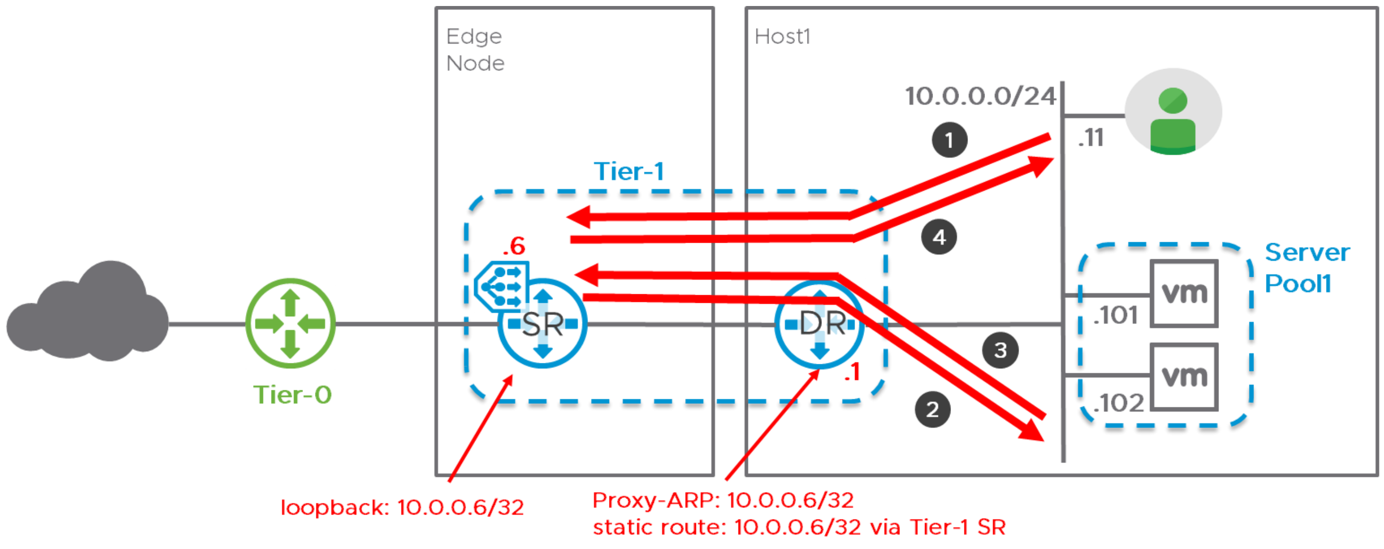


Figure 6-20: Load Balancing VIP IP@ in Tier-1 Downlink Subnet – Logical View

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.)



1: Client-IP@ (10.0.0.11) => VIP-IP@ (10.0.0.6)
2: LB-SNAT-IP@ (100.64.16.3) => Server-IP@ (10.0.0.101)
3: Server-IP@ (10.0.0.101) => LB-SNAT-IP@ (100.64.16.3)
4: VIP-IP@ (10.0.0.6) => Client-IP@ (10.0.0.11)

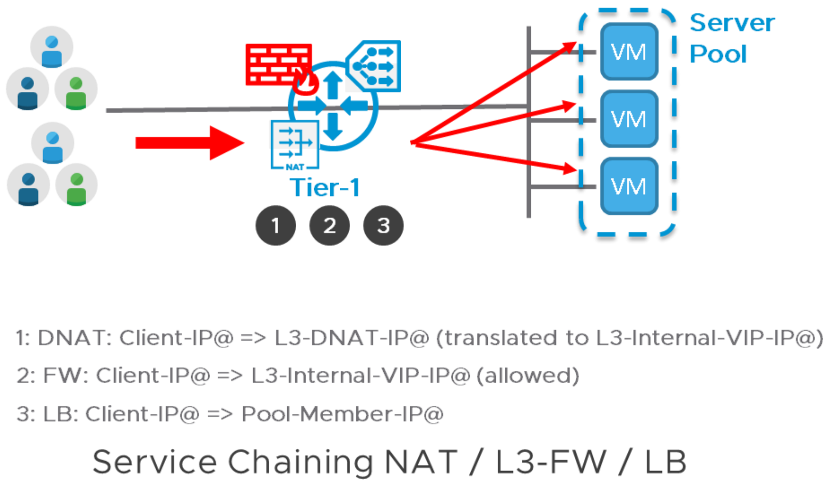
Figure 6-21: Load Balancing VIP IP@ in Tier-1 Downlink Subnet – Tier-1 Expanded View

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.



1: DNAT: Client-IP@ => L3-DNAT-IP@ (translated to L3-Internal-VIP-IP@)

2: FW: Client-IP@ => L3-Internal-VIP-IP@ (allowed)

3: LB: Client-IP@ => Pool-Member-IP@

Service Chaining NAT / L3-FW / LB

Figure 6-22: LB + NAT + FW Services Chaining

7 NSX-T Design Considerations

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 aforementioned connectivity problems.

Once above requirements are met, NSX can be deployment is agnostic to variety of underlay topology and configurations viz:

- 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 business impact with new code versions prior to upgrading those with greater production impact. The tradeoffs of failure domain radius and expense are similar to those in legacy infrastructure and beyond the scope of this document.

This design 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-leaf-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.

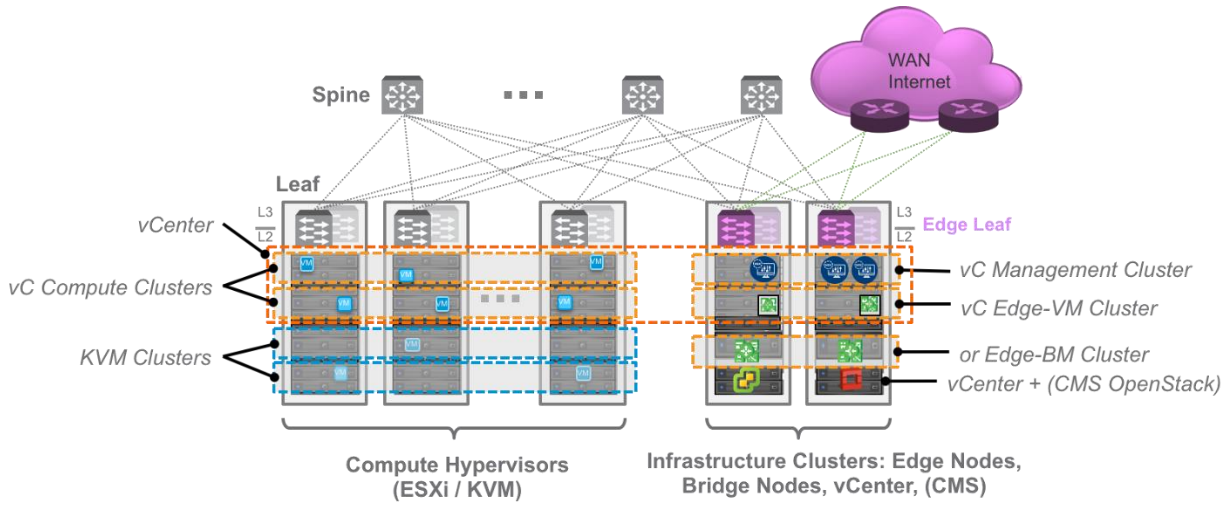


Figure 7-1: Typical Enterprise Design

A layer 2 fabric would also be a valid option, for which there would be no L2/L3 boundary at the TOR switch.

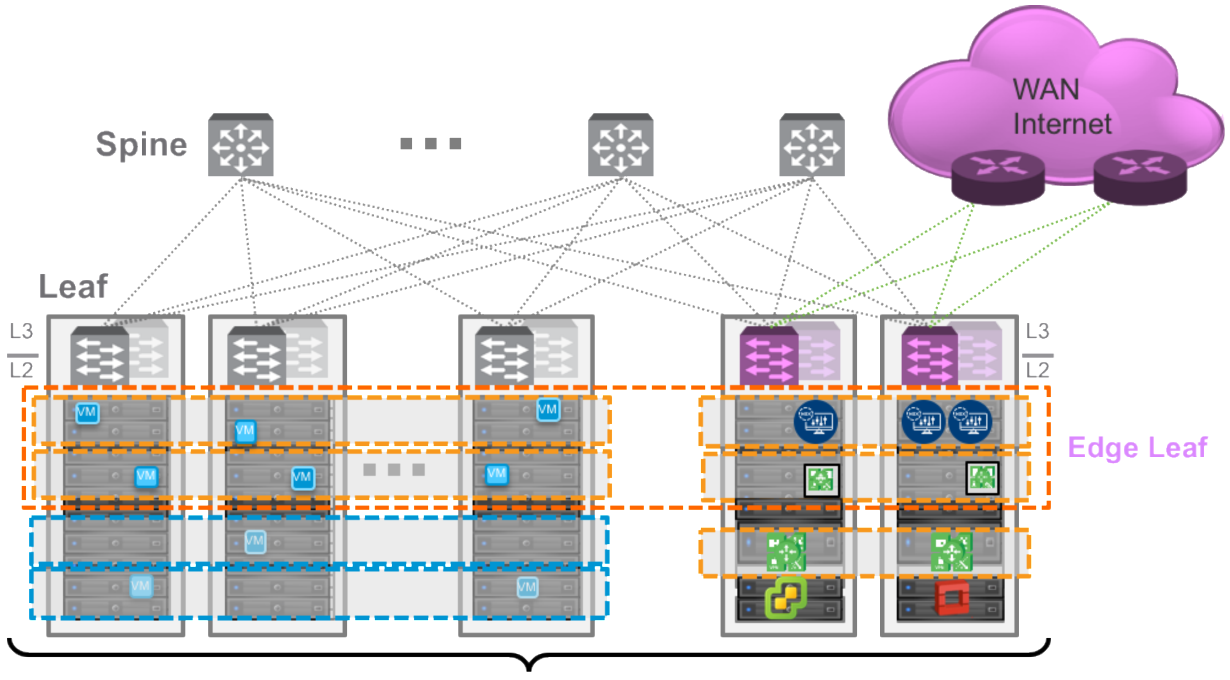
Multiple compute racks are configured to host compute hypervisors (e.g., ESXi, KVM) for the application VMs. Compute racks typically have the same structure and the same rack connectivity, allowing for cookie-cutter deployment. Compute clusters are placed horizontally between racks to protect against rack failures or loss of connectivity.

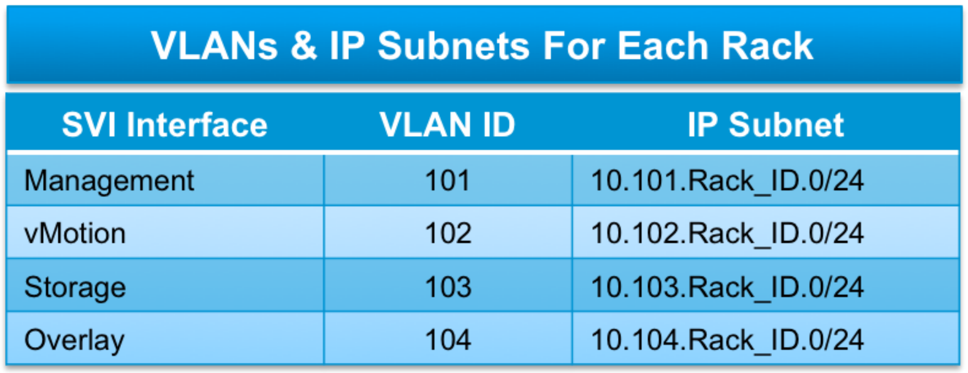
Several racks are designed to the infrastructure. These racks host:

- 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.





VLANs & IP Subnets For Each Rack

SVI Interface	VLAN ID	IP Subnet
Management	101	10.101.Rack_ID.0/24
vMotion	102	10.102.Rack_ID.0/24
Storage	103	10.103.Rack_ID.0/24
Overlay	104	10.104.Rack_ID.0/24

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 https://ports.vmware.com/home/NSX-T-Data-Center.

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 shows ESXi hypervisors in the management rack hosting three NSX-T Manager appliances.

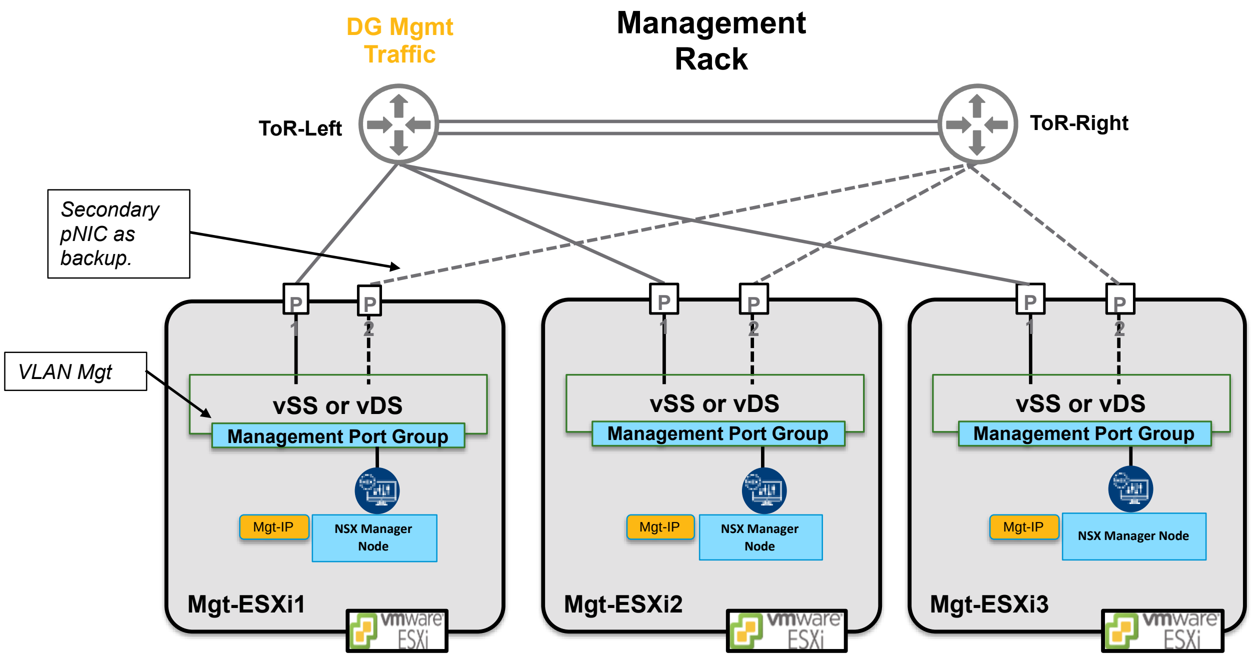


Figure 7-3: ESXi Hypervisor in the Management Rack

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.

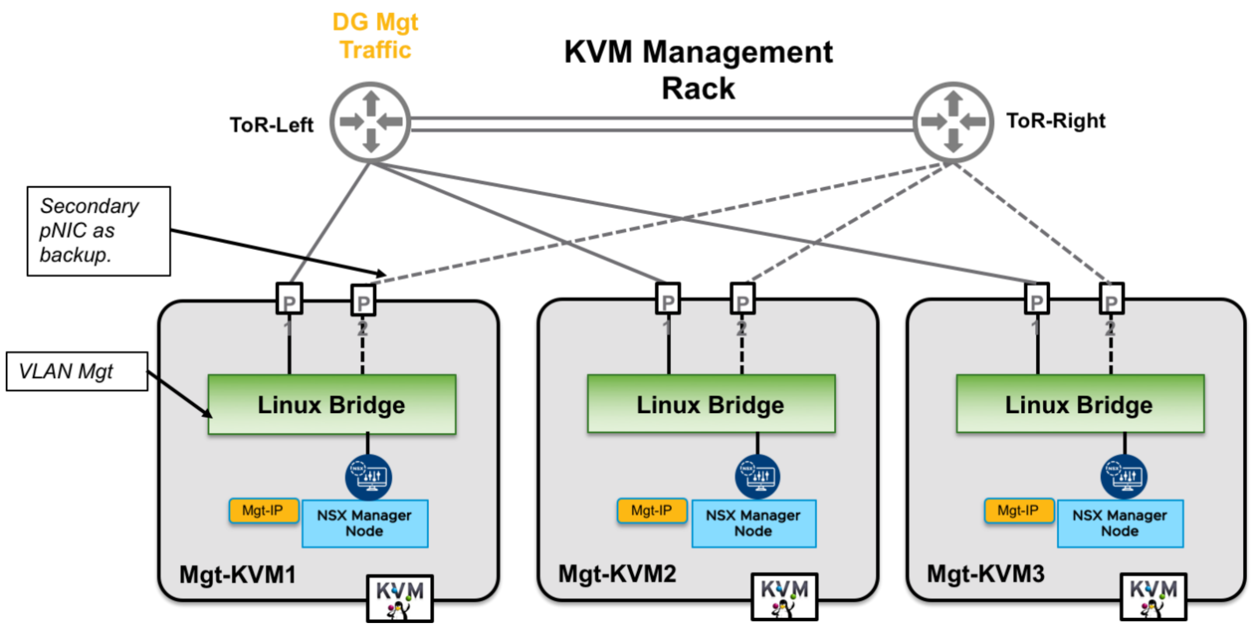


Figure 7-4: KVM Hypervisors in the Management Rack

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 Management 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. It is recommended to spread the deployment of the NSX-T Manager Nodes across separate failure domains to ensure that a single failure 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 nodes 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 deployed in a KVM hypervisor environment.

Additional considerations apply for management Cluster with respect to storage availability and IO consistency. A failure of a datastore should not trigger a loss of Manager Node majority, and the IO access must not be oversubscribed such that it causes unpredictable latency where a Manager node goes into read only mode due to lack of write access. If a single vSAN data store is being used to host NSX-T Manager cluster, additional steps should be taken to reduce the probability of a complete data store failure some of which are addressed in Physical placement considerations for the NSX-T Manager Nodes below. It is also recommended to reserve resources in CPU and memory according to their respective requirements. Please refer to the following links for details

NSX-T Manager Sizing and Requirements:
https://docs.vmware.com/en/VMware-NSX-T-Data-Center/3.0/installation/GUID-AECA2EE0-90FC-48C4-8EDB-66517ACFE415.html

NSX-T Manager Cluster Requirements with HA, Latency and Multi-site:
https://docs.vmware.com/en/VMware-NSX-T-Data-Center/3.0/installation/GUID-509E40D3-1CD5-4964-A612-0C9FA32AE3C0.html

7.2.2 Physical placement considerations for the NSX-T Manager Nodes

The NSX-T Manager Nodes that make up the NSX-T Management Cluster are not required to exist in a single vSphere Cluster or even under a single vCenter as long as the vCenter(s) that they are deployed to are loaded as a Compute Manager and that the IP Connectivity Requirements between the nodes are met. Predominantly however, the most common placement of the NSX-T Manager Nodes is into a single vSphere cluster and in some cases, they may be spread across three vSphere clusters based on a number of factors relating to availability.

Single vSphere Cluster for all NSX-T Manager Nodes in a Manager Cluster
When all NSX-T Manager Nodes are deployed into a single vSphere cluster it is important to design that cluster to meet the needs of the NSX-T Managers with at least the following:

1. At least 4 vSphere Hosts. This is to adhere with best practices around vSphere HA and vSphere Dynamic Resource Scheduling (DRS) as well as allowing all three NSX Manager Nodes to remain available during proactive maintenance or a failure scenario.
2. The hosts should all have access to the same data stores hosting the NSX-T Manager Nodes to enable both DRS and vSphere HA

3. Each NSX-T Manager Node should be deployed onto a different data store (this is supported as a VMFS, NFS, or other data store technology supported by vSphere)
4. DRS Anti-Affinity rules should be put in place to prevent whenever possible two Edge Node VMs from running on the same host.
5. During lifecycle events of this cluster, each node should be independently put into maintenance mode moving any running NSX-T Manager Node off of the host prior to maintenance or any NSX-T Manager Node should be manually moved to a different host.
6. If possible, a rack level or critical infrastructure (e.g. Power, HVAC, ToRs) should also be taken into account to protect this cluster from any single failure event taking down the entire cluster at once. In many cases this means spreading this cluster across multiple cabinets or racks and therefore connecting the hosts in it to a diverse set of physical switches etc.
7. NSX-T Manager backups should be configured and pointed to a location that is running outside of the vSphere Cluster that the NSX Manager Nodes are deployed on.

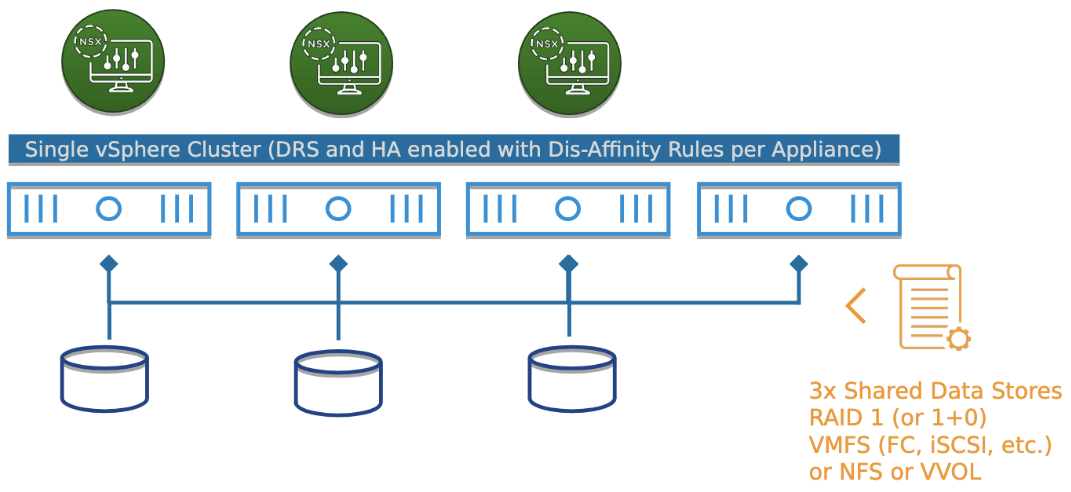

NSX
NSX
NSX
Single vSphere Cluster (DRS and HA enabled with Dis-Affinity Rules per Appliance)
3x Shared Data Stores
RAID 1 (or 1+0)
VMFS (FC, iSCSI, etc.)
or NFS or VVOL

Figure 7-5: Single vSphere Cluster 1:1 Data Store

Single vSphere Cluster when leveraging VSAN as the storage technology
When all NSX-T Manager Nodes are deployed into a single vSphere cluster where VSAN is the storage technology in use there are additional steps that should be taken to protect the NSX Manager Cluster's availability since only a single data store will be presented. VSAN as a part of a HyperConverged Infrastructure solution ties together the Compute, Memory, and Storage resources on a host along with ESXi as the hypervisor to present a single scale-out unit of infrastructure for hosting Virtual Machines, Containers, or even now network attached storage type objects as a single pool across the cluster. The availability of the resources associated with storage are governed by a few specific parameters including, Primary Levels of Failures to Tolerate (PFTT), Secondary Levels of Failures to Tolerate (SFTT), and Failure Tolerance Mode (FTM) (when only a single site in VSAN is configured, PFTT is set to 0 and SFTT is usually

referred to as just FTT). VSAN with each of these settings allows the administrator to tightly control the availability of the objects stored on each VSAN data store however, in order to increase the availability of the objects hosted on a VSAN data store, scaling out the number of hosts that participate in that data store and in turn the vSphere Cluster is usually required. When hosting all of the NSX Manager Nodes in an NSX Manager Cluster in a single vSphere Cluster which has only a single VSAN data store, the following configurations should be made to improve the availability of the NSX-T Management and Control Planes:

1. At a minimum, the vSphere Cluster should be configured with an FTT setting of at least 2 and an FTM of Raid1
   This will dictate that for each object associated with the NSX-T Manager Node, a witness, two copies of the data (or component) are available even if two failures occur, allowing the objects to remain in a healthy state. This will accommodate both a maintenance event and an outage occurring without impacting the integrity of the data on the datastore. This configuration requires at least five (5) hosts in the vSphere Cluster.
2. ToR and Cabinet Level Failures can be accommodated as well, this can be accomplished in multiple ways; either through leveraging VSAN's PFTT capability commonly referred to as Failure Domains or VSAN Stretched Clusters and leveraging a Witness VM running in a third failure domain or by distributing the cluster horizontally across multiple cabinets where no more hosts exist in each Rack or Cabinet than the number of failures that can be tolerated (a maximum of FTT=3 is supported by VSAN). In both of these scenarios, NSX-T Manager Nodes will be spread out across multiple cabinets which will also require IP mobility of the IP Addresses used by the NSX Manager Appliances.
3. When workload is spread across multiple cabinets or ToRs, it is also important to potentially set Host affinities for workloads to better disburse the NSX Manager Nodes across the cabinets and have predictability for which one is running where.
   In either of the first two scenarios, it is strongly recommended that Hosts any time they are proactively removed from service, that they vacate the storage and repopulate the objects on the remaining hosts in the vSphere Cluster.

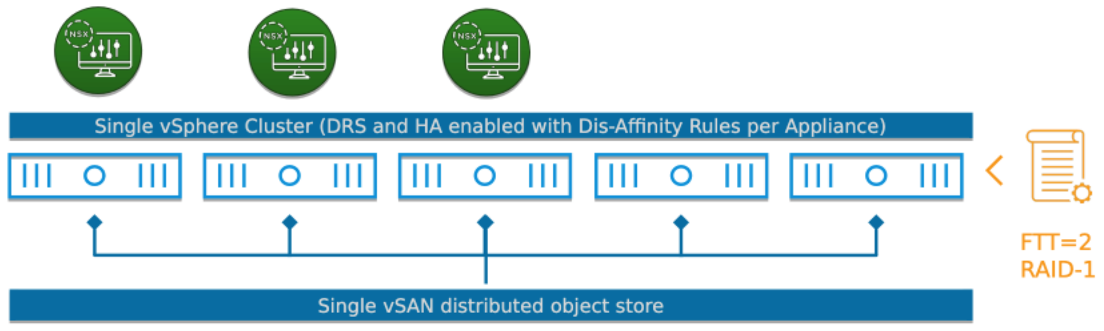

NSX
Single vSphere Cluster (DRS and HA enabled with Dis-Affinity Rules per Appliance)
FTT=2
RAID-1
Single vSAN distributed object store

Figure 7-6: Single vSphere Cluster Single VSAN Data Store

Placement of NSX Manager Nodes Across Multiple vSphere Clusters
Depending on the design of the underlying infrastructure, it may become necessary or advantageous to place the three NSX Manager Nodes across multiple vSphere Clusters. This type of design tends to become apparent when a single vSphere cluster is unable to provide the

resiliency or availability for all failure scenarios that are required to be addressed. This can occur for instance if physical infrastructure is preferred to be deployed across multiple facilities or computer rooms, or if storage or other underlying infrastructure is required to be diverse. In this scenario:

1. Each vCenter that is hosting an NSX Manager Node must be added as a Compute Manager inside of the first NSX Manager that is deployed.
2. If the same IP space is not available to each vSphere Cluster, IP Addresses in different subnets will need to be used as well as a load balancer as explained in section 7.2.3 below.
3. If VSAN is used as part of this design, it is recommended to avoid using HCI Mesh and use the local VSAN data store presented to each vSphere Cluster for the NSX Manager Node that is running in it.
4. It is still recommended that each vSphere Cluster hosting an NSX Manager Node adhere to the vSphere best practices for both VMware DRS and HA for sizing and have at least 4 hosts.

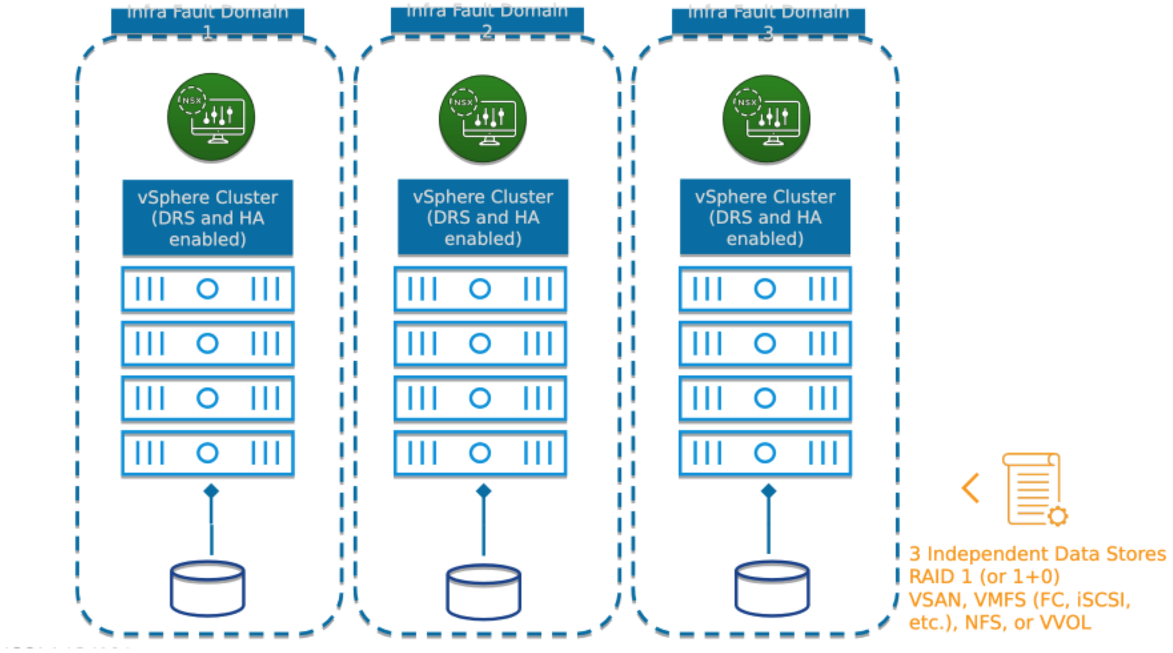

Infra Fault Domain 1
Infra Fault Domain 2
Infra Fault Domain 3
NSX
vSphere Cluster (DRS and HA enabled)
vSphere Cluster (DRS and HA enabled)
vSphere Cluster (DRS and HA enabled)
3 Independent Data Stores
RAID 1 (or 1+0)
VSAN, VMFS (FC, iSCSI, etc.), NFS, or VVOL

Figure 7-7: 3x vSphere Clusters Each in a Different Infrastructure Failure Domain

7.2.3 Deployment Options for NSX-T Management Cluster

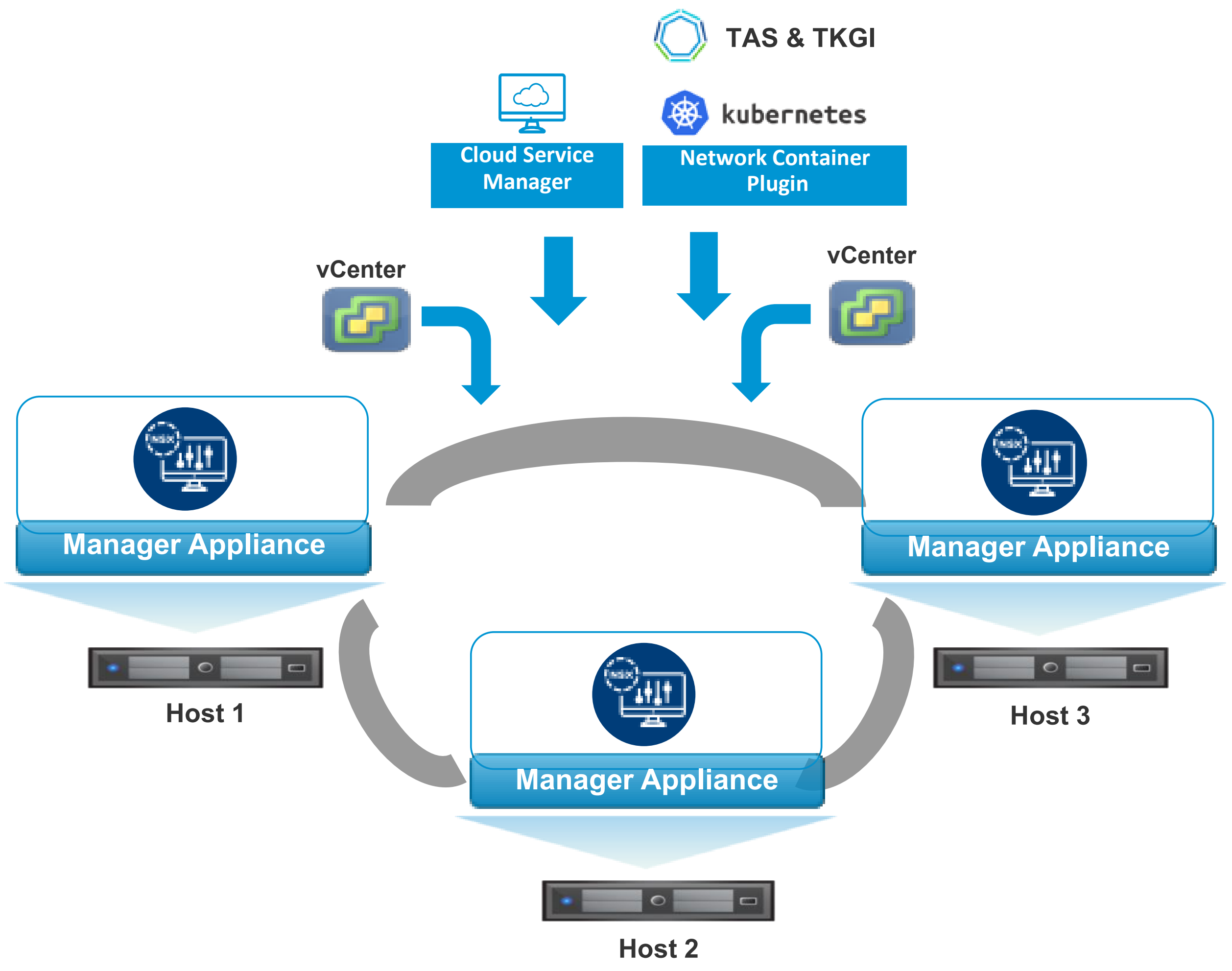


Figure 7-8: NSX Manager Appliances with Combined Role

Figure 7-8: NSX Manager Appliances with Combined Role shows the manager component, the central control component, and the policy component in an NSX Manager appliance. Three appliances form a cluster. The database is replicated to all the nodes in the cluster, so there is a single database cluster instance. The three hosts depicted in this figure are not required to be part of the same vSphere cluster.

The benefit of clustering is that it provides high availability of all management services such as UI and API access to the cluster. Combining the NSX-T Manager, policy, and central controller reduces the number of appliances deployed and allows greater flexibility with availability models as discussed later in this section. Once the cluster is formed, the cluster manager creates a single database which is the datastore service. It then creates the control plane by putting all the controllers into a controller group. Finally, it creates the manage plane by putting the managers into the manager group. Similarly, it creates other service groups as needed. The workload is distributed and shared in the service group.

Consumption Methods for NSX-T Manager Appliance and Communication

NSX-T Manager appliance serves two critical areas of consumption. The first one is the external systems and user access. Many different end points (such as HTTP, vRA, Terraform, Network Container Plugin, custom automation modules) can consume NSX-T Manager from northbound via an IP address. It's is a single point of entry (using RESTful API - GUI internally makes and API call). Second is communication to NSX-T components (controllers and transport node). The controller communication to transport node is done via controller role (element) within the NSX-T appliance node. The controller communication to NSX-T components were described chapter 2. The controller availability models remain majority based requiring all three nodes to be available for normal operations. However, starting with NSX-T 2.4 release, the NSX-T Manager role has multiple availability models. The rest of the section discusses the NSX-T Manager role configuration and availability options. There are three different configuration modes available for northbound access to the NSX-T Manager cluster.

- Default deployment (each node uniquely addressable, no common IP address)
- Cluster VIP based deployment
- External Load Balancer based deployment

Default Deployment
The default (and the simplest option, with the least number of IP addresses consumed) is to deploy a 3-node cluster without any additional configuration. With this option, each node is accessible via distinct IP address (or FQDN) and thus multiple endpoints (user and automation systems) can access each different node to build redundancy and load balancing model for NSX-T Manager role. Here the availability is driven via external system choosing different IP address (FQDN). However, in case of the node failure the system using that node must externally intervene to point to another available node. For an example, if vRA or API script uses the FQDN of node A, in case node A fails, there has to be some manual intervention to make the script continues to work, either you change the FQDN in your API script, or update the FQDN entry in the DNS. In this configuration, using round robin DNS will result in intermittent connectivity in a failure scenario. But in terms of topology requirement, as long as there is IP connectivity between all the nodes, this mode will work.

Cluster VIP based deployment
The second deployment option is based on simple active/standbys redundancy model, in which one has to configure a virtual IP address on the management cluster. Cluster VIP configuration option provide node level redundancy through the virtual IP address on the cluster itself. This virtual IP (like VRRP/HSRP) provides redundancy of accessing the cluster via single FQDN. In other words: the entire northbound access to the NSX-T Manager is available via this FQDN (or IP). Since it is a single FQDN name available to all end points, all the GUI and API requests are accessed through single node owning the VIP as shown in *Figure 7-9: NSX Manager Appliances Availability with Cluster VIP*. Essentially, it is a simple availability model, which is far better default option where external intervention is not required, and availability of NSX-T Manager role is improved from external restore option to full in-line availability which did not exist in previous releases.

Cluster virtual IP address is an IP address floating among the cluster nodes. One of the cluster nodes is assigned as the owner of the cluster VIP. If case of failure, a new owner will be assigned by the system. Since the cluster VIP must remain the same, it assumes that other nodes are available in in the same subnet as the cluster VIP feature uses gratuitous ARP to update the mac-address and the ARP table. Thus, it is mandatory to have all nodes in the cluster must be in the same subnet for the VIP to work. From the physical topology perspective, the nodes placement can vary. For the L2 topology the nodes can be in different rack or the same as long they have L2 adjacency. For the L3 topology all nodes must be in the same rack assuming VLAN/subnet is confined to a rack. Alternatively, one can cross-connect the host to two distinct ToRs on two different rack to be rack resilient.

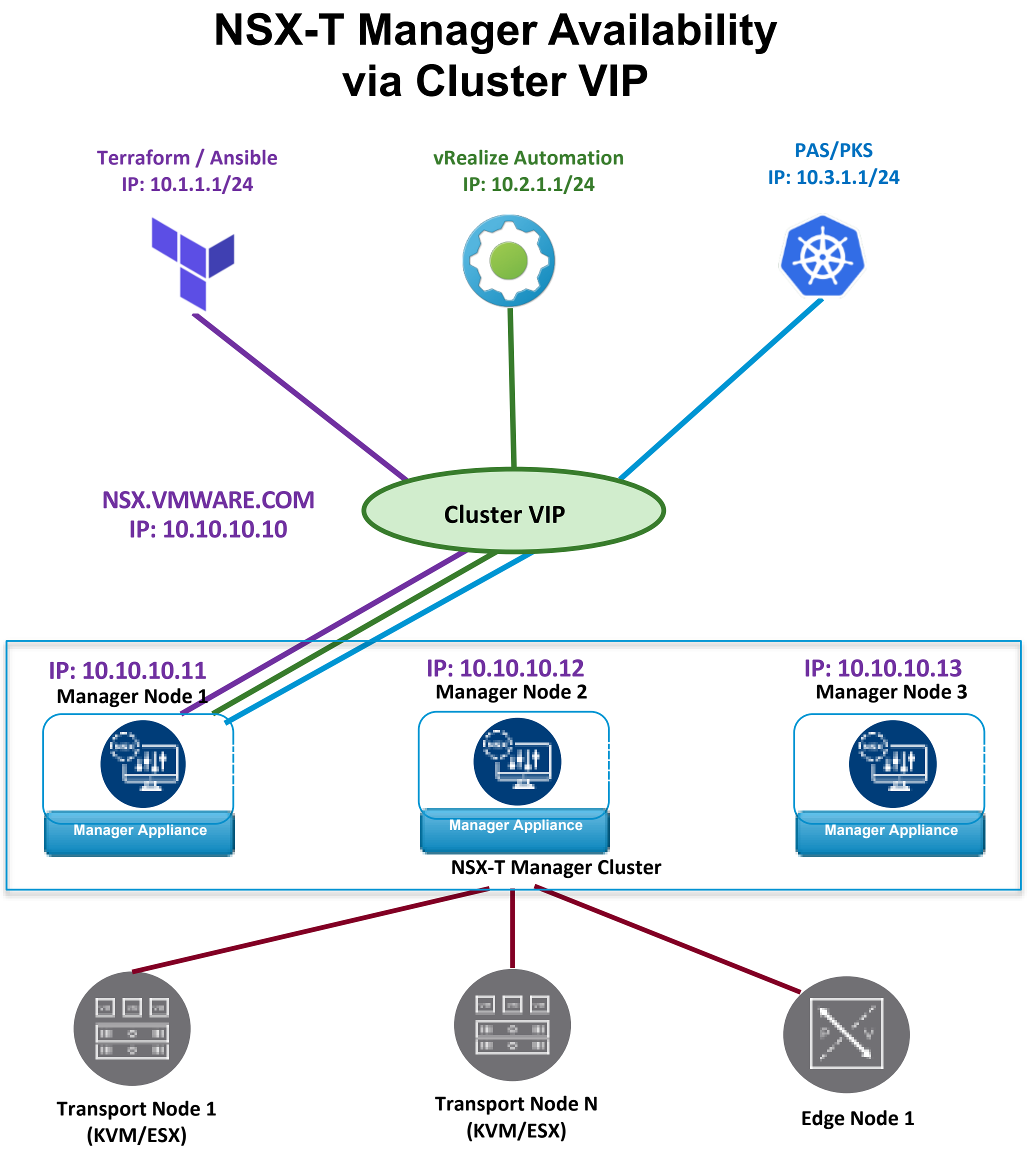


Figure 7-9: NSX Manager Appliances Availability with Cluster VIP

The NSX-T Manager availability has improved by an order of the magnitude from a previous option; however, it is important to clear the distinction between node availability vs load-balancing. In the case of cluster VIP all the API and GUI requests go to one single node, one cannot achieve a load-balancing of GUI and API sessions. In addition, the existing sessions established on a failed node, will need to re-authenticated and re-established at new owner of the cluster VIP. The availability is also designed to leverage critical failure of certain services relevant to NSX-T Manager, thus one cannot guarantee failure in certain corner cases. The communication from northbound is via cluster VIP while the communication among the cluster nodes and to other transport node is done via IP address assigned to each manager node.

The cluster VIP is the preferred and recommended option for achieving high availability with NSX-T Manager appliance nodes.

External Load Balancer based deployment

The third deployment option is to keep the same configuration as the first option but adding an external load balancer. A VIP on the load balancer will represent the manager nodes as the physical servers in the server pool. Then the UI and API access to the management cluster will go through the VIP on the load balancer. The advantage of this option is that not only the endpoint access the NSX-T Manager nodes will have load-balancing but also the cluster management access is highly available via a single IP address. The external load-balancer option also makes the deployment of NSX-T manger nodes independent of underlying physical topology (agnostic to L2 or L3 topology). Additionally, one can distribute nodes to more than one rack to achieve rack redundancy (in L2 topology it is the same subnet but different rack, while in L3 topology it will be distinct subnet per rack). The downside of this option is that it requires an external load balancer and configuration complexity based on load-balancer models. The make and model of load-balancer are left to user preference however one can also use NSX-T native load balancer included as part of the system or standalone NSX-T Advanced load balancer (formally AVI network) offered as a part of NSX-T Datacenter portfolio

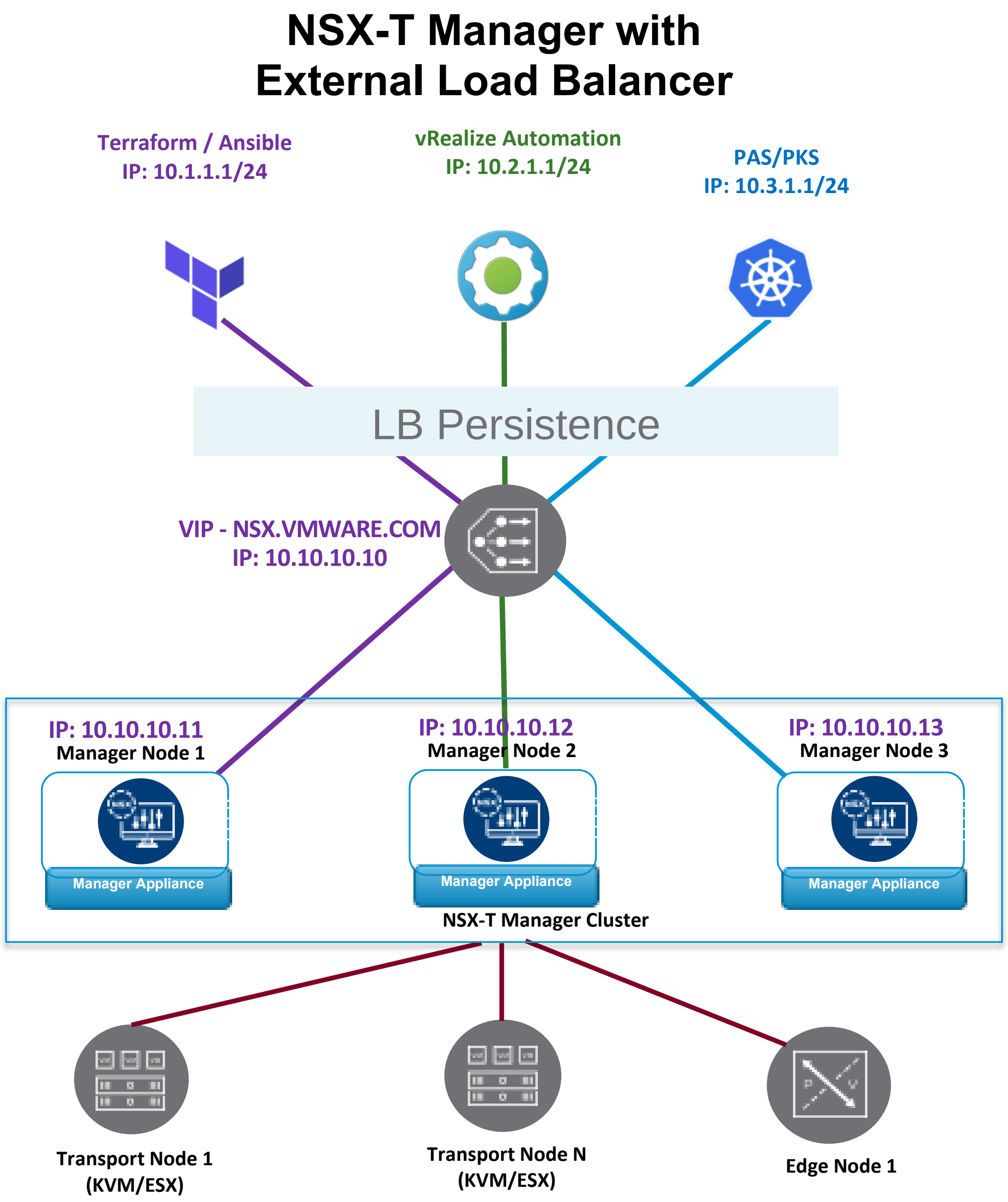


Figure 7-10: NSX Manager Appliances with External Load Balancer

Figure 7-10: NSX Manager Appliances with External Load Balancer shows simple source IP load balancing choice with external load balancer. In this option only the northbound endpoints with different source IP will be load-balanced among the available manager appliance nodes. NSX-T Manager can be authenticated via four ways - HTML basic authentication, client certificate authentication, vIDM and session. The API based client can use all four forms of authentication while web browsers use session-based authentication. The session-based authentication typically requires LB persistence configuration while API based access does not mandate that. It is for this reason above *Figure 7-10: NSX Manager Appliances with External Load Balancer* represent VIP with LB persistent configuration for both browser (GUI) and API based access.

While one can conceive advanced load-balancing schema in which dedicated VIP for browser access with LB persistent while other VIP without LB persistence for API access. However, this option may have limited value in terms of scale and performance differentiation while complicating the access to the system. It is for this reason it is highly recommended to first adopt basic option of LB persistence with single VIP for all access. Overall recommendation still to start with cluster VIP and move to external LB if real need persist.

7.3 Compute Cluster Design (ESXi/KVM)

This section covers both ESXi and KVM compute hypervisors; discussions and recommendations apply to both types unless otherwise clearly specified.

Compute hypervisors host the application VMs in the data center. In a typical enterprise design, they will carry at least two kinds of traffic, typically on different VLANs – management and overlay. Because overlay traffic is involved, the uplinks are subjects to the MTU Requirements mentioned earlier. Additionally, based on type of hypervisor, compute hosts may carry additional type of infrastructure traffic like storage (VSAN, NFS and iSCSI), vMotion, high availability etc. The ESXi hypervisor defines specific VMkernel interfaces, typically connected to separate VLANs, for this infrastructure traffic. Similarly, for the KVM hypervisor, specific interfaces and VLANs are required. Details on specific hypervisor requirements and capabilities can found in documentation from their respective vendors.

A specific note for the KVM compute hypervisor: NSX uses a single IP stack for management and overlay traffic on KVM hosts. Because of this, both management and overlay interfaces share the same routing table and default gateway. This can be an issue if those two kinds of traffic are sent on different VLANs as the same default gateway cannot exist on two different VLANs. In this case, it is necessary to introduce more specific static routes for the overlay remote networks pointing to a next hop gateway specific to the overlay traffic.

Generalized Traffic Engineering and Capability with NSX

NSX-T offers choices with management of infrastructure and guest VM traffic (overlay or VLAN) through flexibility of uplink profiles and teaming type as described in chapter 3. This chapter utilizes configuration choices and capability based on requirements and best practices prevalent in existing data-center deployments. Typically, traffic management carries two overarching goals while expecting availability, namely:

Optimization of all available physical NICs– In this choice, all traffic types share all available pNICs. Assumption is made that by providing all pNICs to all traffic, one can avoid traffic hot spot during peak/burst and probability of contention is reduced due to number of links and speed offered. This type of traffic management typically suitable with 25 Gbps or greater speed links. In the case of lower speed pNIC, it may be necessary to enable traffic management tools such as NIOC to build an assurance for a traffic type. One example of such traffic is VSAN traffic. The type of teaming type offered in NSX-T that enables this behavior is called “Load Balanced Source Teaming”

Deterministic Traffic per pNIC– In this choice, certain traffic type is only carried on a specific pNIC thus allowing dedicated bandwidth for a given traffic type. Additionally, it allows deterministic failure as one or more links could be only be in standby mode. Based on number of pNICs, one can design a traffic management schema that avoid contention of two high bandwidth flows (e.g. VSAN vs vMotion) and highly interactive traffic such as transactional and web. The teaming type offered in NSX-T that enables this behavior is called "Failover Order". One can build a failover teaming mode with only one pNIC or more. When a single pNIC is used, by design, its failure is not covered by a standby pNIC but by some other redundancy mechanism. An additional place where Deterministic Traffic per pNIC may be leveraged is in the case of multiple distinct physical networks e.g. DMZ, Storage, or Backup Networks where the physical underlay differs based on pNIC.

Additionally, one can design a traffic management schema that utilize both above principles. This design guide leverages both type of principle based on specific requirements and makes generalized recommendations.

7.3.1 Running a VDS prepared for NSX on ESXi hosts

NSX-T 3.0 introduces the capability of running NSX directly on the top of a VDS (with VDS version 7.0 or later.) This short section introduces the reasons for this feature, its impact on ESXi host design with NSX and some guidelines for moving to this new model.

7.3.1.1 NSX on VDS

Simpler install
The N-VDS introduced on the ESXi platform is very close to the VDS. In fact, the name "N-VDS" was chosen to highlight this tight relationship. Still, the N-VDS is an opaque switch (an opaque switch and an opaque network means it's not instantiated via vCenter and does not have any object existence native to vCenter) that needs to be instantiated separately, or migrated to, when the user wants to start using NSX on ESXi. The capability of running NSX directly on the top of an existing VDS removes this burden and makes the deployment and adoption of NSX must simpler. This is especially critical with the two pNICs design and/or fully collapsed design where management, edge and applications VMs co-exist on the same hypervisor. There is no need for migration of VMkernel interfaces and specific considerations for security and availability.

Compatibility with third party solutions
With the N-VDS, NSX segments appeared as opaque network in vCenter. Even if opaque networks have been available in vCenter for almost a decade, way before NSX-T was developed, many third-party solutions still don't take this network type into account and, as a result, fail with NSX-T. When running NSX on VDS, NSX segments are represented as DVPGs (now onward called NSX DVPG) in vCenter. Third party scripts that had not been retrofitted for opaque networks can now work natively with NSX.

7.3.1.2 Impact on ESXi host design

As we have seen earlier in this chapter, the traffic in/out an ESXi host can be classified in two broad categories:

- Infrastructure traffic. Any traffic that is originating from the ESXi host and its functionality to support application, storage, availability and management. This traffic is typically initiated and received on VMkernel interfaces defined on the host and includes traffic for management, vMotion, storage, high availability etc.
- VM and/or application traffic: This is the traffic between virtual machines running on the host. This traffic might be local to the hypervisor but can also extend to VMs on remote hosts. NSX is all about providing advanced networking and security features for VM traffic.

Until now, when the administrator introduced NSX, they needed to deploy a new N-VDS virtual switch on their hosts. The ESXi platform can run multiple separate virtual switches (VSS/VDS/N-VDS) side-by-side with no problem, however, those virtual switches cannot share physical uplinks. The administrator is thus left with two main options:

1. Deploy an N-VDS for VM traffic along with the existing virtual switch (VSS/VDS) handling infrastructure traffic. This solution is very easy to deploy as it does not impact the current host operations. However, it requires separate uplinks for the N-VDS, meaning additional connectivity to the physical infrastructure.
2. The second, an efficient option is to consolidate both infrastructure and VM traffic on a single N-VDS. Deploying this model is more complex as it implies a virtual switch migration: VMKernel interfaces and physical uplinks need to be moved from VSS/VDS to the N-VDS. When the hosts only have two high-speed uplinks, which is increasingly the case with modern servers, migrating to a single N-VDS becomes mandatory to maintain uplink redundancy for the virtual switch.

Because of those considerations, the NSX design guide traditionally addresses a 4 (or more) pNICs design, corresponding to the first option, and a two pNIC design for the second. The introduction of NSX on VDS changes all this. NSX can be installed on a VDS without incurring migration of infrastructure traffic VMkernel, making the second option just as simple as the first one.

The next sections, showing the ESXi compute node design options, will thus focus on installing NSX on VDS in a two pNIC scenario. This scenario will in fact be unchanged if there are more than two pNICs on the host. The use-cases will still cover a four pNICs design, for those who plan on keeping the N-VDS for now, and for the cases when multiple virtual switches are a requirement for other reasons.

7.3.1.3 When to run NSX on VDS

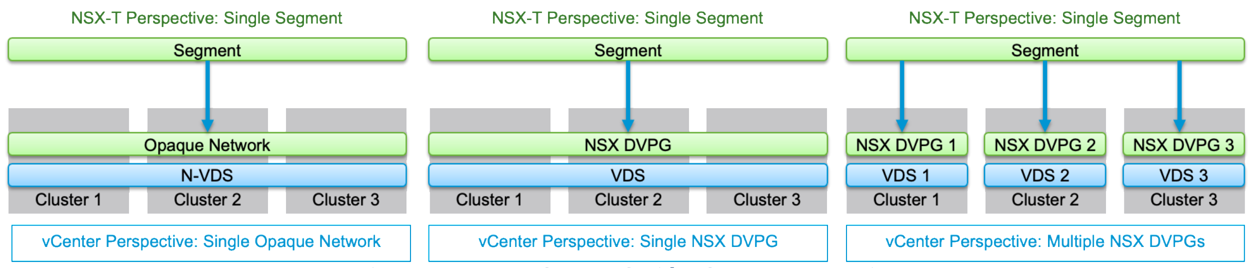
As mentioned earlier, in order to run NSX on VDS, you need NSX-T 3.0 or later and a VDS version 7.0 or later.

- For a greenfield deployment that meet those requirements, we recommend starting with NSX on VDS. This is the simpler approach and in future N-VDS shall converge on the VDS.
- VMkernel should remain on DVPG with VDS with NSX
- For those already running NSX on N-VDS, or for those with a new install that cannot meet the version requirements, the recommendation is to stay on N-VDS for now.

- The N-VDS remains fully supported. In this case one must migrate and keep VMkernel on NSX unless one has 4 pNICs configurations
- There is almost no functionality difference between N-VDS and VDS with NSX. In fact, one could even mix VDS and N-VDS in the same NSX network. For a given compute cluster do not mix and match the NSX virtual switch type. For a given host with more than 2 pNICs, coexistence of all NSX virtual switch (not the third party) allowed except N-VDS and VDS with NSX in the same host.
- One can introduce new compute cluster or vCenter within the brownfield deployment, for which the recommendation is to deploy VDS with NSX with properly supported software on compute and NSX. In this case VMkernel can remain on DVPG.
- The goal is to eventually convert every NSX deployment to the VDS model. Future conversion tool will automate this conversion and make it straightforward.
- One can also migrate their current N-VDS deployment into a VDS one right now. However, the recommendation is to wait for the conversion tool as a manual migration would be unnecessarily complex.

7.3.1.4 NSX on VDS and Interaction with vSphere & Other Compute Domains

The relationship and representative difference between N-VDS vs NSX on VDS is subtle and requires consideration in designing the cluster and operational understanding. The N-VDS has a complete independence to underlying compute manager (vSphere or any other compute domains like or in cloud like AWS, Azure or Google Cloud). Unlike deployment of VDS via vCenter, N-VDS deployment is managed via NSX manager. Because of this decoupling it allows consistent connectivity and security with multiple compute domains. This consistent connectivity is shown in below *Figure 7-11: N-VDS vs. VDS with NSX – Representation* first part with N-VDS and its relation to vCenter. With NSX-T 3.0, the NSX-T can be enabled on traditional VDS allowing same level of flexibility, however now there is a mandatory requirement of having vCenter to instantiate a VDS. This capability when enabled, depicted in below *Figure 7-11: N-VDS vs. VDS with NSX – Representation* center part as a NSX DVPG. The center part of the figure below depicts a case of single VDS with NSX which is logically similar to first one, where only difference is representation in vCenter - opaque vs NSX DVPG. The third part of the figure represent multiple VDS. This is possible either with single vCenter with each cluster having dedicated VDS or with multiple vCenters with VDS. In this later case of multiple VDSs, the same segment of NSX is represented via unique NSX DVPG under each VDS or vCenters. This might represent a challenge operationally identifying VM connectivity to VDS and the automation that relies on the underlying assumption; however, future releases shall make this identification easier with unique names. Typically, it is a good practice to invoke a single VDS per compute domain and thus have a consistent view and operational consistency of the VM connectivity. However, there are cases where single VDS invocation may not be ideal from separation of workload for security, automation, storage policy, NIOC control and provisioning boundary. Thus, it is acceptable to have a multiple VDS per given vCenter.



NSX-T Perspective: Single Segment
Segment
Opaque Network
N-VDS
Cluster 1
Cluster 2
Cluster 3
vCenter Perspective: Single Opaque Network
NSX-T Perspective: Single Segment
Segment
NSX DVPG
VDS
Cluster 1
Cluster 2
Cluster 3
vCenter Perspective: Single NSX DVPG
NSX-T Perspective: Single Segment
Segment
NSX DVPG 1
NSX DVPG 2
NSX DVPG 3
VDS 1
VDS 2
VDS 3
Cluster 1
Cluster 2
Cluster 3
vCenter Perspective: Multiple NSX DVPGs

Figure 7-11: N-VDS vs. VDS with NSX – Representation

The details of these differences and additional considerations are documented with following KB articles

https://kb.vmware.com/s/article/79872

Co-existence with existing NSX, KVM and New vSphere Clusters
In practical deployment, where one has existing NSX-T deployed with N-VDS (ESXi) or OVS (KVM). The core realization of consistent networking and security does not change with advent of VDS with NSX. The *Figure 7-12: Multi-domain compute co-existence* describe such configuration. Of course, for the VDS with NSX based cluster requires appropriate vSphere and ESXi version and NSXDVPG port for a VM connectivity.

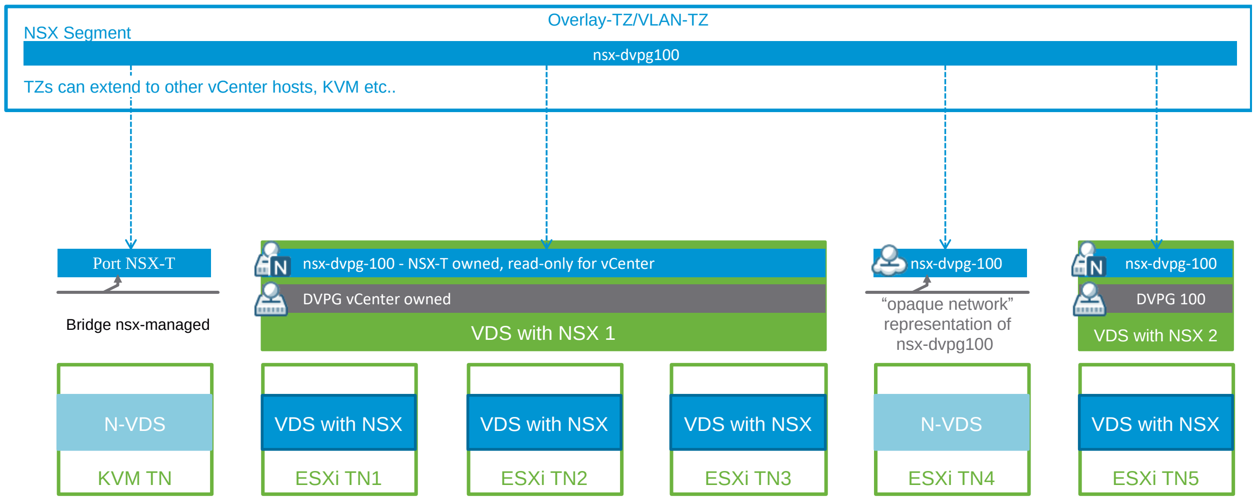


Figure 7-12: Multi-domain compute co-existence

The key concept here is that NSX abstract the connectivity and security via segment. This segment is represented via various realization like NSX DVPG in VDS with NSX, Port-NSX-T in KVM or an opaque network in N-VDS. Regardless of the underlying switch DFW can be realized either on VLAN or overlay however only with NSX DVPG and not via vSphere DVPG.

7.3.2 ESXi-Based Compute Hypervisor with two pNICs

This section targets typical enterprises deployments deploying compute hypervisors with the following parameters:

- Two pNICs

- All host traffic (VM and infrastructure traffic) shares the common NICs
- Each host traffic type has a dedicated IP subnet and VLAN

The teaming mode offers a choice in the availability and traffic load-sharing design. NSX offers two types of teaming mode design for the ESXi hypervisor – failover order and load balanced source. In this section only a two-pNIC design is shown, however base design principle remains the same for more than two pNICs.

7.3.2.1 Failover Order Teaming Mode

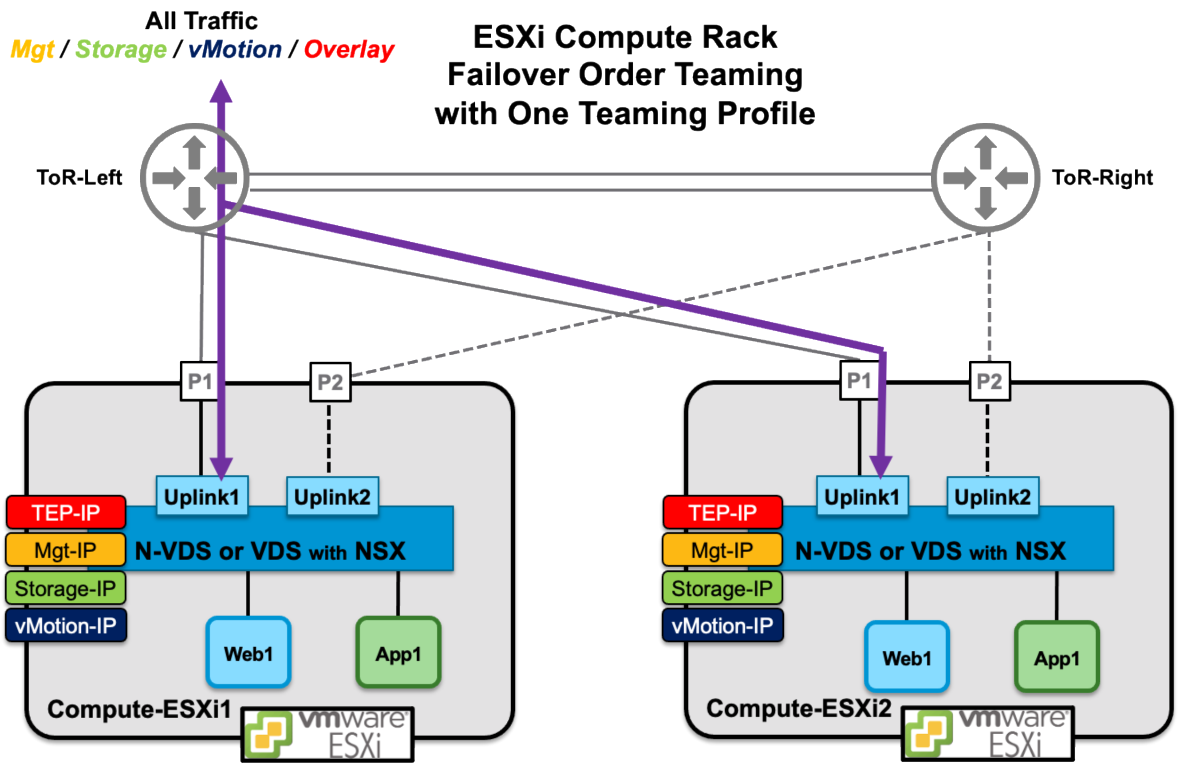


Figure 7-13: ESXi Compute Rack Failover Order Teaming with One Teaming Policy

In *Figure 7-13: ESXi Compute Rack Failover Order Teaming with One Teaming Policy*, a single virtual VDS or N-VDS is used with a 2 pNICs design and carries both infrastructure and VM traffic. Physical NICs “P1” and “P2” are attached to different top of rack switches. The teaming policy selected is failover order active/standby; “Uplink1” is active while “Uplink2” is standby.

- If the virtual switch is an N-VDS, all traffic on the host is carried by NSX segments (VLAN or overlay) and the redundancy model can be achieved with a single default NSX teaming policy.
- If the virtual switch is a VDS, only NSX DVPG traffic will follow the NSX teaming policy. The infrastructure traffic will follow the teaming policy defined in their respective VDS standard DVPGs configured in vCenter.

The top-of-rack switches are configured with a first hop redundancy protocol (e.g. HSRP, VRRP) providing an active default gateway for all the VLANs on “ToR-Left”. The VMs are, for example, attached to overlay segments defined in NSX with the default gateway set to the logical interface of a Tier1 gateway. With the use of a single teaming policy, the above design allows for a simple configuration of the physical infrastructure and simple traffic management at the expense of leaving an uplink completely unused. It is however easy to load balance traffic across the two uplinks while maintaining the deterministic nature of the traffic distribution. The following example is showing the same hosts, this time configured with two separate failover order teaming policies: one with P1 active, P2 standby, and the other with P1 standby, P2 active. Then, individual traffic type can be assigned a preferred path by mapping it to either teaming policy.

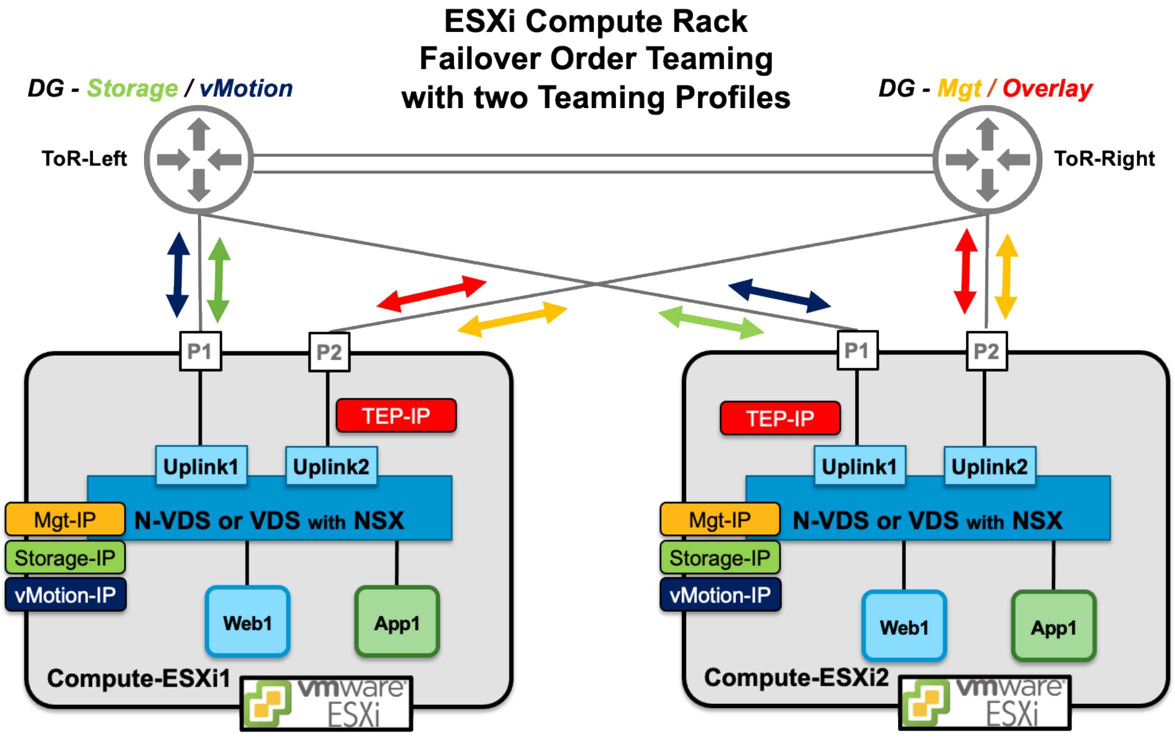


Figure 7-14: ESXi Compute Rack Failover Order Teaming with two Teaming Policies

In *Figure 7-14: ESXi Compute Rack Failover Order Teaming with two Teaming Policies* storage and vMotion traffic are following a teaming policy putting P1 as active, while management and VM traffic are following a teaming policy putting P2 as active.

- When the virtual switch is an N-VDS, all segments follow the same default teaming policy by default. VLAN segments can however be associated to additional teaming policies (identified by a name, and thus called "named" teaming policies). The above design can thus be achieved with a default teaming policy (P2 active/P1 standby) and an additional named teaming policy (P1 active/P2 standby) to which NSX VLAN segments for storage and vMotion traffic are mapped.
- When the virtual switch is an VDS with NSX, the above design is achieved with a default teaming policy P2 active & P1 standby. Then, the DVPGs for infrastructure traffic need to be configured individually: storage and vMotion will have a failover order teaming policy setting P1 active & P2 standby, while the management DVPG will be configured for P2 active & P1 standby.

To limit interlink usage, the ToR switches are configured with a first hop redundancy protocol (FHRP), providing an active default gateway for storage and vMotion traffic on "ToR-Left", management and overlay traffic on “ToR-Right”. The VMs are attached to segments defined on the N-VDS, with the default gateway set to the logical interface of their attached Tier-1 gateway. Use of multiple teaming policies allows utilization of all available pNICs while maintaining deterministic traffic management. This is a better and recommended approach when utilizing “failover mode” teaming for all traffic.

7.3.2.2 Load Balance Source Teaming Mode

NSX-T supports two source teaming policies: load balancing based on source port and load balancing based on source mac address. Those are the exact equivalent to the source teaming policies available on VDS.
Figure 7-15: ESXi Compute Rack Load Balanced Source Teaming shows the same two-pNIC design as in the previous example, this time with either source teaming policy available on VDS and N-VDS. With this kind of policy, potentially both uplinks are utilized based on the hash value generated from the source port originating the traffic or the source MAC address of the traffic. Notice that NSX instantiates one TEP on every uplink part of the source teaming policy in order to be able to send overlay traffic on all those physical ports.
Both infrastructure and guest VM traffic benefit from this policy, allowing the use of all available uplinks on the host. A recommended design change compared to failover teaming policy is the designation of first hop redundancy protocol (FHRP) redundancy. Since all uplinks are in use, FHRP can be used to better distribute different types of traffic, helping reduce traffic across the inter-switch link. As the teaming option does not control which link will be utilized for a VMkernel interface, there will be some inter-switch link traffic; splitting FHRP distribution will help reduce the probability of congestion. The ToR switches are configured with an FHRP, providing an active default gateway for storage and vMotion traffic on “ToR-Left”, management and overlay traffic on “ToR-Right”. The VMs are attached to segments defined in NSX, with the default gateway set to the logical interface of their Tier-1 gateway.

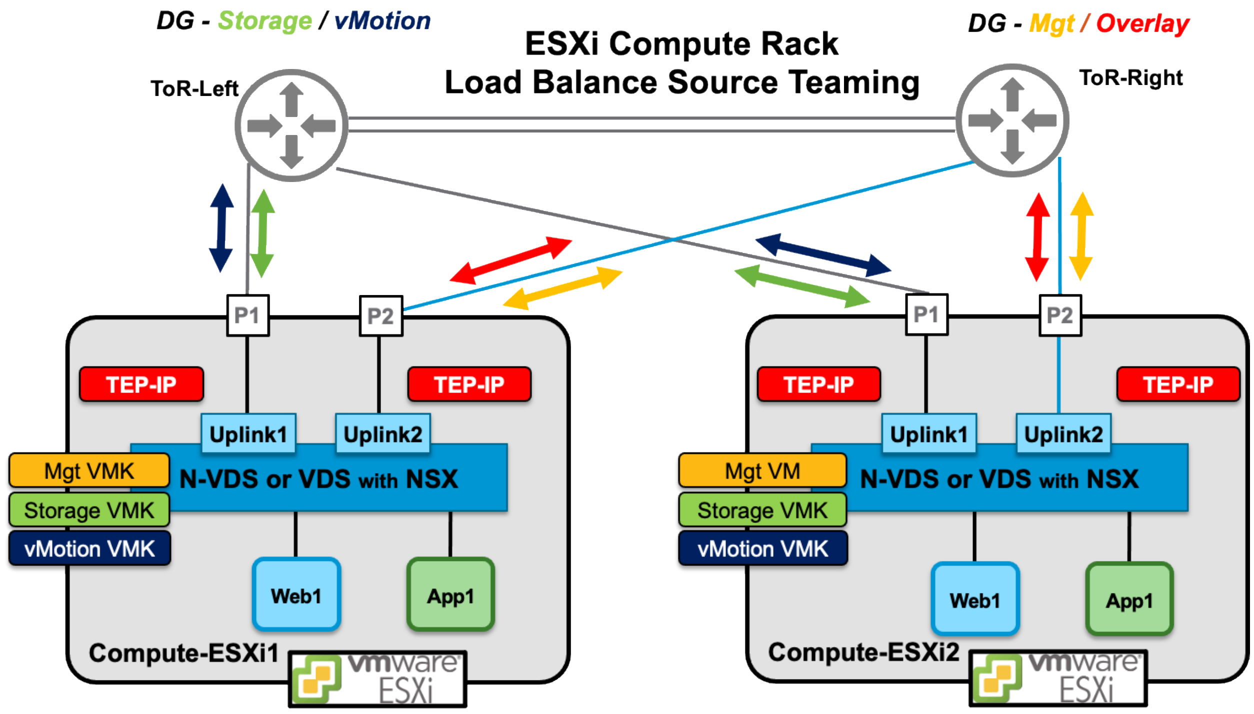


Figure 7-15: ESXi Compute Rack Load Balanced Source Teaming

Additionally, one can utilized a mix of the different teaming policy types together such that infrastructure traffic (VSAN, vMotion, Management) leverage "failover order" enabling deterministic bandwidth and failover, while VM traffic use some "load balance source" teaming policy, spreading VM traffic across both pNICs.

- On a host running NSX with an N-VDS, the default teaming policy will have to be configured for "load balance source", as it's the only policy that overlay traffic follows. Then, individual VLAN segments can be mapped to named teaming policies steering the infrastructure traffic to the desired uplink.
- On a host running VDS with NSX, overlay traffic will follow the default teaming policy defined in NSX. Infrastructure traffic will follow the individual teaming policies configured on their DVPGs in vCenter.

Based on requirement of underlying applications and preference, one can select a type of traffic management as desired for all the infrastructure traffic. However, for the overlay traffic, it is highly recommended to use one of the "load balanced source" teaming policies as they're the only ones allowing overlay traffic on multiple active uplinks and thus provide better throughput in/out of the host for VM traffic.

7.3.2.3 LAG based traffic distribution

An alternate method to distribute traffic is via using LAG. In order to keep ToR redundancy, this scenario would require the ESXi hosts be connected to separate ToRs forming a single logical LAG, based on some multi-chassis link aggregation (MLAG, VPC etc.) Relying on this kind of technology is not recommended because it's vendor dependent and typically involves significant vendor-specific limitations that VMware has not validated. This introduces troubleshooting complexity and potential support coordination challenges across multiple vendors.

However, many times existing deployment of compute may carry this type of teaming and often customer operational model has accepted the risk and knowledge set to operationalize LAG based teaming. For those existing deployment, one can adopt LAG based teaming mode, for compute only workload. In other words, if the compute host is carrying edge VMs (for North-South traffic and requires peering over LAG) traffic then its highly recommended to decouple the edge and compute with either dedicated edge hosts or edge and management. Please refer to a specific section which discussed disadvantage of mixing compute and edge VM further below in this chapter.

7.3.3 ESXi-Based Compute Hypervisor with Four (or more) pNICs

In most cases, a host with 4 or more pNICs can be configured exactly the same way as a 2-pNIC host. There are just more available uplinks available for consumption by the different teaming policies. We are going to focus on few scenarios where 4 pNICs or more is necessary.

7.3.3.1 Simple install, traffic on separate uplinks for policy reason

With a minimum of four pNICs, an ESXi host can run two virtual switches, each with redundant uplinks.

- This property was appreciated by customers as it enabled a simple and non-disruptive installation of NSX on their ESXi hypervisors. They could simply deploy and N-VDS with two dedicated uplinks for VM traffic, while leaving an existing VSS/VDS running on two separate uplinks to handle infrastructure traffic.
- On the top of this simple NSX installation, the model also provides for a strict separation between VM and infrastructure traffic. There are scenarios where this separation is mandated by policy, and the fact that NSX is deployed on its dedicated virtual switch ensured that no misconfiguration could ever lead to VM traffic being sent on the uplinks dedicated to infrastructure traffic, owned by a different virtual switch.

The following *Figure 7-16: ESXi Compute Rack 4 pNICs – VDS and NSX virtual switch* represents an example of a host with 4 uplinks and two virtual switches:

- A VDS dedicated to infrastructure traffic and
- Another NSX prepared VDS or N-VDS that handles VM traffic.

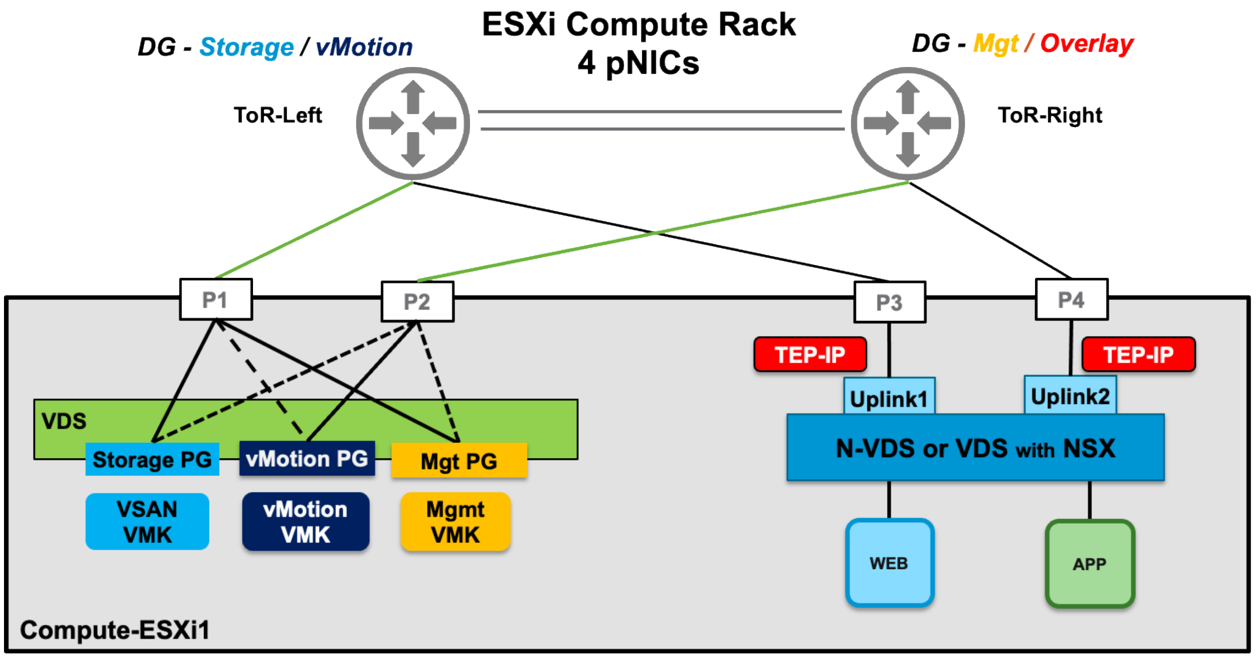


Figure 7-16: ESXi Compute Rack 4 pNICs – VDS and NSX virtual switch

The VDS is configured with pNICs “P1” and “P2”. And each port group is configured with different pNICs in active/standby to use both pNICs. However, the choice of teaming mode on VDS is left up to user or existing implementation. The virtual switch running NSX owns pNICs “P3” and “P4”. To offer usage of both pNICs, N-VDS is configured in load balance source teaming mode, as described in the previous section. Each type of host traffic has dedicated IP subnets and VLANs. To limit interlink usage, the ToR switches are configured with an FHRP, providing an active default gateway for storage and vMotion traffic on “ToR-Left”, management and overlay traffic on “ToR-Right”. When all pNICs are up, only some overlay traffic will cross the inter switch link.

The model in *Figure 7-16: ESXi Compute Rack 4 pNICs – VDS and NSX virtual switch* still makes sense when running NSX on N-VDS. However, now that we can deploy NSX directly on a VDS, the equivalent functionality can be easily achieved with a single VDS running NSX and owning the four uplinks, as represented below.

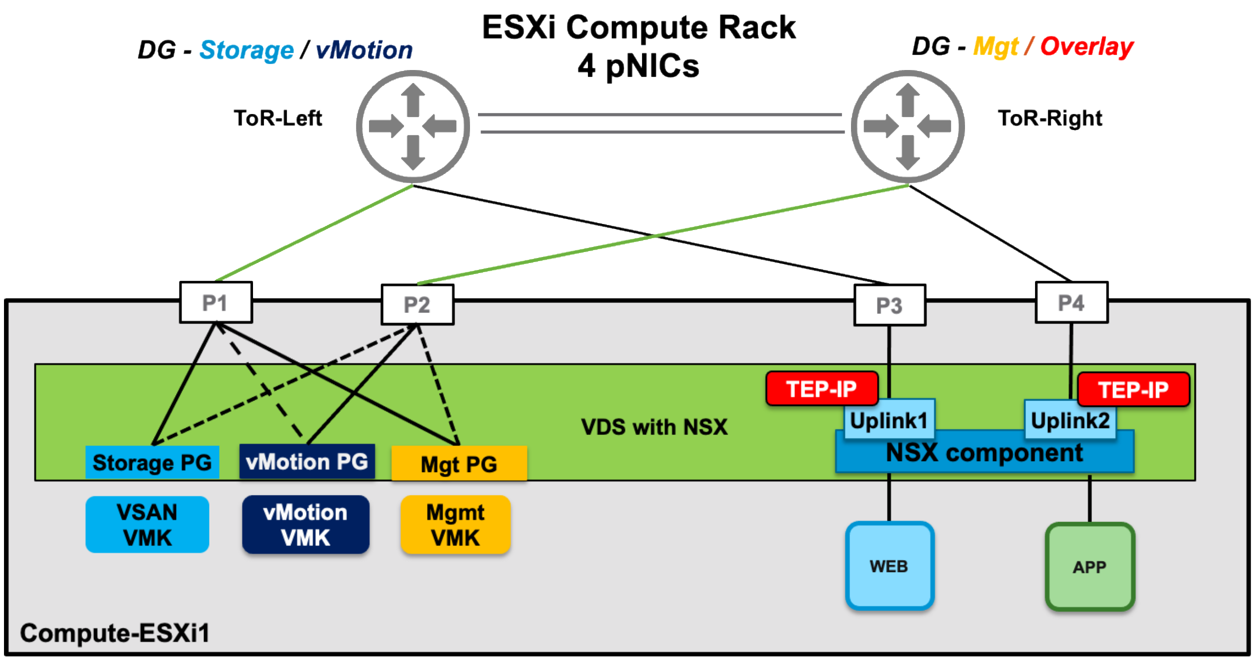


Figure 7-17: ESXi Compute Rack 4 pNICs – VDS and NSX virtual switch

You can achieve this configuration by simply mapping the 4 uplinks of the host to 4 uplinks on the VDS. Then, install NSX using an uplink profile that maps its uplinks (Uplink1/Uplink2 in the diagram) to the VDS uplinks P3 and P4. This model still benefits from the simple, non-disruptive installation of NSX. At the same time, the NSX component can only work with the 2 uplinks mapped to the uplink profile. This means that VM traffic can never flow on P1/P2.

The final added benefit of this model is that the administrator can manage a single virtual switch and if allows flexibility of adding additional uplinks for overlay or infrastructure traffic.

7.3.3.2 Multiple virtual switches as a requirement

Certain scenarios still call for multiple virtual switches on a host. For example:

- Allows compliance-based topology e.g. PCI, HIPPA etc., which often but not always necessitate separate and dedicated infrastructure components (e.g. pNIC, operational controls etc.)
- Build a cloud provider model in which internal or external facing infrastructure requires to be on separate virtual switches.
- There is a specific use case for NFV (Network Function Virtualization) where two pNICs is dedicated to standard virtual switch for overlay and other two pNICs for "enhanced mode" virtual switch. The "enhanced mode" is not discussed here. Please refer to VMware NFV documentation.

In the following scenario, shown in *Figure 7-18: ESXi Compute Rack 4 pNICs- Two N-VDS*, each virtual switch is built to serve specific topology or provide separation of traffic based on enterprise requirements. The virtual switches on a given host can be either VDS or N-VDS (note however that if both virtual switches are prepared for NSX, they can either be both VDS with NSX or both N-VDS, not a mix of N-VDS and VDS with NSX.). The segments cannot extend between two virtual switches as its tied to a transport zone.

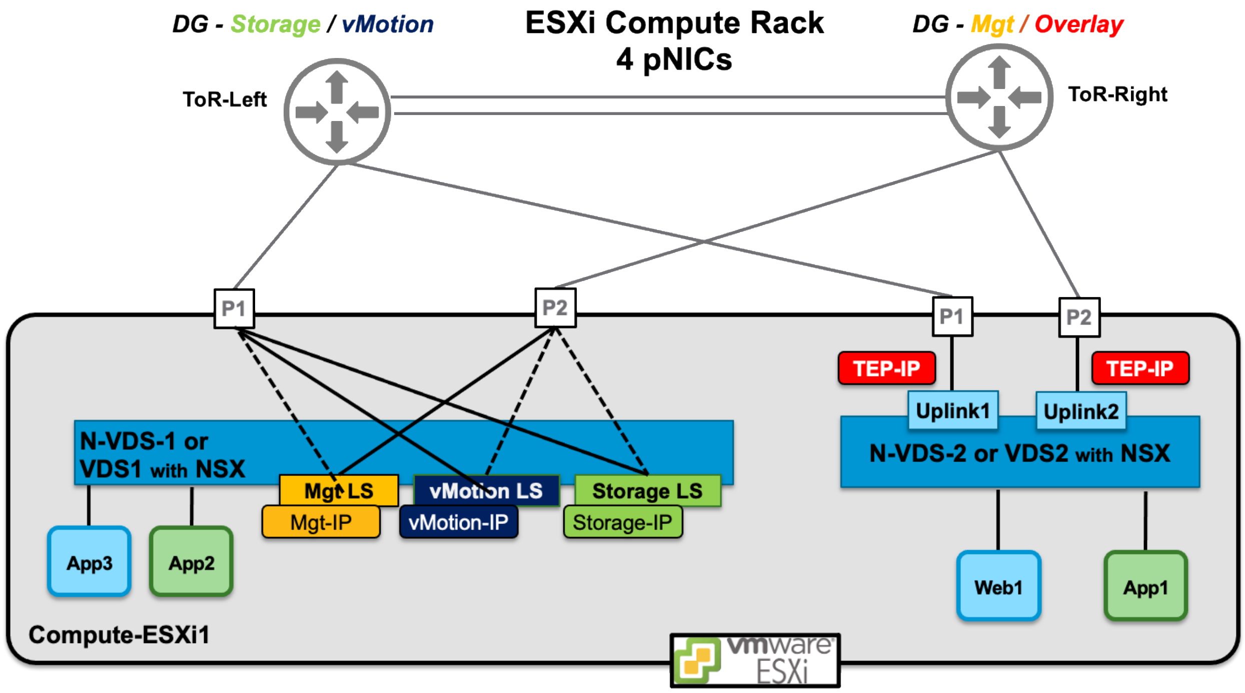


Figure 7-18: ESXi Compute Rack 4 pNICs- Two N-VDS

In any of the below cases the infrastructure traffic will be carried on the first virtual switch. If this is an N-VDS, it will require VMkernel and uplink migration. Here are some few possible examples:

1) First two pNICs are exclusively used for infrastructure traffic and remaining two pNICs for overlay VM traffic. This allows dedicated bandwidth for overlay application traffic. One can select the appropriate teaming mode as discussed in above two pNICs design as appropriate.
2) First two pNICs are dedicated “VLAN only” micro-segmentation and second one for overlay traffic
3) Building multiple overlay for separation of traffic, though TEP IP of both overlays must be in the same VLAN/subnet albeit different transport zones
4) Building regulatory compliant domain either the VLAN only or overlay
5) Building DMZ type isolation

Both virtual switches running NSX must attach to different transport zones. See detail in section Segments and Transport Zones
==
Note: The second virtual switch could be of enhanced datapath type, for the NFV use case. This type is beyond the scope of this design guide. Please refer to Appendix 1 for NFV resources.
==

7.3.4 KVM-Based Compute Hypervisor with two pNICs

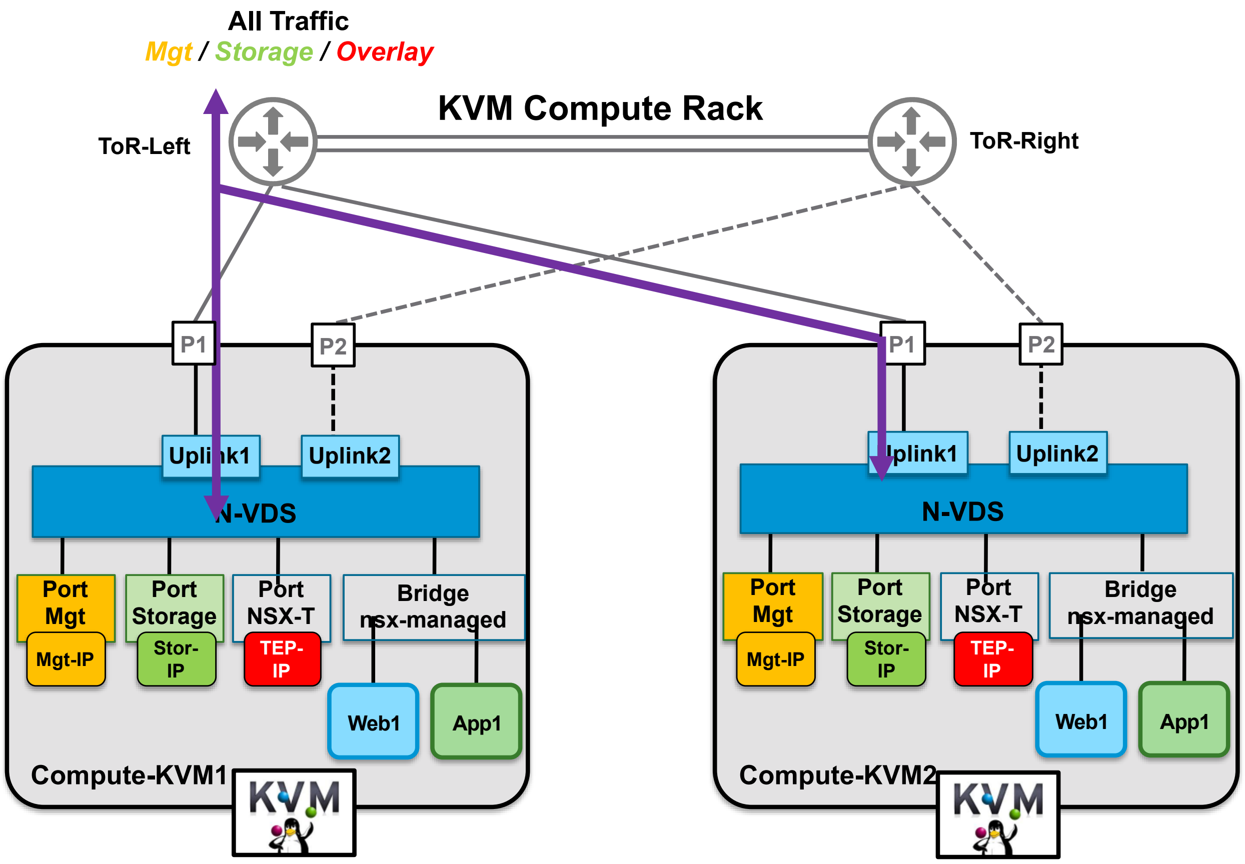
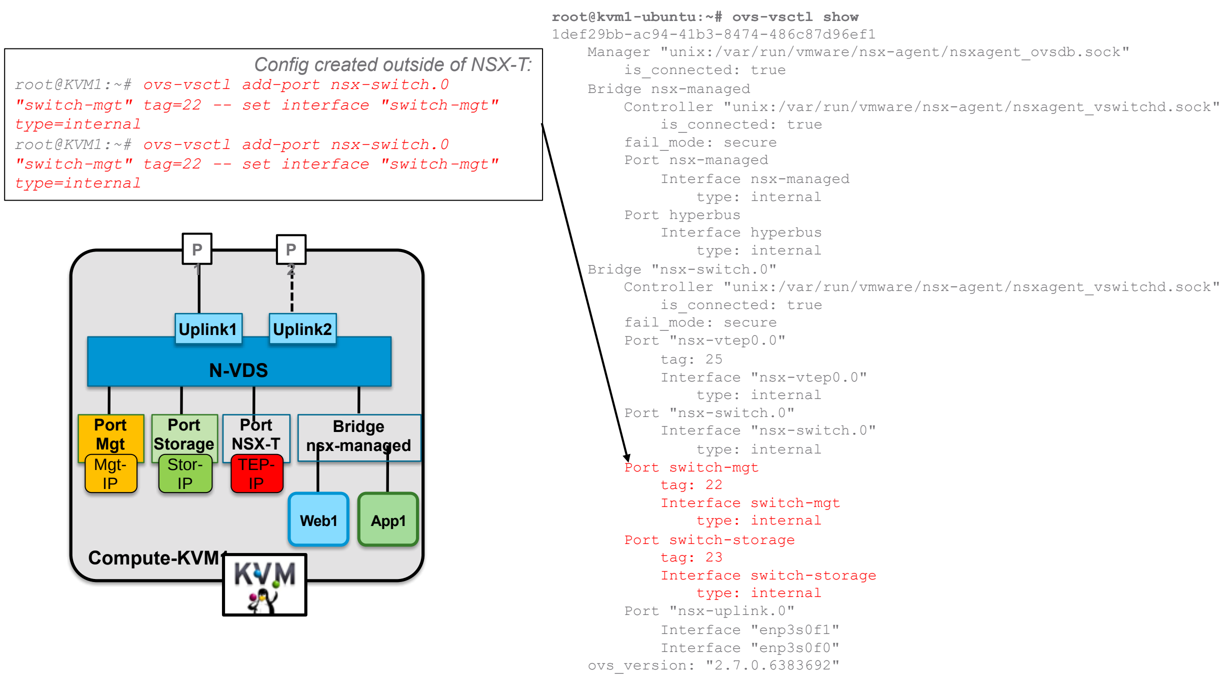


Figure 7-19: KVM Compute Rack Failover Teaming

In *Figure 7-19: KVM Compute Rack Failover Teaming* the design is very similar to ESXi Failover Order Teaming Mode.
A single host switch is used with a 2 pNICs design. This host switch manages all traffic – overlay, management, storage, etc. Physical NICs “P1” and “P2” are attached to different top of rack switches. The teaming option selected is failover order active/standby; “Uplink1” is active while “Uplink2” is standby. As shown logical switching section, host traffic is carried on the active uplink “Uplink1”, while “Uplink2” is purely backup in the case of a port or switch failure. This teaming policy provides a deterministic and simple design for traffic management.

The top-of-rack switches are configured with a first hop redundancy protocol (e.g. HSRP, VRRP) providing an active default gateway for all the VLANs on “ToR-Left”. The VMs are attached to segments/logical switches defined on the N-VDS, with the default gateway set to the logical interface of the distributed Tier-1 logical router instance.

Note about N-VDS ports and bridge:
NSX-T host preparation of KVM creates automatically the N-VDS and its “Port NSX-T” (with TEP IP address) and “Bridge nsx-managed” (to plug the VMs). The other ports like “Port Mgt” and “Port Storage” have to be created outside of NSX-T preparation.



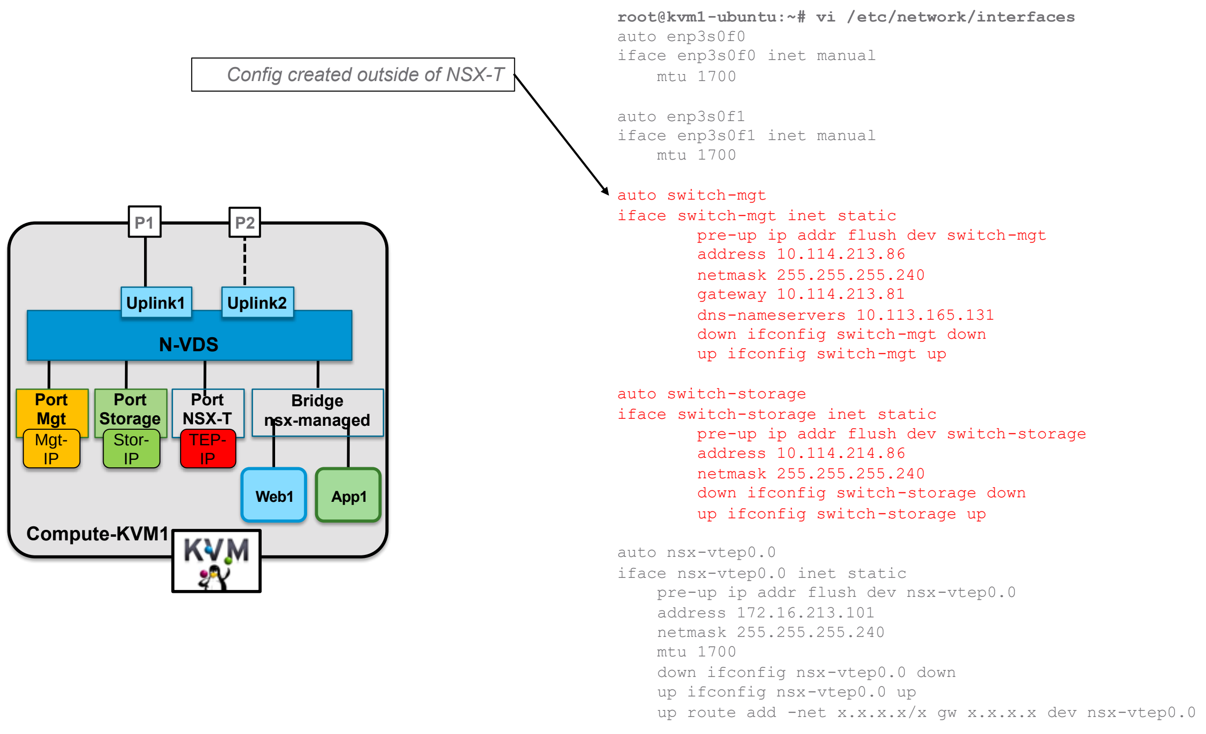
Config created outside of NSX-T:

```
root@KVM1:~# ovs-vsctl add-port nsx-switch.0
"switch-mgt" tag=22 -- set interface "switch-mgt"
type=internal
root@KVM1:~# ovs-vsctl add-port nsx-switch.0
"switch-mgt" tag=22 -- set interface "switch-mgt"
type=internal
```

```
root@kvm1-ubuntu:~# ovs-vsctl show
1def29bb-ac94-41b3-8474-486c87d96ef1
    Manager "unix:/var/run/vmware/nsx-agent/nsxagent_ovsdb.sock"
        is_connected: true
    Bridge nsx-managed
        Controller "unix:/var/run/vmware/nsx-agent/nsxagent_vswitchd.sock"
            is_connected: true
        fail_mode: secure
        Port nsx-managed
            Interface nsx-managed
                type: internal
        Port hyperbus
            Interface hyperbus
                type: internal
    Bridge "nsx-switch.0"
        Controller "unix:/var/run/vmware/nsx-agent/nsxagent_vswitchd.sock"
            is_connected: true
        fail_mode: secure
        Port "nsx-vtep0.0"
            tag: 25
            Interface "nsx-vtep0.0"
                type: internal
        Port "nsx-switch.0"
            Interface "nsx-switch.0"
                type: internal
        Port switch-mgt
            tag: 22
            Interface switch-mgt
                type: internal
        Port switch-storage
            tag: 23
            Interface switch-storage
                type: internal
        Port "nsx-uplink.0"
            Interface "enp3s0f1"
            Interface "enp3s0f0"
    ovs_version: "2.7.0.6383692"
```

Figure 7-20: Creation of the N-VDS Mgt and Storage ports

And IP addresses for those ports have to be created outside of NSX-T preparation.



Config created outside of NSX-T

```
root@kvm1-ubuntu:~# vi /etc/network/interfaces
auto enp3s0f0
iface enp3s0f0 inet manual
    mtu 1700

auto enp3s0f1
iface enp3s0f1 inet manual
    mtu 1700

auto switch-mgt
iface switch-mgt inet static
        pre-up ip addr flush dev switch-mgt
        address 10.114.213.86
        netmask 255.255.255.240
        gateway 10.114.213.81
        dns-nameservers 10.113.165.131
        down ifconfig switch-mgt down
        up ifconfig switch-mgt up

auto switch-storage
iface switch-storage inet static
        pre-up ip addr flush dev switch-storage
        address 10.114.214.86
        netmask 255.255.255.240
        down ifconfig switch-storage down
        up ifconfig switch-storage up

auto nsx-vtep0.0
iface nsx-vtep0.0 inet static
    pre-up ip addr flush dev nsx-vtep0.0
    address 172.16.213.101
    netmask 255.255.255.240
    mtu 1700
    down ifconfig nsx-vtep0.0 down
    up ifconfig nsx-vtep0.0 up
    up route add -net x.x.x.x/x gw x.x.x.x dev nsx-vtep0.0
```

Figure 7-21: Creation Mgt and Storage IP addresses

7.4 Edge Node and Services Design

Edge nodes are available in two form factors – VM and bare metal server. While both form factors offer the same functionality, their physical infrastructure connectivity is quite different, however they have common requirement of three different types of IP networks for specific purposes:

- **Management** – Accessing and controlling the Edge node
- **Overlay (TEP) -** Creating tunnels with peer transport nodes
- **External (N-S) -** Peering with the physical networking infrastructure to provide connectivity between the NSX-T virtual components and the external network

Edge nodes provide a pool of capacity for running centralized services in NSX-T. Edge nodes are always active in the context of connectivity and control plane. They host Tier-0 and Tier-1 routing services, installed in either active/active or active/standby mode. Additionally, if a Tier-0 or Tier-1 router enables stateful services (e.g., NAT, Load Balancer, Gateway Firewall & VPN) it can only be deployed in active/standby mode. The status of active or standby mode is within the context of data plane forwarding rather than related to the Edge node itself. The Edge node connectivity options discussed below are independent of type of services enabled on a given node.

Design choices with Edge node significantly improved with NSX-T 2.5 release. This section is divided into four major areas:

- The bridging design
- The existing design recommendation with release up to version 2.5
- New design recommendation starting with NSX-T release 2.5
- Edge services and resources considerations

7.4.1 Design Considerations with Bridging

The chapter 3 section bridging capability covers the basic functionality and availability model requirements. The next section covers bridging design. The respective topology also covers adding bridging into the mix and its implications.

7.4.1.1 Bridge on a VM form factor Edge

The Edge Bridge is available on both Edge form factors - bare metal or Virtual Machine (VM) The use of the Bridge in the bare metal form factor is relatively straightforward: the bridged traffic is sent on the uplinks of the N-VDS selected by VLAN transport zone specified on the Bridge Profile. There is no Bridge-specific configuration necessary on the physical infrastructure where the bare metal Edge attaches. This section is going to focus on a Bridge running on a VM form factor of the Edge.

7.4.1.1.1 Edge VM vNIC Configuration Requirement with Bridging

For the VM form factor, it is important to remember that the Edge Bridge will end up sourcing traffic from several different mac addresses on its VLAN vNIC. This means, that the uplink vNIC must be connected to a DVPG port group allowing:

- Forged transmit
- Mac learning or promiscuous mode

Both above capabilities are not supported on VSS while supported on VDS. This means it's a strong recommendation is to use VDS when deploying Edge node. Mac learning is available on the VDS as of vSphere 6.7. However, there is no GUI capability on vCenter to configure mac-learning as of this writing but it can be enabled via API or using powerCLI (See https://www.virtuallyghetto.com/2018/04/native-mac-learning-in-vsphere-6-7-removes-the-need-for-promiscuous-mode-for-nested-esxi.html.)

If deployment is running vSphere 6.5 where mac learning is not available, the only other way to run bridging is by enabling promiscuous mode. Typically, promiscuous mode should not be enabled system wide. Thus, either enable promiscuous mode just for DVPG associated with bridge vNIC or it may be worth considering dedicating an Edge VM for the bridged traffic so that other kinds of traffic to/from the Edge do not suffer from the performance impact related to promiscuous mode.

7.4.1.1.2 Edge VM: Virtual Guest Tagging

The Edge Bridge will be sending bridged traffic with an 802.1Q tag on its VLAN uplink. That means that this Edge VM vNIC will have to be attached to a port group configured for Virtual Guest Tagging (VGT, i.e. the DVPG shows as VLAN Trunk in the vCenter UI.) Refer VLAN TAG Requirements for more information.

7.4.1.1.3 Edge VM Configuration Example for the Bridge

The following *Figure 7-22: Dedicated Edge VM for Bridging* represents an Edge VM dedicated to bridging and following the rules enunciated earlier in this section. The Edge VM has four vNICs, but this design only uses 3:

- vNIC1 is dedicated to management traffic
- vNIC2 is the uplink of N-VDS1, the N-VDS that will be used for overlay traffic. The overlay DVPG is using active/standby both pNICs of the host for redundancy.
- vNIC3 is the uplink of N-VDS2 that is attached to the VLAN transport zone "N-VDS2" where the bridged traffic will be sent. The "Bridge VLAN" DVPG has the following configuration:
  - Virtual Guest Tagging is enabled so that it is possible to bridge to several segments to different VLAN IDs
  - Forged transmit and mac learning, so that the bridge can send traffic sourced from different mac addresses. If mac learning is not possible, the promiscuous can be configured instead at the expense of degraded performance.
  - Active standby teaming policy leveraging the same pNICs (but not necessarily in the same order) as the overlay DVPG. That last point is important and will be justified in the next part.

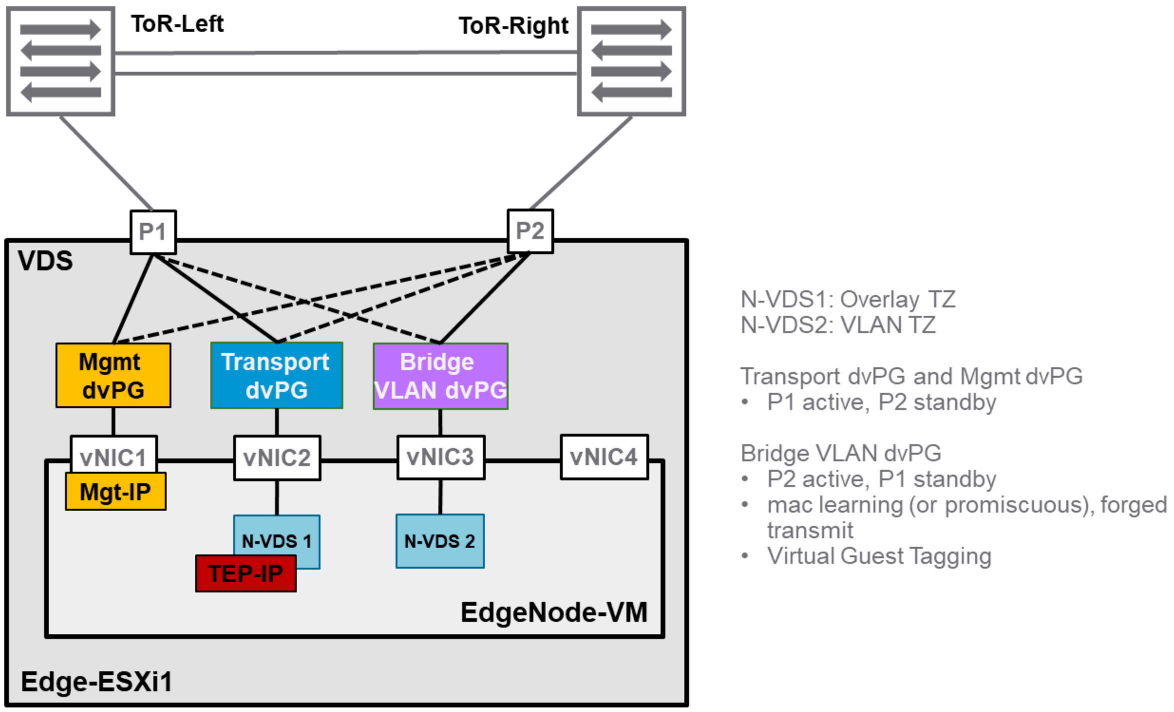


Figure 7-22: Dedicated Edge VM for Bridging

7.4.1.1.4 Edge VM: Edge uplink protection

As we have seen, the Edge Bridge sends/receives two kinds of traffic on its uplinks: overlay traffic and VLAN traffic. This part discusses how to protect both against failure in the data path on the host.

The Edge HA mechanism is exchanging BFD hellos over the tunnels between the different Edges in the Edge Cluster. As a result, overlay traffic is protected against failure in the data path. In *Figure 7-22: Dedicated Edge VM for Bridging* above, if both P1 and P2 went down on the host, all the tunnels between this Edge VM and its peers would go down. As a result, this Edge VM would be considered as failed by Edge HA and another Edge would take over the services it was running (including, but not limited to, the bridge service.)

7.4.1.2 Redundant VLAN connectivity

The Edge Bridge HA mechanism does not protect against connectivity problem in the VLAN infrastructure beyond the Edge physical uplink.

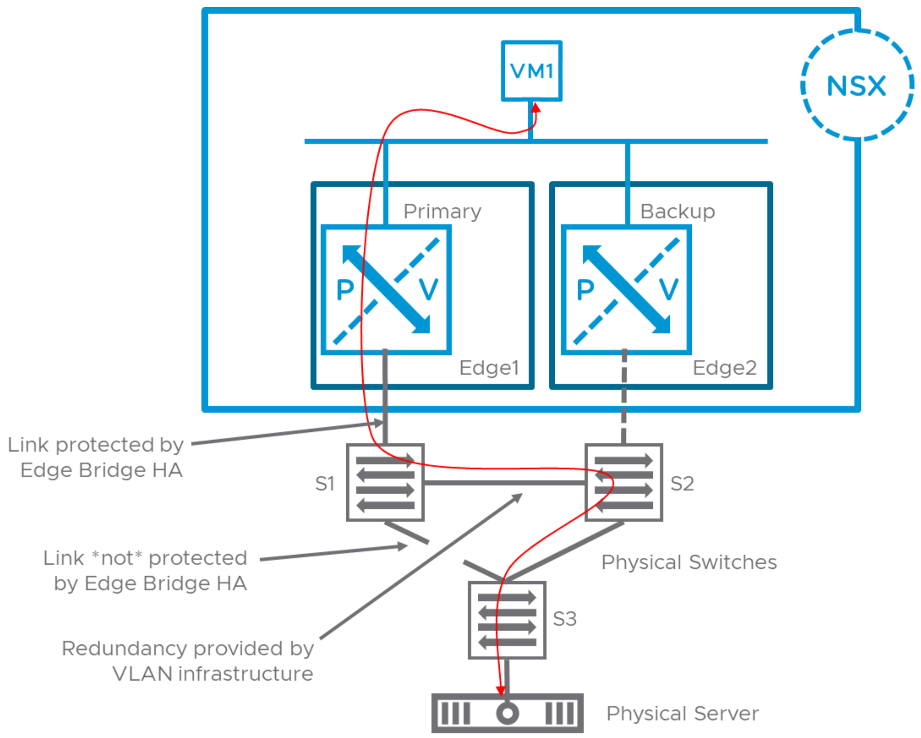

VM1
NSX
Primary
Backup
P
V
P
V
Edge1
Edge2
Link protected by Edge Bridge HA
S1
S2
Link *not* protected by Edge Bridge HA
Physical Switches
S3
Redundancy provided by VLAN infrastructure
Physical Server

Figure 7-23: Physical bridging infrastructure must be redundant

In the above scenario, the failure of the uplink of Edge 1 to physical switch S1 would trigger an Edge Bridge convergence where the Bridge on Edge 2 would become active. However, the failure of the path between physical switches S1 and S3 (as represented in the diagram) would have no impact on the Edge Bridge HA and would have to be recovered in the VLAN L2 domain itself. Here, we need to make sure that the alternate path S1-S2-S3 would become active thanks to some L2 control protocol in the bridged physical infrastructure.

7.4.1.3 Preemptive vs. non-preemptive

The choice is between precise bandwidth allocation on the uplinks and minimum disruption.
The preemptive model allows making sure that, when the system is fully operational, a Bridge is using a specified uplink for its VLAN traffic. This is required for scaling out the solution, precisely distributing the load across several Edge Bridges and getting more aggregate bandwidth between virtual and physical by doing Segment/VLAN load balancing.
The non-preemptive model maximizes availability. If the primary fails then recovers, it will not trigger a re-convergence that could lead to unnecessary packet loss (by preempting the currently active backup.) The drawback is that, after a recovered failure, the bridged traffic remains polarized on one Edge, even if there was several Bridge Profiles defined on this pair of Edges for Segment/VLAN load balancing. Also note that, up to NSX-T release 2.5, a failover cannot be triggered by user intervention. As a result, with this design, one cannot assume that both Edges will be leveraged for bridged traffic, even when they are both available and several Bridge Profiles are used for Segment/VLAN load balancing. This is perfectly acceptable if availability is more important than available aggregate bandwidth.

7.4.1.4 Performance: scaling up vs. scaling out

The performance of the Edge Bridge directly depends on the Edge running it. NSX thus offers the option to scale up the Edge Bridge from a small form factor Edge VM running several other centralized services to a powerful bare metal Edge node dedicated to bridging.
Scaling out is also possible, as a complement to or instead of scaling up. By creating two separate Bridge Profiles, alternating active and backup Edge in the configuration, the user can easily make sure that two Edge nodes simultaneously bridge traffic between overlay and VLAN. The diagram below shows two Edges with two pairs (numbered 1 and 2) of redundant Edge Bridges. The configuration defines the Primary 1 on Edge 1 and Primary 2 on Edge 2. With preemption configured, this ensures that when both Edges are available, both are active for bridging traffic.

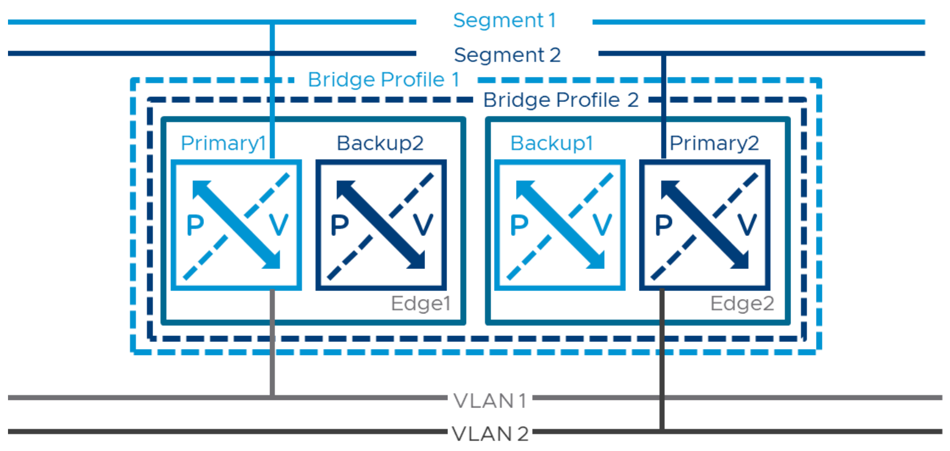


Figure 7-24: Load-balancing bridged traffic for two Logical Switches over two Edges (Edge Cluster omitted for clarity.)

Further scale out can be achieved with more Edge nodes. The following diagram shows an example of three Edge Nodes active at the same time for three different Logical Switches.

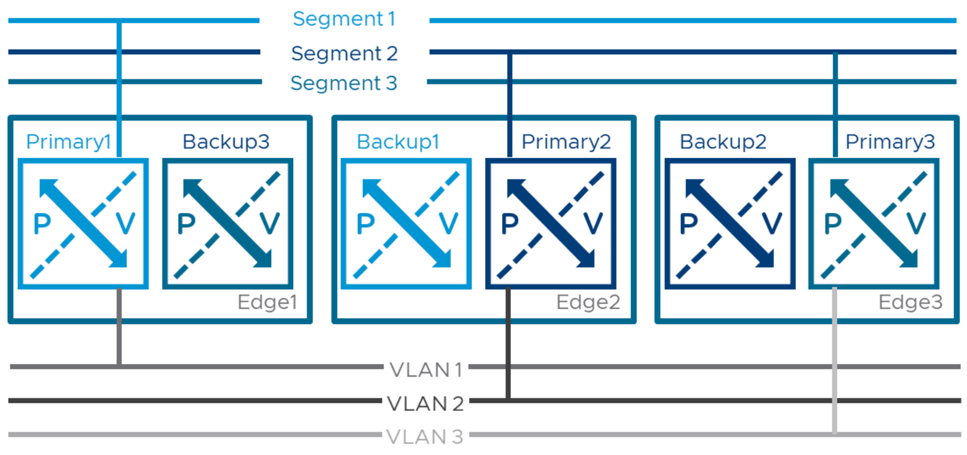


Figure 7-25: Load-balancing example across three Edge nodes (Bridge Profiles not shown for clarity.)

Note that if several Bridge Profiles can be configured to involve several Edge nodes in the bridging activity, a given Bridge Profile cannot specify more than two Edge nodes.

7.4.2 Multiple N-VDS Edge Node Design *before* NSX-T Release 2.5

The "three N-VDS per Edge VM design" as commonly called has been deployed in production. This section briefly covers the design, so the reader does not miss the important decision which design to adopt based on NSX-T release target.

The multiple N-VDS per Edge VM design recommendation is valid regardless of the NSX-T release. This design must be followed if the deployment target is NSX-T release 2.4 or older. The design recommendation is still completely applicable and viable to Edge VM deployment running NSX-T 2.5 release. In order to simplify consumption for the new design recommendation, the pre-2.5 release design has been moved to Appendix 5. The design choices that moved to appendix covers

- 2 pNICs bare metal design necessitating straight through LAG topology
- Edge clustering design consideration for bare metal
- 4 pNICs bare metal design added to support existing deployment
- Edge node design with 2 and 4 pNICs

It's a mandatory to adopt Appendix 5 recommendation for NSX-T release up to 2.5 and beyond. The newer design as described in section The Design Recommendation with Edge Node NSX-T Release 2.5 Onward will not operate properly if adopted in release before NSX-T 2.5.   In addition, readers are highly encouraging to read the below reasoning to appreciate the new design recommendation.

7.4.3 The Design Recommendation with Edge Node NSX-T Release 2.5 *Onward*

The design consideration for Edge node has changed with two critical areas of enhancements

- **Multi-TEP support for Edge** – Details of multi-TEP is described in Chapter 4. Just like an ESXi transport node supporting multiple TEP, Edge node has a capability to support multiple TEP per uplink with following advantages:
  - Removes critical topology restriction with bare metal – straight through LAG
  - Allowing the use of multiple pNICs for the overlay traffic in both bare metal and VM form factor.
  - An Edge VM supporting multiple TEP allows it to have two uplinks from the same N-VDS, allowing utilization of both pNICs. Efficient load sharing among host to Edge VM.
- **Multiple teaming policy per N-VDS** – Default and Named Teaming Policy
  - Allows specific uplink to be designated or pinned for a given VLAN
  - Allowing uplinks to be active/standby or active-only to drive specific behavior of a given traffic types while co-existing other traffic type following entirely different paths
- **Normalization of N-VDS configuration** – All form factors or Edge and deployments uses single N-VDS along with host. Single teaming policy for overlay – Load Balanced Source. Single policy for N-S peering – Named teaming Policy

- **Reduction in management and control plane load** – With each N-VDS, additional resources are used such as IP addressing for management, connections to NSX manager and BFD sessions to all transport nodes as well all the Edge nodes. The BFD sessions are fully meshed, in other words the session counts increase with each N-VDS with N(N-1) expansion. The CPU resources are also consumed by multiple N-VDS within the same Edge VM.

The above functionalities and enhancements allows a consistent configuration for any types of deployment choices – bare metal Edge, Edge VM on VDS enabled ESXi host and Edge VM on N-VDS enable ESXi host. In conjunction, while maintaining the existing best practices design of N-S connectivity that is deterministic and distinct peering to two ToRs. This peering recommendation is common to all design variation and thus only discussed once below.

One common misconception prevails that separation of TEP and BGP on two different switches somehow increases the resiliency or availability of the system. That is not the case at all. In fact, when both TEP and BGP are configured on the same virtual switch, enables consistent failover of both TEP and BGP at the same time. The dual VTEP and BGP combination allows consistent configuration either with Edge VM or bare metal Edge. However, there are corner use cases where asymmetric bandwidth ration of E-W vs N-S exist in that case specific optimization of design may be appropriate.

A special consideration is required with deployment of multiple TEP enabled Edge (VM or Bare Metal) deployed with a physical fabric such as ACI. Before NSX-T 3.0.2, the deployment with multi-TEP will result into intermittent connectivity because the way Edge represent IP/MAC association and enforcement that exist in physical fabric. This condition can be remediated by either disabling a multi-TEP configuration in Edge VM, while running a straight through LAG configuration for the Bare Metal Edge. The less optimal option such as disabling flow cache is possible but not advised due to reduced performance of edge VM, however, may work in specific situation.

7.4.3.1 Deterministic Peering with Physical Routers

The goal of the N-S connectivity is simple, deterministic and redundant configuration without incurring any dependencies on Spanning-tree related configuration. This means the peering VLAN is confined to a specific ToR and do not span across ToR. This topology choice also allows direct mapping from Edge node uplinks to physical NIC of the devices (bare metal or ESXi host) and eventually to ToR interface. This creates 1:1 mapping of physical connectivity and logical peering connectivity from Edge node to physical router. Resulting in to simple, operationally deterministic connectivity of N-S traffic forwarding and troubleshooting. As operator always knows the specific peering is impacted during the failure of pNIC, ToR or Edge-Uplink. In the typical enterprise design, Edge nodes in *Figure 7-26: Typical Enterprise Bare metal Edge Note Logical View with Overlay/External Traffic* are assigned to a Tier-0 router. This Tier-0 router peers with the physical infrastructure using eBGP. Two adjacencies per Edge node with two logical switch connects to distinct "External-VLAN" per ToR. *Figure 7-26: Typical Enterprise Bare metal Edge Note Logical View with Overlay/External Traffic* represents the logical view of BGP peering.

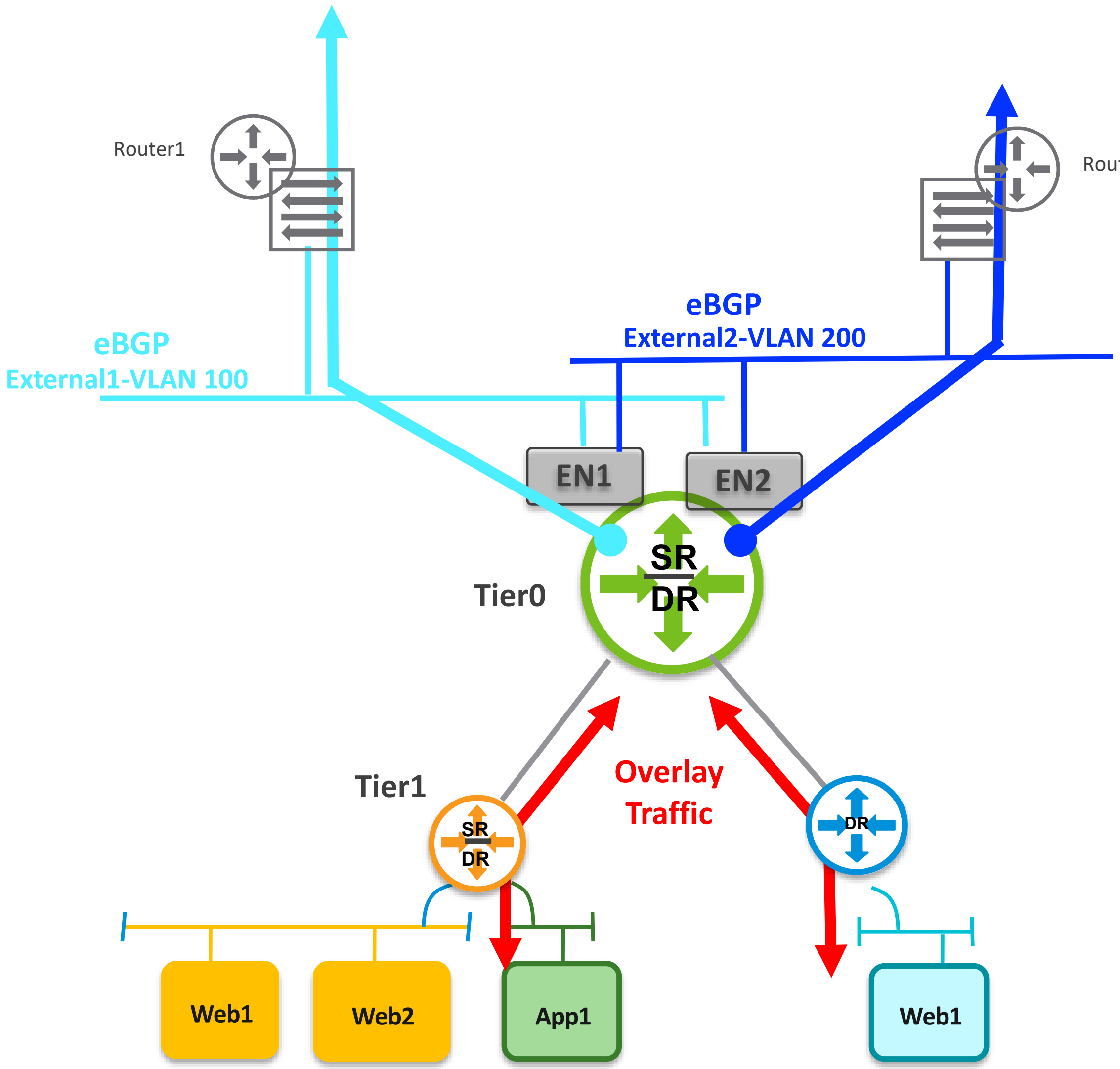


Figure 7-26: Typical Enterprise Bare metal Edge Note Logical View with Overlay/External Traffic

From the perspective of the physical networking devices, the Tier-0 router looks like a single logical router; logically, the adjacency to "Router1" is hosted on Edge node "EN1", while "EN2" is implementing the peering to "Router2".

Those adjacencies are protected with BFD, allowing for quick failover should a router or an uplink fail. See the specific Graceful Restart and BFD Interaction with Active/Standby interaction based on type of services – ECMP or stateful services – enabled in the Edge node and type of physical routers supported.

7.4.4 Bare Metal Edge Design

The bare metal Edge node is a dedicated physical server that runs a special version NSX-T Edge software. The bare metal Edge node requires a NIC supporting DPDK. VMware maintains a list of the compatibility with various vendor NICs.

This design guide covers a common configuration using the minimum number of NICs on the Edge nodes. The design covers commonly deployed bare metal configuration.

7.4.4.1 NSX-T 2.5 Based Bare metal Design with 2 pNICs

Typically, many modern pNIC capable of performing at line rate for majority of workloads and services. Thus, Edge VM with 2 pNICs design with NIC speed of 10/25 Gbps is good enough when compared to 2 pNICs bare metal design. However, the bare metal with two or greater pNICs configuration is desired for few reasons. Those are:

- Consistent footprint (CPU and pNIC) configuration matching compute
- Requirement of line rate services
- Higher bandwidth pNIC (25 or 40 Gbps)
- Adaptation for certain workload that requires near line rate throughput with low packet size (~ 250 Bytes)
- Sub-second link failure detection between physical and Edge node
- Focused Operational responsibility and consistency as appliance model with network operation team
- Multiple Tier-0 deployment models with top Tier-0 driving the bandwidth and throughput with higher speed (40 Gbps) NICs.

The details guidance and configuration recommendation is already covered in Single N-VDS Bare Metal Configuration with 2 pNICs in logical routing chapter 4. However, few additional considerations that applies to bare metal design as follows:

- Management interface redundancy is not always required but a good practice. In-band option is most practical deployment model
- BFD configuration recommendation for link failure detection is 300/900 mSec (Hello/Dead), however assure BFD configuration matches between both ToR and Edge node. Recommended BGP timer is set to either default or matching remote BGP peer
- Without BFD, recommended BGP timer is 1/3 Sec (Hello/Dead)

Figure 7-27: 4-way ECMP Using Bare Metal Edges shows a logical and physical topology where a Tier-0 gateway has four external interfaces (as Edge instances is defined globally, instantiated in each node). External interfaces 1 and 2 are provided by bare metal Edge node “EN1”, whereas External interfaces 3 and 4 are provided by bare metal Edge node “EN2”. Both the Edge nodes are in the same rack and connect to TOR switches in that rack. Both the Edge nodes are configured for Multi-TEP and use named teaming policy to send traffic from VLAN 300 to TOR-Left and traffic from VLAN 400 to TOR-Right. Tier-0 Gateway establishes BGP peering on all four external interfaces and provides 4-way ECMP.

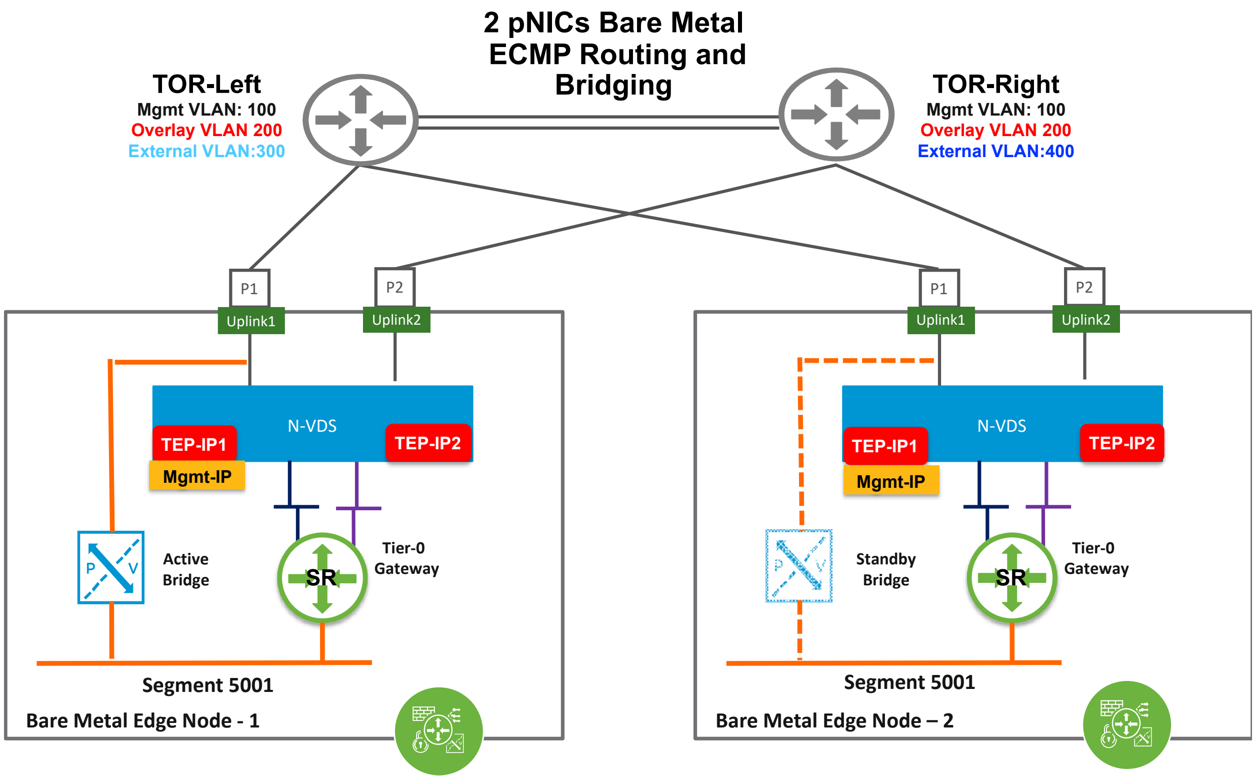


Figure 7-27: 4-way ECMP Using Bare Metal Edges

Bridging Design with 2 pNICs Bare Metal Node

As discussed in High Availability with Bridge Instances, the bridge instance with active-backup pair is shown in above picture. By default, the bridge instance will always select the first active pNIC. Any additional bridge instances will still continue using the same pNIC. User have a choice to select distinct uplink via API call as shown in Appendix4 However, overall discussion on bridge load balancing see below.

When configuring bridging on a bare metal Edge, traffic load balancing can be configured on a per segment basis. Two levels of traffic load balancing can be configured:

- **Between Edges:** Considering *Figure 7-27: 4-way ECMP Using Bare Metal Edges* below two different Bridge Profiles BP1 and BP2 can configured, with BP1 selecting EN1 as active, while BP2 selects EN2 as active. By mapping segments to either BP1 or BP2, in stable condition, their bridged traffic will be handled by either Edge. This the recommended method for achieving load balancing.
- **Between uplinks on a given Edge:** Either in *Figure 7-27: 4-way ECMP Using Bare Metal Edges* or *Figure 7-28: 4 pNIC Bare Metal - ECMP & Bridging*, each Edge has multiple uplinks capable of carrying VLAN bridged traffic. However, by default, the Bridge will only the first uplink specified in the teaming policy of the VLAN transport zone used for bridged traffic. It is however possible to override this default on a per segment basis, using a named teaming policy privileging the other uplink. The only way to achieve this today in NSX-T 2.5 is

via the API method described in Appendix 4. This method is recommended if deployment needs several bridge instances active at once and bare metal uplink bandwidth is heavily utilized (either by multiple bridge instances or by N-S overlay traffic).

7.4.4.2 NSX-T 2.5 Based Bare metal Design with greater than 2 pNICs (4/8/16)

The bare metal configuration with greater than 2 pNICs is the most practical and recommended design. This is because 4 or more pNICs configuration substantially offer more bandwidths compared to equivalent Edge VM configuration for the NIC speeds above 25 Gbps or more. The same reasons for choosing bare metal applies as in 2 pNICs configuration as discussed above.

The configuration guideline with multiple NICs is discussed at Single N-VDS Bare Metal Configuration with Six pNICs. This design again uses single N-VDS as baseline configuration and separate of overlay and N-S traffic on a set of pNICs. The critical pieces to understand is the follow the teaming design consideration as discussed in the Single N-VDS Bare Metal Configuration with Six pNICs where the first two uplinks (uplink 1 and uplink 2) in below diagram associate with Load-Balance Source ID teaming assigning overlay traffic to first two pNICs. The N-S peering design remains the same with single pNIC in each of the associated uplink profile.

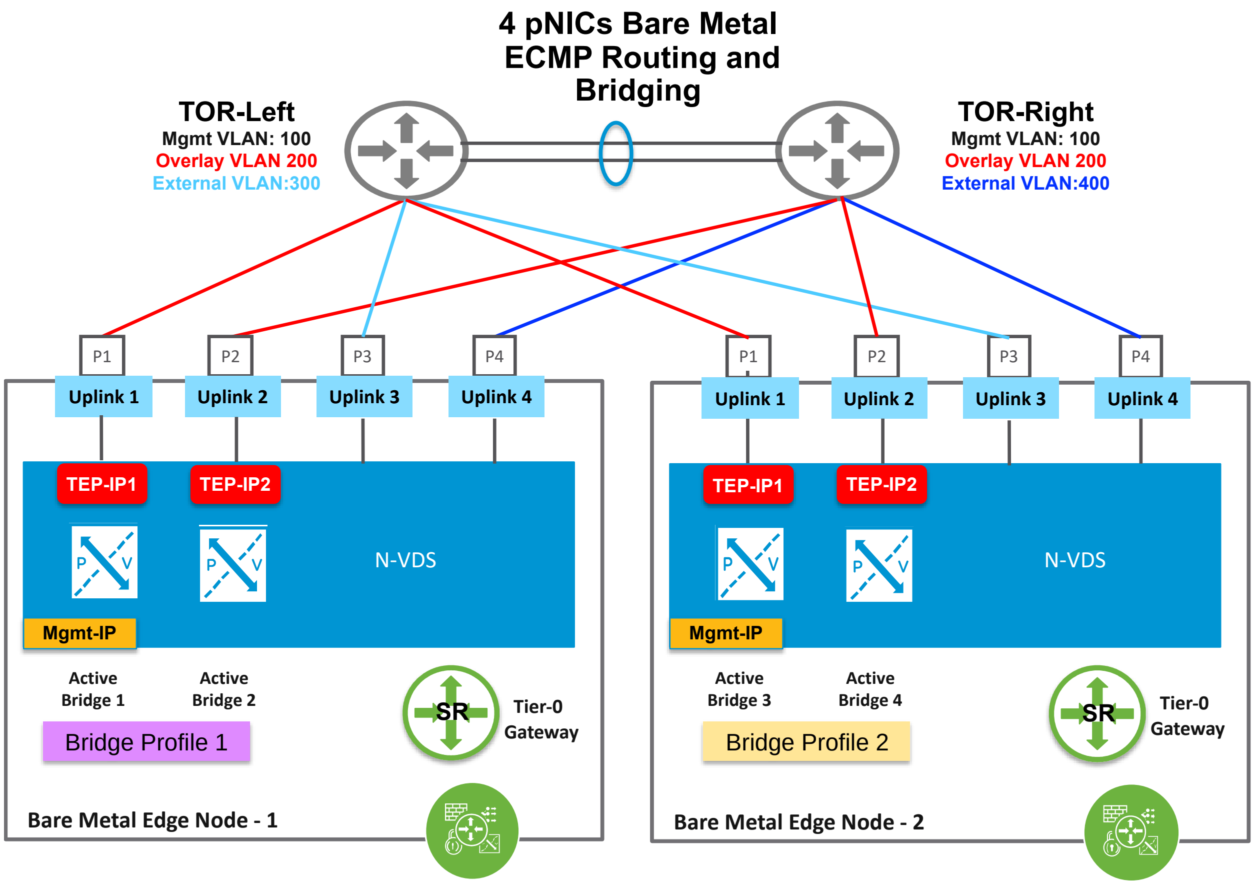


Figure 7-28: 4 pNIC Bare Metal - ECMP & Bridging

The bare metal design with more than four pNICs for data plane follows the similar logic of maintaining symmetric bandwidth for overlay and N-S traffic. E.g. with eight pNICs design one can allocate first four pNICs for overlay and rest for N-S peering. The design with that combination requires for TEP IPs and four BGP peers per bare metal node and thus additional planning is desire on subnet/VLAN for transport and N-S ToR.

Bridging Design with greater than 2 pNICs bare metal node: See the bridging design for load balancing in NSX-T 2.5 Based Bare metal Design with 2 pNICs. If the bridging bandwidth requirements is high or undergoing a large scale migration to NSX-T based cloud, it may require to dedicate 2 pNICs for bridging traffic and in that case the above 4 pNICs design configuration changes to first two pNICs used for TEP/BP traffic and other two pNICs (P3 andP4) for bridging. The same availability and selective load-balancing consideration applies here as well as discussed in 2 pNICs section.

7.4.5 Edge Node VM

This section covers the Edge VM design in various combinations. This design is solely based on single N-VDS per Edge VM for basic overlay and N-S connectivity. This design is consistent with the design that has been discussed for bare metal edge and remains the same for 2 pNIC or 4 pNIC design. The design pattern benefits in following ways:

- Symmetric bandwidth offering to both overlay and N-S
- Deterministic peering of N-S
- Consistent design iteration with collapsed cluster design where Edge VM is deployed on host with N-VDS
- Repetitive with pNIC growth

7.4.5.1 NSX-T 2.5 Edge node VM connectivity with VDS with 2 pNICs

The figure below shows the Edge VM connectivity with 2 pNIC ESXi host. The design configuration for overlay and N-S is described in detail at Single N-VDS Based Configuration - Starting with NSX-T 2.5 release.

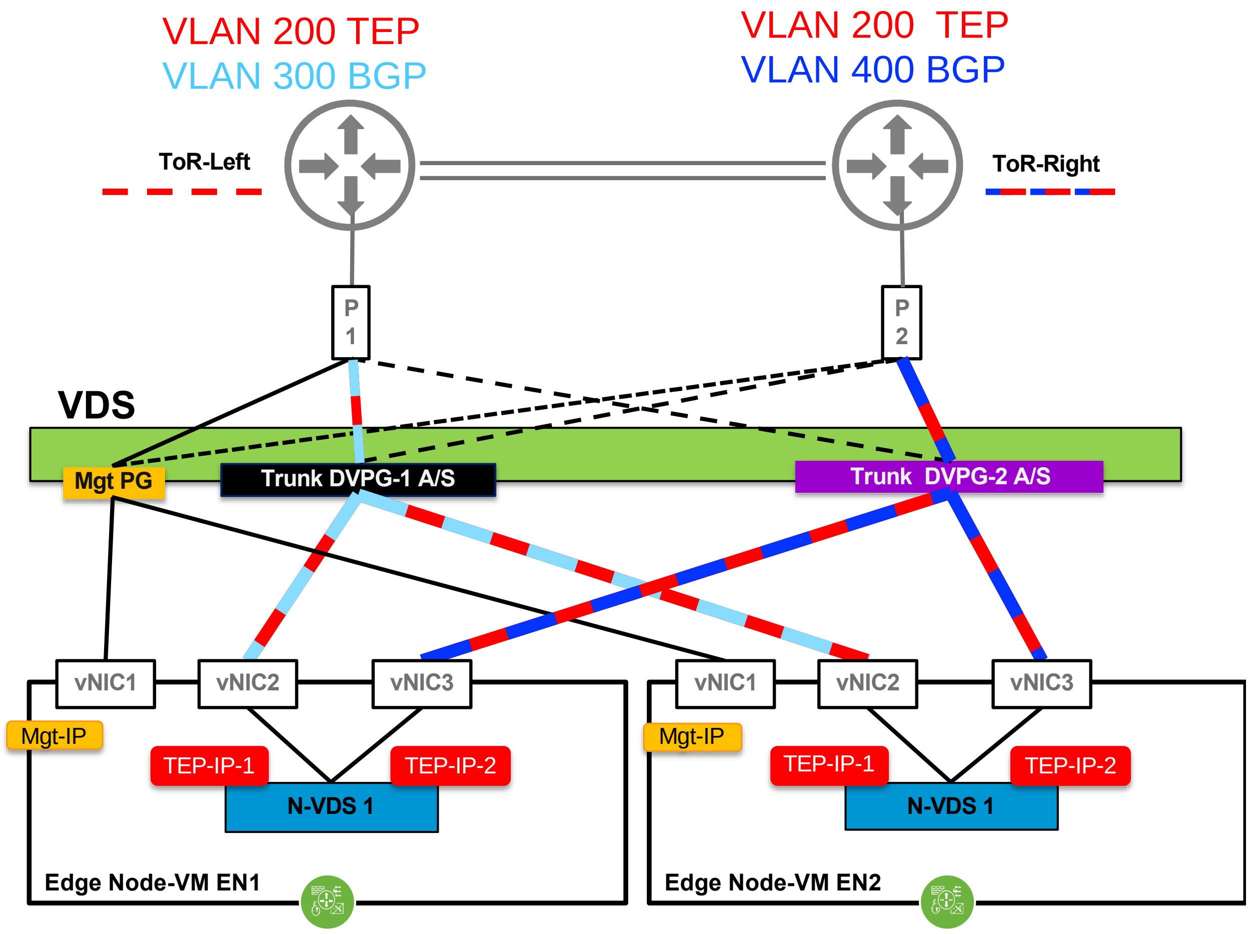


Figure 7-29: Single N-VDS per Edge VM - Two Edge Node VM on Host

The key design attributes are as follows:

- Transport zone – one overlay and VLAN – consistent compared to three N-VDS design where external VLANs have two specific VLAN transport zone due to unique N-VDS per peering
- N-VDS-1(derived from matching transport zone name – both overlay and VLAN) defined with dual uplinks that maps to unique vNICs, which maps to unique DVPG at VDS – duality is maintained end-to-end
- N-VDS-1 carries multiple VLANs per vNIC – overlay and BGP peering
  - The overlay VLAN must be same on both N-VDS uplink with source ID teaming
  - BGP Peering VLAN is unique to each vNIC as it carries 1:1 mapping to ToR with named teaming policy with only one active pNIC in its uplink profile
- VDS DVPG uplinks is active-standby (Failover Order teaming for the trunked DVPG) to leverage faster convergence of TEP failover. The failure of either pNIC/ToR will force the TEP IP (GARP) to register on alternate pNIC and TOR. This detection happens only after BFD from N-VDS times out, however the mapping of TEP reachability is maintained throughout the overlay and thus system wide update of TEP failure is avoided (host and controller have a mapping or VNI to this Edge TEP), resulting into reduced control plane update and better convergence. The BGP peering recovery is not needed as

alternate BGP peering is alive, the BGP peering over the failed pNIC will be timed out based on either protocol timer or BFD detection.

- Recommendation is not to use the same DVPG for other types of traffic in the case of collapsed cluster design to maintain the configuration consistency
- BFD configuration recommendation for link failure detection is 1/3 Sec. (Hello/Dead), however assure BFD configuration matches between both ToR and Edge node. Recommended BGP timer to either default or matching remote BGP peer. Sub-second BFD timers (500 ms) is also possible with NSX-T 3.0 to reduce the link failure detection time.
- Without BFD, recommended BGP timer is set to 1/3 Sec. (Hello/Dead)

Bridging Design with Edge VM: The bridging design choice consists of either enabling bridging instances on existing N-VDS inside Edge VM or dedicating separate N-VDS for bridging. The current guidance is to use dedicated N-VDS for bridging instances.

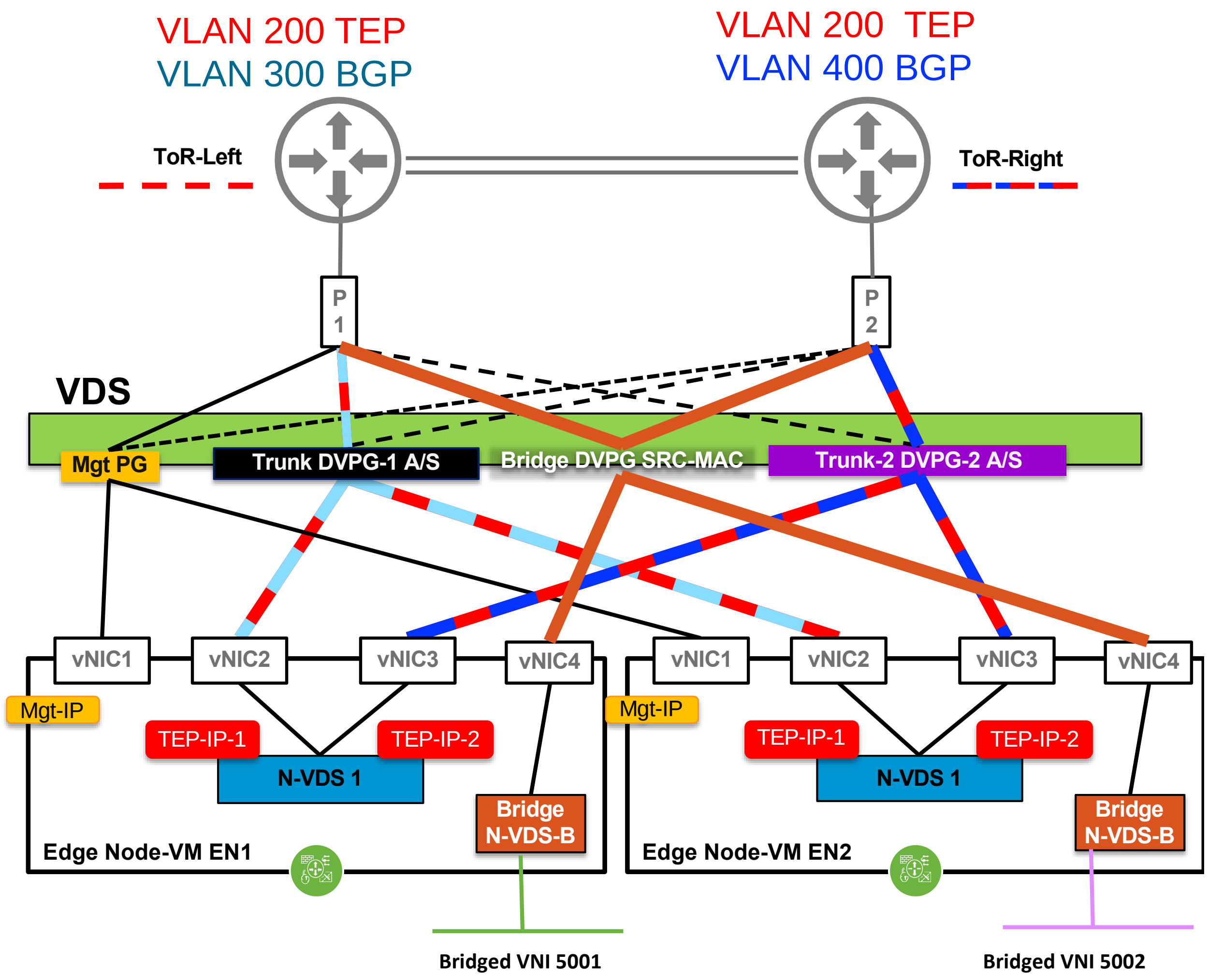


Figure 7-30: Edge VM with Bridging

The key design attributes are:

- Additional vNIC (vNIC 4 in the picture) in Edge VM which maps to dedicated bridge instance
- The bridge N-VDS-B must be attached to separate VLAN transport zone since two N-VDS cannot be attached to same transport zone. Overlay transport zone is defined once per Edge VM node and thus traffic is internally wired between two N-VDS. If a dedicated Edge VM node is chosen for bridged traffic, then the overlay transport zone must be the same for carrying the overlay traffic to bridge instance, while VLAN transport zone is whatever needed for carrying bridged VLANs.
- Dedicated DVPG group defined at VDS to with load balance based on source mac address teaming policy. This should help distributed flows from various sources of MAC across available uplinks links
- The bridge DVPG must be enabled with mac-learning. See additional details on this topic at Edge VM vNIC Configuration Requirement with Bridging.
- For load balancing of bridge traffic, multiple bridge instances are allowed, the bridge instances shown in picture are for illustrating the diversification of bridge placement. If deployment requires significant bandwidth for bridged traffic, either deploy additional pNIC and add a dedicated Edge VM just for the bridging as shown in 7.4.1.1.3. The bridge placement per uplink as discussed in bare metal case is not applicable here since there is only one uplink from the bridge
- Choose preemptive vs non-preemptive mode based on need to consistent traffic load balancing

The picture above shows multiple Edge VM per host to illustrate the symmetry and bandwidth capacity planning matching the proportional throughput from 10/25 Gbps NICs. Additional Edge VM can be added assuming oversubscription is afforded to build a cost-effective design. Alternative is to deploy four pNICs and repeat the same building block of pNIC mapping as shown in below section.

7.4.5.2 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 Edge VM can be deployed in same host. The design choices covering compute host with four pNICs is already discussed in ESXi-Based Compute Hypervisor with Four (or more) pNICs. The design choices with four pNICs hosts utilized for collapsed management and edge or collapsed compute and edge are discussed further in Collapsed Management and Edge Resources Design.

The below design choice with four pNICs is optimal for having multiple Edge nodes per host without any oversubscription. 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 the 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.

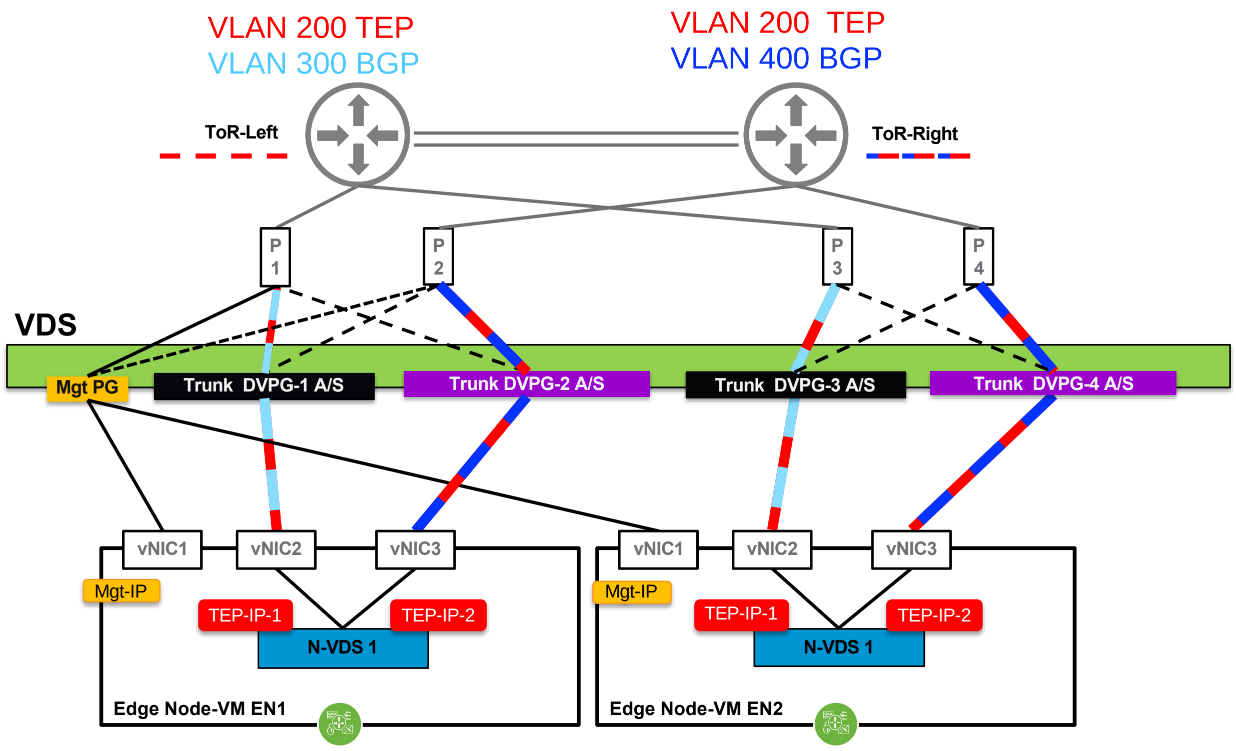


Figure 7-31: Two Edge VM with Dedicated pNICs

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.

7.4.5.3 NSX-T 2.5 Edge node VM connectivity with N-VDS with 2 pNICs

The Edge node VM connectivity to N-VDS is required when Edge node is connected with compute hypervisor running guest VM on overlay and host has only 2 pNICs. Additionally, many organizations streamline connectivity options by selecting N-VDS as a standard mode of deployment in which Edge cluster is built with N-VDS and not VDS. Another use case for this is single collapsed cluster design with 2 pNIC where all the components of NSX-T are on N-VDS. The case of four pNICs design option (N-VDS and VDS) are discussed later in this chapter.

The *Figure 7-32: Two Edge Node VM on Host with N-VDS* shows two Edge VMs connected to host N-VDS-1 with 2 pNICs. The traffic engineering principle remains the same as Edge VM connected to VDS as show in NSX-T 2.5 Edge node VM connectivity with VDS with 2 pNICs. However, there are some important differences.

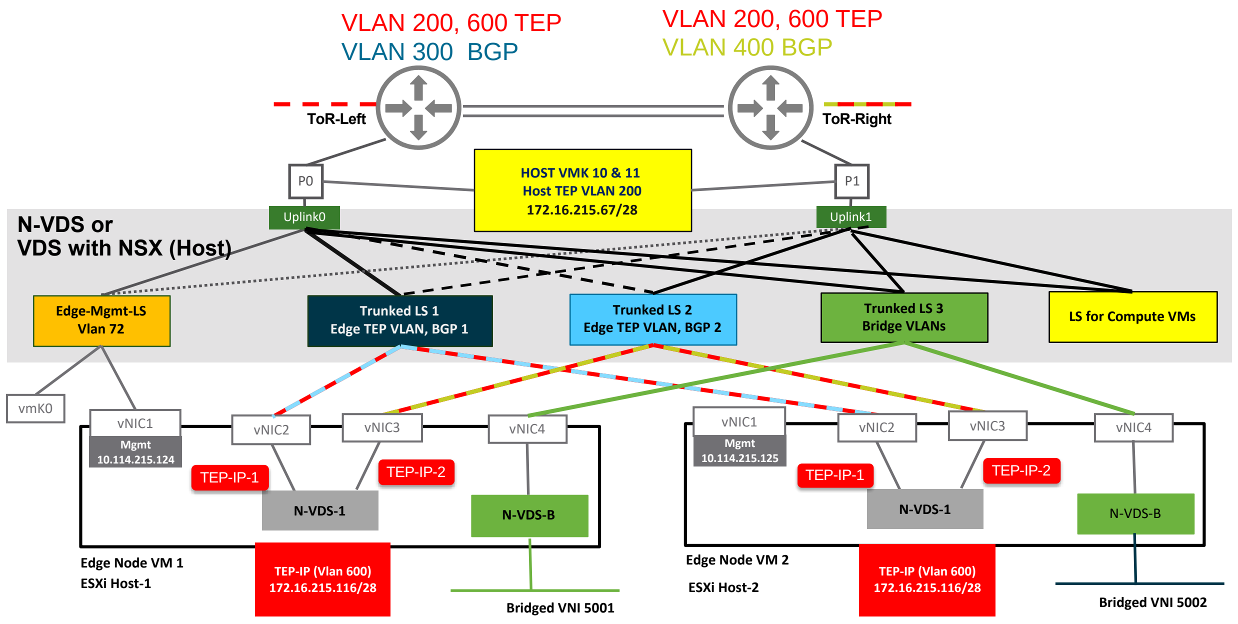


Figure 7-32: Two Edge Node VM on Host with N-VDS

A 2 pNIC ESXi host providing connectivity to overlay workloads would typically have an N-VDS installed with both pNICs connected to the N-VDS for redundancy. All the VMkernel interfaces on this ESXi host also reside on N-VDS. Similarly, if the Edge node needs to be hosted on this ESXi host, it needs to be connected on the segments/logical switches defined on this N-VDS. Four VLAN backed segments or logical switches, “Edge-Mgmt-LS”, “Trunk-LS1”, “Trunk-LS2” and “Trunk-LS3” have been defined on the host N-VDS-1, named as “N-VDS-1” to provide connectivity to Edge VMs.

Teaming policy defined on the Edge N-VDS define how traffic will exit out of the Edge VM. This traffic is received by the compute host N-VDS, and the teaming policies defined at the segment level will define how this traffic exists the hypervisor.

Edge VM is configured to use the same teaming policy as explained in *Figure 7-29: Single N-VDS per Edge VM - Two Edge Node VM on Host*. The only difference is that Edge VM in *Figure 7-29: Single N-VDS per Edge VM - Two Edge Node VM on Host* is connected to VDS DVPG and in this case, it is connected to N-VDS-1 segments.

It is also critical to note that above *Figure 7-32: Two Edge Node VM on Host with N-VDS* shows collapsed cluster use case, the compute guest VM will be attached to host N-VDS. The Edge N-VDS-1 must be attached to the same transport zones (VLAN and overlay) as host N-VDS and thus the same name is used here. The VLAN/subnet for host overlay (TEP) and Edge VMs N-VDS overlay must be different and routing between host TEP and Edge-VM occurs at the physical layer, this requirement is coming from protecting the host overlay from VM generating overlay traffic.

For a design with VDS with NSX, the edge VM connectivity is exactly to the same as VDS. When one enables VDS with NSX functionality under the same host with 2 pNICs, the assumption is that application guest VM is also cohabit with Edge VMs, essentially a fully collapsed cluster design. This design is discussed under Fully Collapsed Single vSphere Cluster with 2 pNICs Host.

For the bridging services, one must enable mac-learning on N-VDS which available as natively as compared VDS. In addition, the VLAN transport zone for the bridge must be different then the host N-VDS, as in this recommendation the dedicated N-VDS-B is used for bridging traffic.

7.4.6 NSX-T Edge Resources Design

The previous section covered the Edge node wiring for both bare metal and VM. It explains how overlay, N-S peering and bridging connectivity can be achieved with choices of design with number of pNICs and availability model through the choice of right teaming behavior. This section goes details into building services (e.g. ECMP, FW, NAT, LB and VPN) with either bare metal or VM. In addition, several considerations that goes inn optimizing right footprint of resources. There are two major considerations in designing NSX-T services cluster – Type of services enabled and clustering.

7.4.6.1 Edge Services

The guideline that governs the overall roadmap of developing services models.

- Service Level Agreement desired for each service. It can be broad, bandwidth/throughput of each service, separation of Tier-0 or Tier-1 to have an independence operational control or varying levels of services specific offering
    - Not just for bandwidth but scale
    - Configuration controls – overlapping NAT, change control of security vs NAT
    - Multi-tenant – dedicated Tier-1 per tenant or services as a tenant
    - Services controls – failure behavior – only Tier-0 or only Tier-1, Automation control etc.
- ECMP to physical devices only run at Tier-0, however that does not mean there is no ECMP from Tier-1, there are up to 8 paths from Tier-1 to Tier-0 and up to 8 distinct BGP peering from Tier-0
    - For a given Edge node there can only one Tier-0 services, however one can have multiple Tier-1 services. If Tier-0 is enabled with stateful services for a workload like Kubernetes (TKGI-PKS or OpenShift), then for the other workloads it may require separate Tier-0 (SLA considerations) and thus separate Edge node. Multi-tier Tier-0 model is only possible with running multiple instances Edge node VM or dedicated bare metal per Tier-0.
- As of NSX-T release 2.5 all edge services can be deployed in either Tier-0 or Tier-1. However, there are exception for other services
    - VPN can run on Tier-0 with BGP but not at Tier-1, VPN at Tier-1 can enabled wit static routing
    - In line LB can only be enable on Tier-1. Use in- line LB for preserving server pools.
    - One arm LB can be deployed as standalone Tier-1 services. It can be attached to either Tier-0 or Tier-1 as a VLAN or overlay services port. To optimize East-West distributed routing, use one-arm LB with overlay services port. The one-arm

LB allows sperate life cycle of Edge node, from configuration changes to resizing without directly affecting existing Tier-1 gateway for other traffic.

- Services port (SP) can be attached as VLAN or overlay. It can be attached to either Tier-0 or Tier-1. Edge node must be in active/standby mode. Typically, services interface should be enabled on Tier-1 to avoid forcing the Tier-0 in active/standby mode and thus limiting ECMP bandwidth for the entire NSX-T domain. Avoid using overlay services interface attaching to Tier-0 unless it is used for LB one arm mode. Services interface should not be used for a single tier topology with logical network (allows fully distributed routing for) typical small scale or small size multi-tenant design unless specific use case requires it.

Preemptive vs Non-preemptive Mode with Active/Standby Services

Each stateful services can be configured for either preemptive or non-preemptive mode. The design choice is between deterministic balancing of services among available resources (bandwidth and CPU) verses reducing disruption of services.

- The preemptive model allows making sure that, when the system is fully operational, pool of edge resources (bandwidth and CPU) always get balanced after the restoration of host or Edge VM. However, preemptive mode triggers the switchover of Edge VM running services, leading secondary disruption causing packet loss. Operationally this may not be acceptable triggering intentional switchover.
- The non-preemptive model maximizes availability and is the default mode for the service deployment. If the active fails then recovers; it will be in standby mode, it will not trigger a re-convergence that could lead to unnecessary packet loss (by preempting the currently active.) The drawback is that, after a recovered failure, the services remains polarized on a host or an edge cluster. This leads to an oversubscription of a host or uplink bandwidth. If availability is more important than oversubscription (bandwidth and CPU), this mode is perfectly acceptable. Typically, one can restore the rebalancing of the services during off-peak or planned maintenance window.

Services can be enabled either in shared or dedicated Edge node.

- **Shared Mode**: Shared mode is the most common deployment mode and a starting point for building the edge services model. Tier-0 or Tier-1 not enabled with stateful service, by default runs in distributed mode. In shared mode, typically Tier-0 runs ECMP service while Tier-1 can runs stateful services (aka either active or standby mode for that services). If the Edge node fails, all the services within that nodes fails (this is an SLA choice see first bullet). Below *Figure 7-33: Shared Service Edge Node Cluster* shows the flexibility in deploying ECMP services along with variable services model for Tier-1. Tier-0, represented by the green node, running the ECMP service on all four Edge nodes providing aggregated multi-Gbps throughput for combined Tier-1 services. The Tier-1 services are deployed based on tenants or workload needs. For an example few Tier-1 services (red, black and blue) are stateful over a pair of Edge nodes where many services are spread over four nodes. In other words, they do not have to be deployed on the same nodes so the services can scale. The stateful services have a SR component running on the Edge nodes. The active SR component is shown with solid color Tier-1 router icon while the standby on in light faded icon. The Tier-1 routing function can be entirely distributed (aka stateless yellow Tier-1) and thus does not have SR component and thus they exist on each Edge node by its nature of distributed router component, below figure depiction of for it is for illustration purpose only. Note that active/standby services all have distributed routing (DR) component running in all Edge nodes but traffic will be always be going through active services. This services configuration can be applicable to both bare metal and Edge VM.

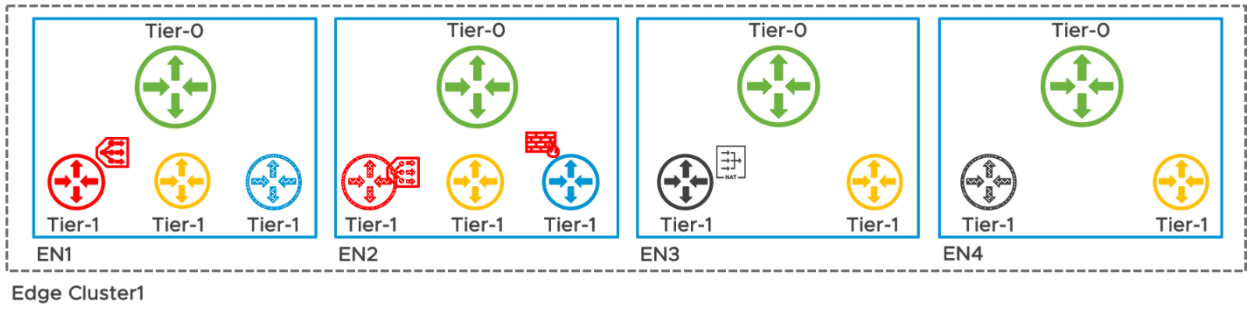


Figure 7-33: Shared Service Edge Node Cluster

The shared mode provides simplicity of allocating services in automated fashion as NSX-T tracks which Edge node is provisioned with service and reduced that Edge node as potential target for next services deployment. However, each Edge node is sharing CPU and thus bandwidth is shared among services. In addition, if the Edge node fails, all the services inside Edge nodes fails together. Shared edge mode if configured with preemption for the services, leads to only service-related secondary convergence. On the other hand, it provides optimized footprint of CPU capacity per host. If the high dedicated bandwidth per service and granular services control is not a priority, then use shared mode of deployment with Edge services.

- **Dedicated Mode:** In this mode, Edge node is either running ECMP or stateful services but not both. This mode is important for building scalable and performance-based services edge cluster. Separation of services on dedicated Edge node allows distinct operational model for ECMP vs stateful services. The choices of scaling either ECMP or stateful services can be achieved via choice of bare metal or multiple of Edge VMs.

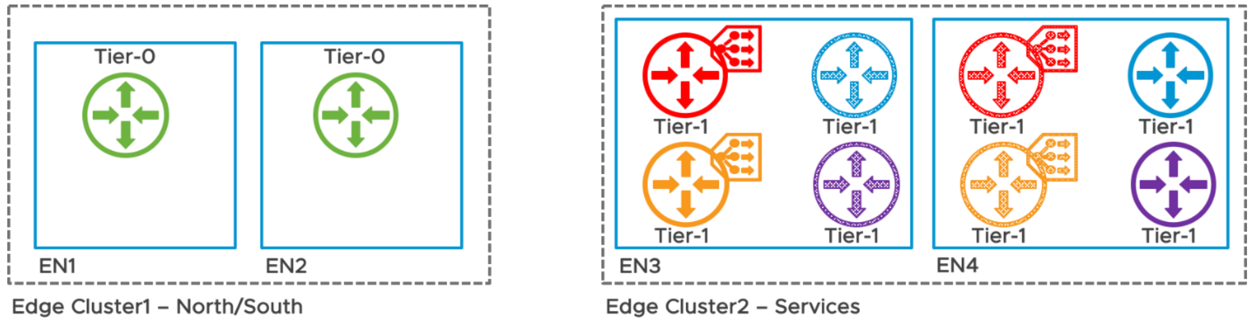


Figure 7-34: Dedicated Service Edge Node Cluster

Figure 7-34: Dedicated Service Edge Node Cluster described dedicated modes per service, ECMP or stateful services. One can further enhanced configuration by deploying a specific service per Edge node, in another word each of the services in EN3 and EN4 gets deployed as an independent Edge node. It's the most flexible model, however not a cost-effective mode as each Edge node reserves the CPU. In this mode of deployment one can choose preemptive or non-preemptive

mode for each service individually if deployed as a dedicated Edge VM per services. In above figure if preemptive mode is configured, all the services in EN3 will experience secondary convergence. However, if one segregate each service to dedicated Edge VM, one can control which services can be preemptive or non-preemptive. Thus, it is a design choice of availability verses load-balancing the edge resources. The dedicated edge node either per service or grouped for set of services allows deploying a specific form factor Edge VM, thus one can distinguish ECMP based Edge VM running larger form (8 vCPU) allowing dedicated CPU for high bandwidth need of the NSX-T domain. Similar design choices can be adopted by allowing smaller form factor of Edge VM if the services do not require line rate bandwidth. Thus, if the multi-tenant services do not require high bandwidth one can construct a very high density per tenant Edge node services with just 2 vCPU per edge node (e.g. VPN services or a LB deployed with DevTest/QA). The LB service with container deployment is one clear example where adequate planning of host CPU and bandwidth is required. A dedicated edge VM or cluster may be required as each container services can deploy LB, quickly exhausting the underlying resources.

Another use case to run dedicated services node is multi-tier Tier-0 or having a Tier-0 level multi-tenancy model, which is only possible with running multiple instances of dedicated Edge node (Tier-0) for each tenant or services and thus Edge VM deployment is the most economical and flexible option. For the startup design one should adopt Edge VM form factor, then later as growth in bandwidth or services demands, one can lead to selective upgrade of Edge node VM to bare metal form. For Edge VM host convertibility to bare metal , it must be compatible with bare metal requirement. If the design choice is to immunize from most of the future capacity and predictive bandwidth consideration, by default going with bare metal is the right choice (either for ECMP or stateful services). This decision to go with VM verses bare metal also hinges on operational model of the organization in which if the network team owns the lifecycle and relatively want to remain agnostic to workload design and adopt a cloud model by providing generalized capacity then bare metal is also a right choice.

7.4.6.2 Edge Cluster

Edge cluster is logical grouping of Edge node (VM or BM). This clustering should not be confused with vSphere clustering concept, which is orthogonal to Edge Cluster. Edge cluster functionality allows the grouping of up to ten Edge nodes per cluster. One can have maximum 16 edge clusters totaling 160 Edge nodes per NSX-T Manager. The grouping of Edge nodes offers the benefits of high availability and scale out performance for the Edge node services. Additionally, multiple Edge clusters can be deployed within a single NSX-T Manager, allowing for the creation of pool of capacity that can be dedicated to specific services (e.g., NAT at Tier-0 vs. NAT at Tier-1). Some rules apply while designing edge clusters:

- Tier-0 cannot span across cluster, it must confine to a cluster
- Active/standby services cannot span across cluster (Tier-0 or Tier-1)
    - Thus, one can create dedicated cluster just for Tier-0 services (e.g. ECMP) or Tier-1 services as discussed above
- Cluster striping can be vertical or horizontal and will depend on mode of deployment of Edge node – shared vs dedicated, rack-availability, and deterministic edge cluster choice.

The fault domain capability introduced in NSX-T 2.5 is necessary in certain configuration as discussed later

- Specific considerations apply for bare-metal and multi-tier T0 topologies as discussed below
- Within a single Edge cluster, all Edge nodes should be the same type – either bare metal or VM. Edge node VMs of different size can be mixed in the same Edge cluster, as can bare metal Edge nodes of different performance levels based on pNICs, however those combination is discouraged but supported for upgrades and other lifecycle reasons.

A mixture of different sizes/performance levels within the same Edge cluster can have the following effects:

- With two Edge nodes hosting a Tier-0 configured in active/active mode, traffic will be spread evenly. If one Edge node is of lower capacity or performance, half of the traffic may see reduced performance while the other Edge node has excess capacity.
- For two Edge nodes hosting a Tier-0 or Tier-1 configured in active/standby mode, only one Edge node is processing the entire traffic load. If this Edge node fails, the second Edge node will become active but may not be able to meet production requirements, leading to slowness or dropped connections.

7.4.6.2.1 Services Availability Considerations with Edge Node VM

The availability and service placement for Edge node VM depends on multiple factors due to nature of its flexibility as a VM. Design choices revolves around shared vs dedicated services deployment, number of Edge nodes, in-rack vs multi-rack availability and number of pNIC available in the host, growth, capacity and finally bandwidth required as a whole and per services. In addition, restricted design consideration when Edge node VM coexist with another compute VMs in the same host. In this section the focus is mostly in the context of dedicated edge cluster and availability with two pNICs.

There are two forms of availability to consider for Edge VM. First is Edge node availability as a VM and second is the service that is running inside Edge VM. Typically, the Edge node VM availability falls into two models. In-rack verses multi-rack. In-rack availability implies minimum two hosts are available (for both ECMP and stateful services) and failure of a host will trigger either re-deployment of Edge node to available host or a restart of the Edge VM depending on the availability of the underlying hypervisor. For multi-rack availability, the recommendation is to keep availability model for Edge node recovery/restoration/redeployment restricted to rack avoiding any physical fabric related requirement (independent of L2 or L3 fabric).

For the simplest and most common form of Edge deployment is shown in below *Figure 7-35: ECMP Base Edge Node Cluster Growth Pattern*, in which entire NSX-T domains is only requiring on Tier-0 active/active (ECMP) services. In this case, it is important to remember that all Tier-1 are distributed by default and thus does not require any specific consideration. The services enablement assumes single rack deployment, with minimum two Tier-0 (ECMP only services) Edge Nodes. The growth pattern starts with two hosts to avoid single point of failure, addition of two additional Edge nodes per host, leading to four hosts with eight Edge nodes delivering eight ECMP forwarding paths. Notice the edge cluster striping is vertical and not much impact how it is striped. If one has requirement to support multi-tenant with each tenant requiring dedicated Tier-0, one must stripe more than one cluster and vertically for which minimum unit of deployment is two hosts with two Edge nodes (this is not shown in below diagram, but one can imagine that arrangement of ECMP services)

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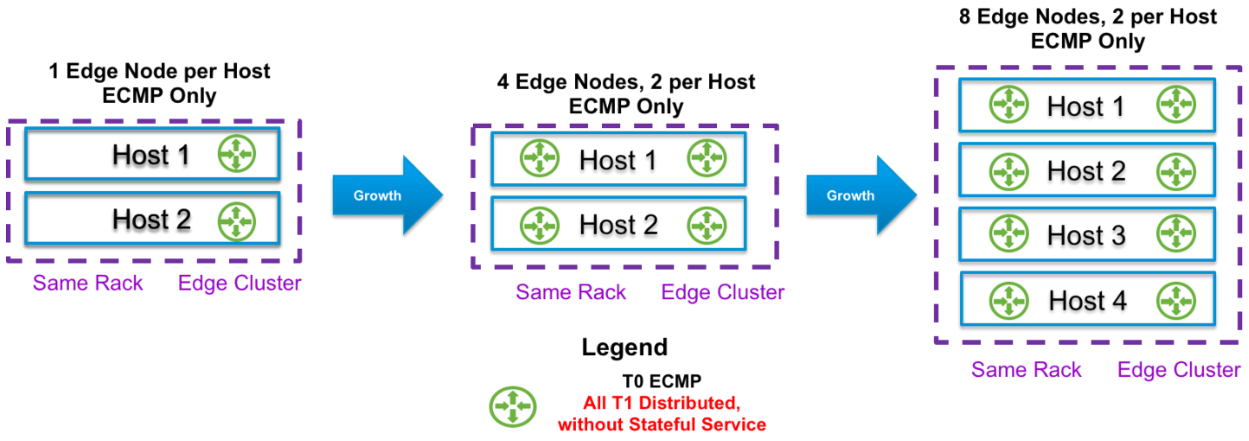


Figure 7-35: ECMP Base Edge Node Cluster Growth Pattern

For the deployment that requires stateful services the most common mode of deployment is shared Edge node mode (see Figure 7-33: Shared Service Edge Node Cluster) in which both ECMP Tier-0 services as well stateful services at Tier-1 is enabled inside an Edge node, based on per workload requirements. The *Figure 7-36: Shared Services Edge Node Cluster Growth Patterns* below shows shared edge not for services at Tier-1, red Tier-1 is enabled with load-balancer, while black Tier-1 with NAT. In addition, one can enable multiple active-standby services per Edge node, in other word one can optimize services such that two services can run on separate host complementing each other (e.g. on two host configuration below one can enable Tier-1 NAT active on host 2 and standby on host 1) while in four hosts configuration dedicated services are enabled per host. For the workloads which could have dedicated Tier-1 gateways, are not shown in the figure as they are in distributed mode thus, they all get ECMP service from Tier-0. For the active-standby services consideration, in this case of in-rack deployment mode one must ensure the active-standby services instances be deployed in two different host. This is obvious in two edge nodes deployed on two hosts as shown below as NSX-T will deploy them in two different host automatically. The growth pattern is just adding two more hosts so on. Note here there is only one Edge node instances per host with assumption of two 10 Gbps pNICs. Adding additional Edge node in the same host may oversubscribed available bandwidth, as one must not forget that Edge node not only runs ECMP Tier-0 but also serves other Tier-1s that are distributed.

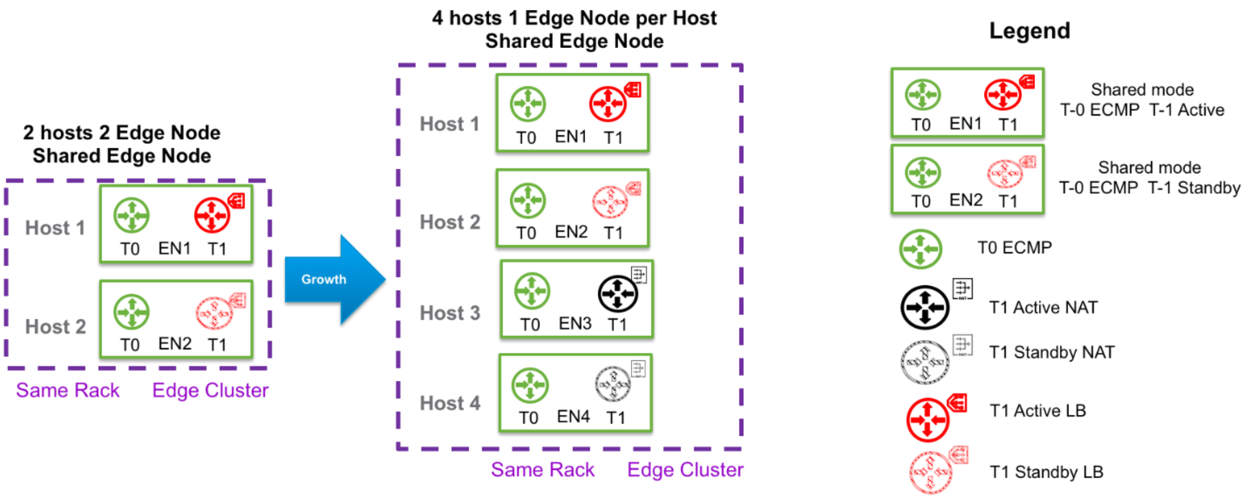


Figure 7-36: Shared Services Edge Node Cluster Growth Patterns

The choices in adding additional Edge node per host from above configuration is possible with higher bandwidth pNIC deployment (25/40 Gbps). In the case four Edge node deployment on two hosts, it is required to ensure active-standby instances does not end up on Edge nodes on the same hosts. One can prevent this condition by building a horizontal Failure Domain as shown in below *Figure 7-37: Two Edge Nodes per Host – Shared Services Cluster Growth Pattern*. Failure domain in below figures make sure any stateful services.

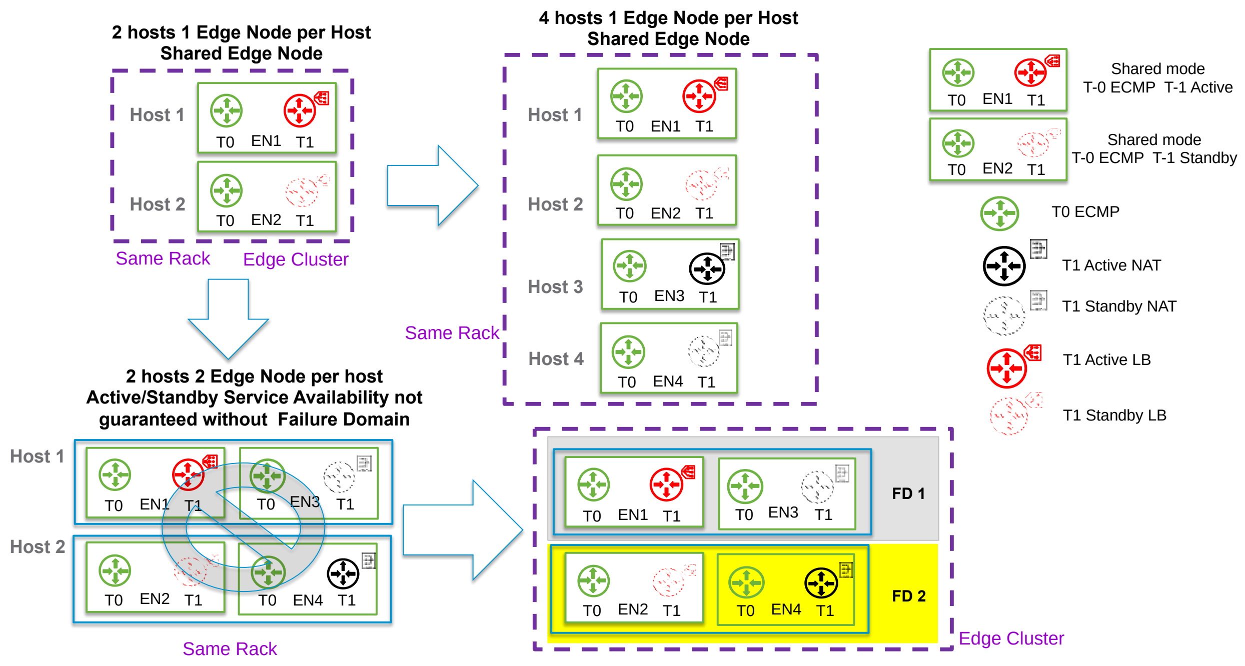


Figure 7-37: Two Edge Nodes per Host – Shared Services Cluster Growth Pattern

An edge cluster design with dedicated Edge node per services is shown in below *Figure 7-38: Dedicated Services per Edge Nodes Growth Pattern*. In a dedicated mode, Tier-0 is only running ECMP services belongs to first edge cluster while Tier-1 running active-standby services on second edge cluster. Both of this configuration are shown below.

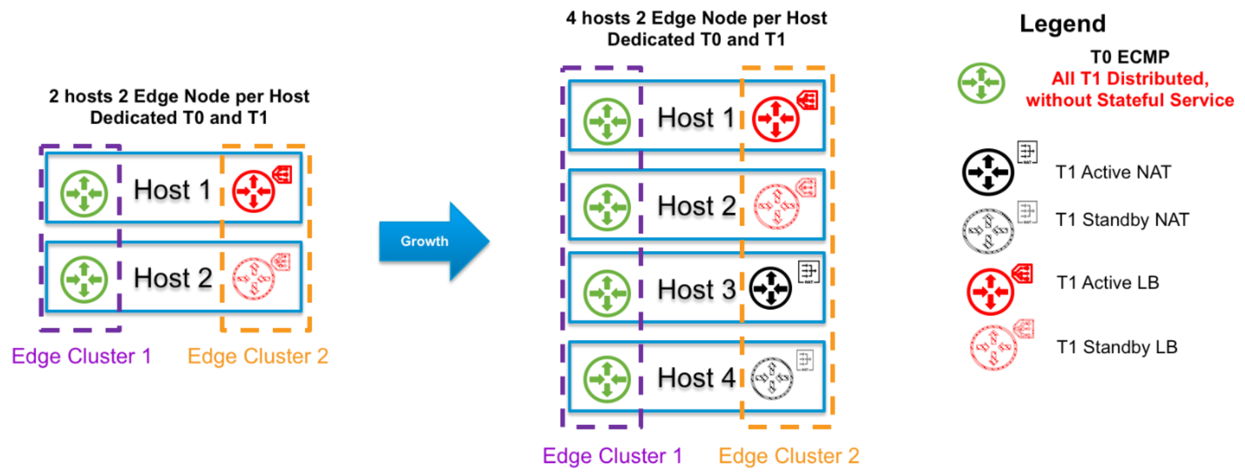


Figure 7-38: Dedicated Services per Edge Nodes Growth Pattern

Notice that each cluster is striped vertically to make sure each service gets deployed in separate host. This is especially needed for active/standby services. For the ECMP services the vertical striping is needed when the same host is used for deploying stateful services. This is to avoid over deployment of Edge nods on the same host otherwise the arrangement shown in *Figure 7-35: ECMP Base Edge Node Cluster Growth Pattern* is a sufficient configuration.

The multi-rack Edge node deployment is the best illustration of Failure Domain capability available in NSX-T release 2.5. It is obvious each Edge node must be on separate hypervisor in a separate rack with the deployment with two Edge nodes.

The case described below is the dedicated Edge node per service. The figure below shows the growth pattern evolving from two to four in tandem to each rack. In the case of four hosts, assuming two Edge VMs (one for ECMP and other for services) per host with two hosts in two different rack. In that configuration, the ECMP Edge node is stripped across two racks with its own Edge cluster, the placement and availability are not an issue since each node is capable of servicing equally. The Edge node where services is enabled must use failure domain vertically striped as shown in below figure. If the failure domains are not used, the cluster configuration will mandate dedicated Edge cluster for each service as there is no guarantee that active-standby services will be instantiated in Edge node residing in two different rack. This mandate minimum two edge clusters where each cluster consist of Edge node VM from two racks providing rack availability.

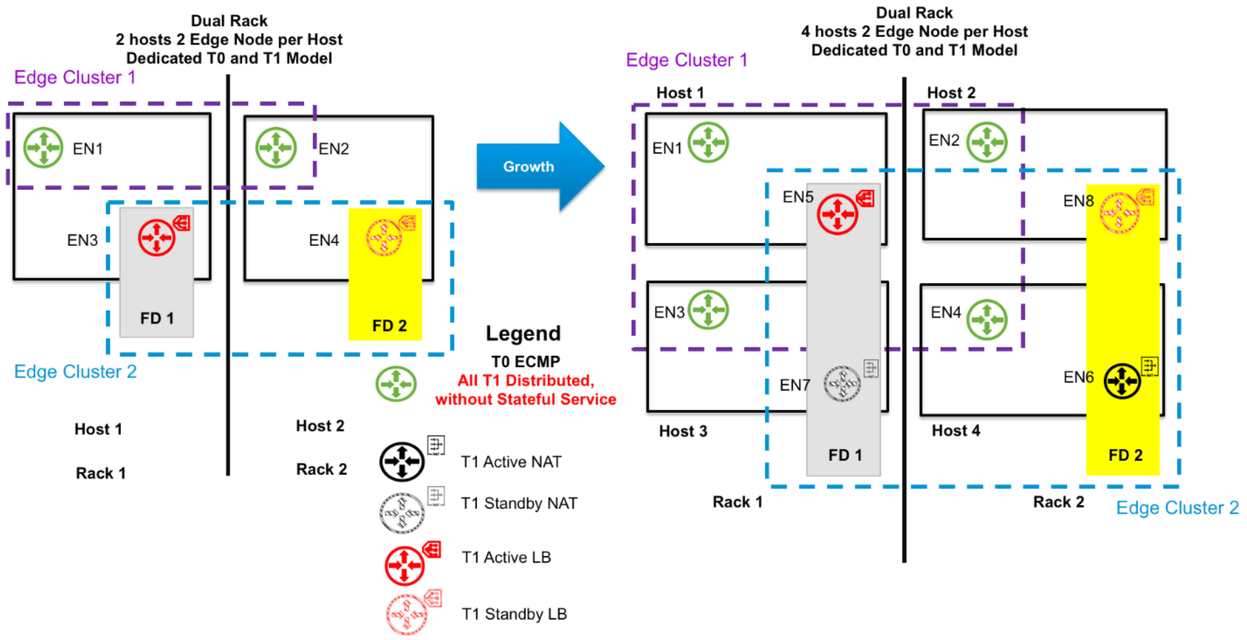


Figure 7-39: Dedicated Services per Edge Nodes Growth Pattern

Finally, the standby edge reallocation capability (only available to Tier-1servrices) allows a possibility of building a multiple availability zones such that a standby edge VM can be instantiated automatically after minimum of 10 minutes of failure detection. If the Edge node that fails is running the active logical router, the original standby logical router becomes the active logical router and a new standby logical router is created. If the Edge node that fails is running the standby logical router, the new standby logical router replaces it.

There are several other combinations of topologies are possible based on the requirements of the SLA as described in the beginning of the section. Reader can build necessary models to meet the business requirements from above choices.

7.4.6.3 Edge Node VM Physical Host Considerations for Resiliency

As discussed above, there are numerous technical solutions in place to ensure that if/when an Edge Node fails that the services running on that Edge Node are recovered and continued in a reasonable amount of time. That said, there are steps that can be taken when designing the environment hosting the Edge Node VMs to limit the impact of a failure event. An Edge Node VM inherits the resiliency from the underlying platform that is hosting it, it is imperative that the hosting platform is configured in a way to remove single points of failures whenever possible such as:

1. Redundant Power and UPS infrastructure
2. Redundant Physical pNICs
3. Redundant northbound switches
4. Fault tolerant storage platform for hosting the Edge Node VM

In addition to removing the single points of failures from the individual host, limiting the potential for cascading failures across a single NSX Edge Cluster is also a key design consideration. Some of the important steps that should be taken to achieve this are:

1. Deployment of Edge Nodes in an NSX Edge Cluster across multiple northbound switches preventing a single set of ToRs from taking down all NSX Edge Services.
2. Deployment of Edge Node VMs across multiple datastores to prevent a single datastore event (datastore corruption, array availability, etc.) from bringing down multiple Edge Nodes at the same time.
3. Configuration of NSX Failure domains (as described in the previous section) where some Edge Nodes do share some single points of failure to ensure the availability of the services in the event of a failure.
4. Deployment of additional NSX Edge Node capacity to address the recovery of NSX Services from a failed Edge Node to other Edge Nodes.
5. Proactively choose IP Subnets for N/S Peering that can accommodate addition additional T0 Peering IPs in the event that additional Edge Nodes must be brought online to restore additional T0 connectivity.

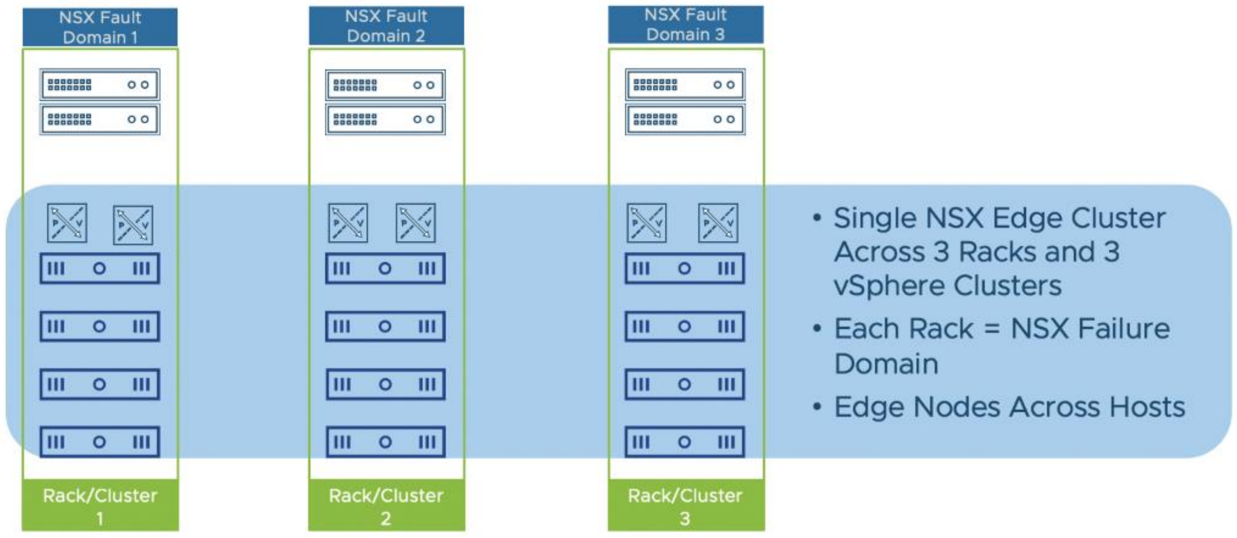

NSX Fault Domain 1
NSX Fault Domain 2
NSX Fault Domain 3
• Single NSX Edge Cluster Across 3 Racks and 3 vSphere Clusters
• Each Rack = NSX Failure Domain
• Edge Nodes Across Hosts
Rack/Cluster 1
Rack/Cluster 2
Rack/Cluster 3

Figure 7-40: Single Edge Cluster

While most of these recommendations can be implemented in any environment, in Hyper Converged Infrastructure or VSAN based environments item number 2 (Deployment of Edge Node VMs across multiple datastores) may become challenging. With VSAN, it is strongly recommended that the following configurations are made:

1. Edge Node VMs in a single NSX Edge Cluster should be placed across a minimum of two (2) vSphere Clusters and therefore two (2) or more VSAN datastores.
2. Each Edge Node VM hosted in a single vSphere Cluster using VSAN would then be configured as a Failure Domain in NSX to ensure placement of Active/Standby Services across the two datastores.
3. The number of vSphere Clusters used to host the NSX Edge Cluster's Edge Node VMs should provide sufficient throughput for the T0 Gateways running inside the NSX Edge Cluster in the event of a failure of one of the vSphere Clusters.

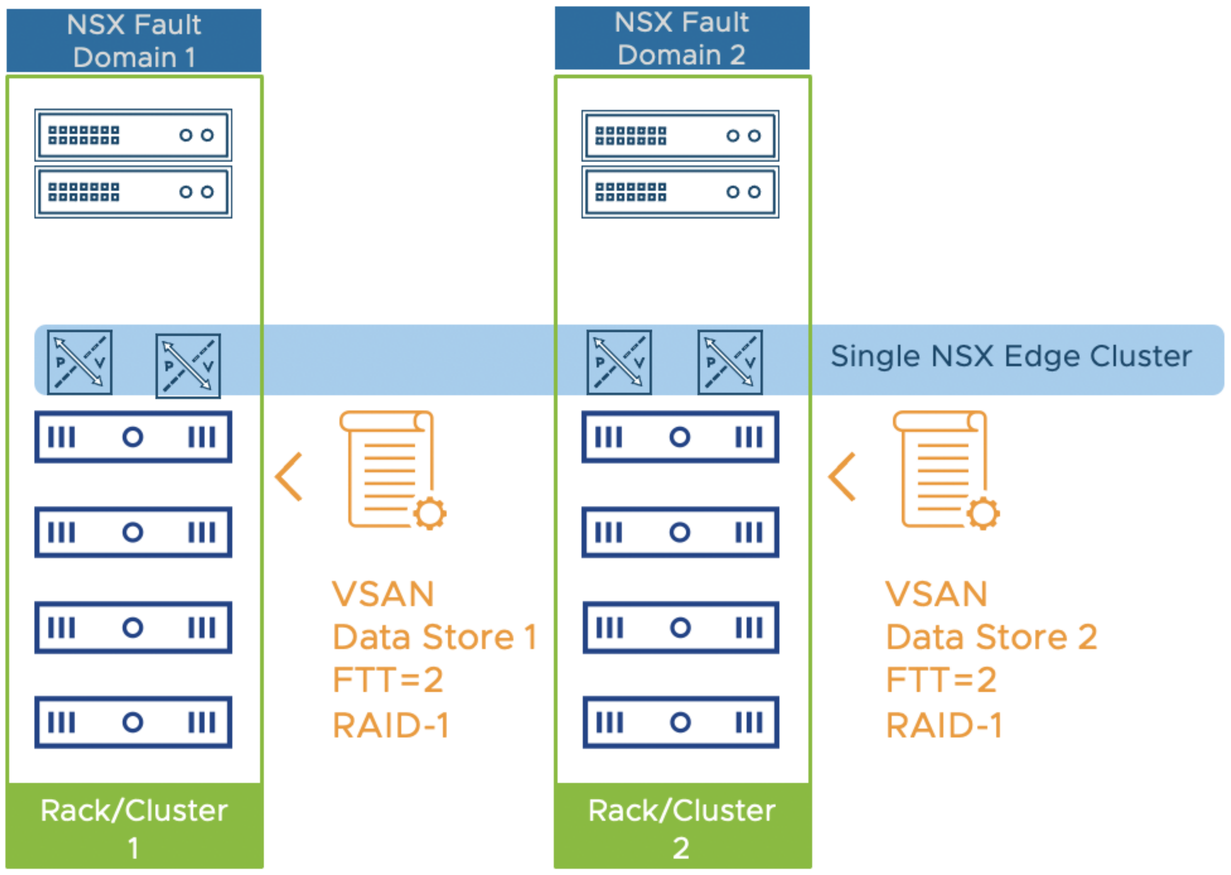


Figure 7-41: Single NSX Edge, FTT=2

If deployment of the NSX Edge Cluster across multiple VSAN datastores is not feasible then the following configurations can be made to minimize the potential of a cascading failure due to the VSAN datastore:

1. At a minimum, the vSphere Cluster should be configured with an FTT setting of at least 2 and an FTM of Raid1
   This will dictate that for each object associated with the NSX Edge Node VMs, a witness, two copies of the data (or component) are available even if two failures occur, allowing the objects to remain in a healthy state. This will accommodate both a maintenance event and an outage occurring without impacting the integrity of the data on the datastore. This configuration requires at least five (5) hosts in the vSphere Cluster.
2. ToR and Cabinet Level Failures can be accommodated as well, this can be accomplished in multiple ways; either through leveraging VSAN's PFTT capability commonly referred to as Failure Domains or VSAN Stretched Clusters and leveraging a Witness VM running in a third failure domain or by distributing the cluster horizontally across multiple cabinets where no more hosts exist in each Rack or Cabinet than the number of failures that can be tolerated (a maximum of FTT=3 is supported by VSAN). In both of these scenarios, NSX Edge Nodes will be spread out across multiple cabinets which will also require IP mobility of the IP Addresses used by the NSX Edge Node for both TEP and N/S Connectivity if it is capable of running T0 Gateways.
3. When workload is spread across multiple cabinets or ToRs, it is also important to potentially set Host affinities for workloads to better disburse the NSX Edge Nodes

across the cabinets and have predictability for which one is running where and Dis-Affinity rules to minimize Edge Node VMs running on the same host unless specifically designed to do so.

4. It is strongly recommended that Hosts, any time they are proactively removed from service, vacate the storage and repopulate the objects on the remaining hosts in the vSphere Cluster.

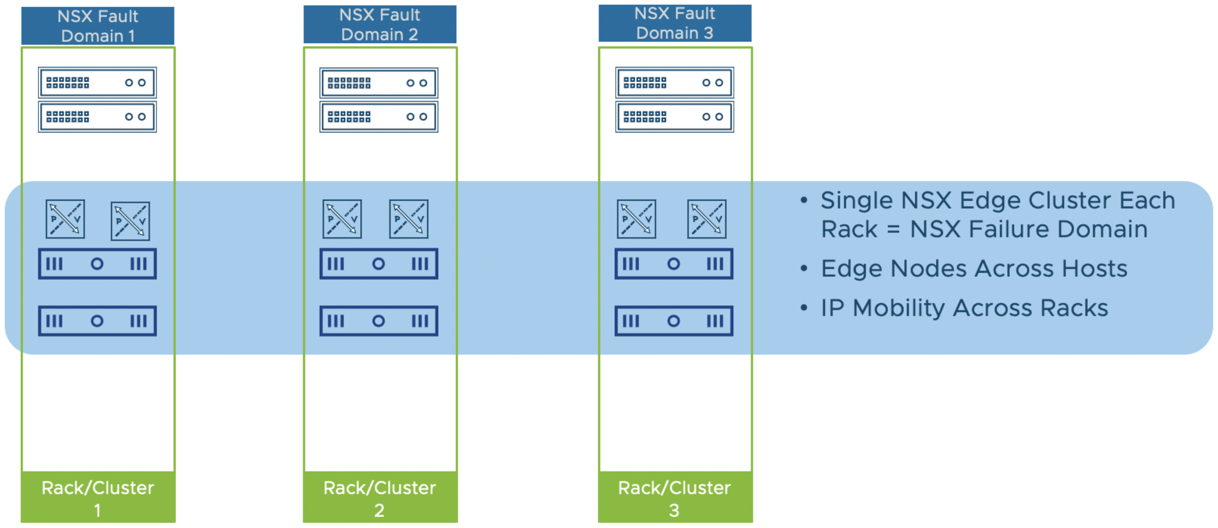

NSX Fault Domain 1
NSX Fault Domain 2
NSX Fault Domain 3
• Single NSX Edge Cluster Each Rack = NSX Failure Domain
• Edge Nodes Across Hosts
• IP Mobility Across Racks
Rack/Cluster 1
Rack/Cluster 2
Rack/Cluster 3

Figure 7-42: Single NSX Edge Cluster, Each Rack NSX Failure Domain

While VSAN Stretched Cluster and other Metro-Storage Cluster technologies provide a very high level of storage availability, NSX Edge Nodes provide an "Application Level" availability through horizontal scaling and various networking technologies. If a dedicated vSphere Cluster is planned to host the Edge Node VMs, using two independent clusters that are in diverse locations as opposed to a single vSphere Cluster stretched across those locations should seriously be considered to simplify the design.

7.5 Multi-Compute Workload Domain Design Consideration

NSX-T enables an operational model that supports compute domain diversity, allowing for multiple vSphere domains to operate alongside a KVM-based environment. NSX-T also supports PaaS compute (e.g., Pivotal Cloud Foundry, Red Hat OpenShift) as well as cloud-based workload domains. This design guide only covers ESXi and KVM compute domains; container-based workload requires extensive treatment of environmental specifics and has been be covered in Reference Design Guide for PAS and PKS with VMware NSX-T Data Center. *Figure 7-43: Single Architecture for Heterogeneous Compute and Cloud Native Application Framework* offers capability of NSX-T supporting of diverse compute workloads domains.

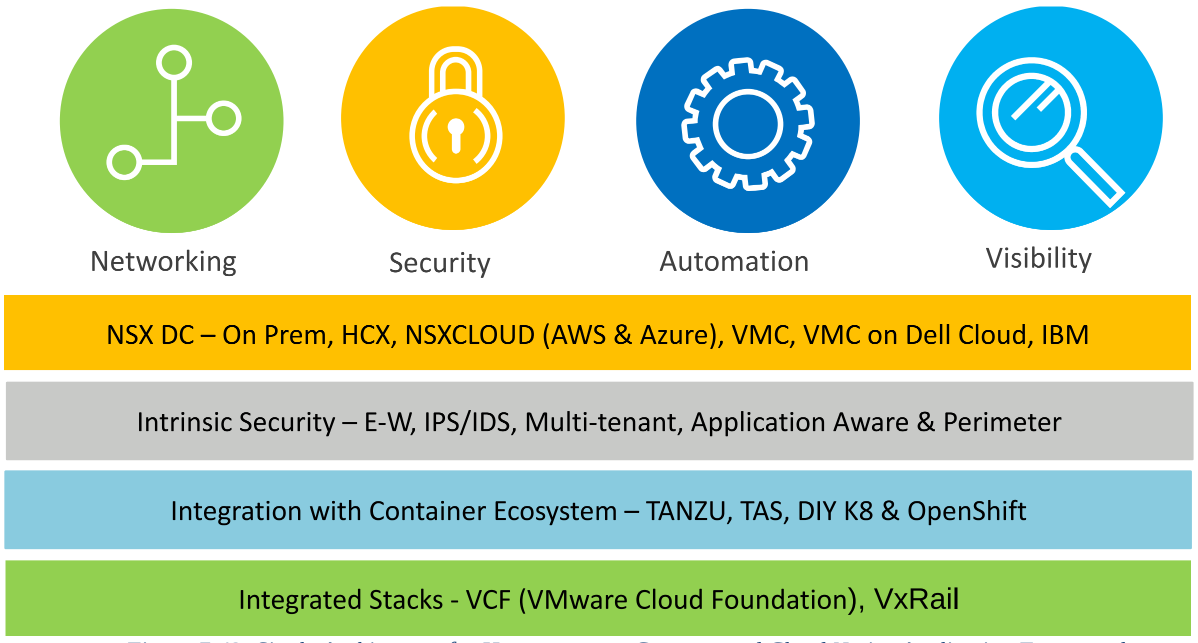

Networking
Security
Automation
Visibility
NSX DC – On Prem, HCX, NSXCLOUD (AWS & Azure), VMC, VMC on Dell Cloud, IBM
Intrinsic Security – E-W, IPS/IDS, Multi-tenant, Application Aware & Perimeter
Integration with Container Ecosystem – TANZU, TAS, DIY K8 & OpenShift
Integrated Stacks - VCF (VMware Cloud Foundation), VxRail

Figure 7-43: Single Architecture for Heterogeneous Compute and Cloud Native Application Framework

Important factors for consideration include how best to design these workload domains as well as how the capabilities and limitations of each component influence the arrangement of NSX-T resources. Designing multi-domain compute requires considerations of the following key factors:

- **Type of Workloads**
  - Enterprise applications, QA, DevOps
  - Regulation and compliance
  - Scale and performance
  - Security
- **Compute Domain Capability**
  - Underlying compute management and hypervisor capability
  - Inventory of objects and attributes controls
  - Lifecycle management
  - Ecosystem support – applications, storage, and knowledge
  - Networking capability of each hypervisor and domain
- **Availability and Agility**
  - Cross-domain mobility (e.g., multi-vCenter and KVM)
  - Hybrid connectivity
- **Scale and Capacity**
  - Compute hypervisor scale
  - Application performance requiring services such as NAT or load balancer
  - Bandwidth requirements, either as a whole compute or per compute domains

NSX-T provides modularity, allowing design to scale based on requirements. Gathering requirements is an important part of sizing and cluster design and must identify the critical criteria from above set of factors.

Design considerations for enabling NSX-T vary with environmental specifics: single domains to multiples; few hosts to hundreds; scaling from basics to compute domain maximums. Regardless of these deployment size concerns, there are a few baseline characteristics of the NSX-T platform that need to be understood and can be applicable to any deployment models.

7.5.1 Common Deployment Consideration with NSX-T Components

Common deployment considerations include:

- NSX-T management components require only VLANs and IP connectivity; they can co-exist with any hypervisor supported in a specific release. NSX-T manger node operation is independent of vSphere. It can belong to any independent hypervisor or cluster as long as the NSX-T Manager node has consistent connectivity and latency to the NSX-T domain.
- For a predictable operational consistency, NSX-T Manager appliance and Edge node VM elements must have their resources reserved.
- An N-VDS can coexist with another N-VDS VDS, however they cannot share interfaces.
- An Edge node VM has an embedded N-VDS which encapsulates overlay traffic for the guest VMs. It does not require a hypervisor be prepared for the NSX-T overlay network; the only requirements are a VLAN and proper jumbo MTU. This allows flexibility to deploy the Edge node VM in either a dedicated or shared cluster.
- For high availability:
  - Three NSX-T Manger Appliance (NSX-T managers and controllers) must be on different hypervisors
  - Edge node VMs must be on different hypervisors to avoid single point of failure
- Understanding of design guidance for Edge node connectivity and availability as well as services – ECMP and/or stateful – dependencies and the related Edge clustering choices.

Deployment models of NSX-T components depend on the following criteria:

- Multi-domain compute deployment models
- Common platform deployment considerations
- Type of hypervisor used to support management and Edge components
- Optimization of infrastructure footprint – shared vs. dedicated resources
- Services scale, performance, and availability

The following subsections cover three arrangements for components applicable to these criteria. The first design model offers collapsed management/Edge resources and compute/Edge resources. The second one covers a typical enterprise-scale design model with dedicated management and Edge resources. These design modes offer an insight into considerations on and value of each approach. They do not preclude the use other models (e.g., single cluster or dedicated purpose built) designed to address specific use cases.

7.5.2 Collapsed Management and Edge Resources Design

This design assumes multiple compute clusters or domains serving independent workloads. The first example offers an ESXi-only hypervisor domain, while the second presents a multi-vendor environment with both ESXi and KVM hypervisors. Each type of compute could be in a separate domain with a dedicated NSX-T domain; however, this example presents a single common NSX-T domain.

Both compute domains are managed as shown in *Figure 7-44: Collapsed Management and Edge Resources Design – ESXi Only* via a common cluster for NSX-T management and Edge resources. Alternatively, a dedicated Edge cluster serving could be used to independently support the compute domain. The common rationales for allowing the management and Edge resources are as follows:

- Edge services are deterministic and CPU-centric, requiring careful resource reservation. Mixing Edge and management components is better since management workload is predictable compared to compute workload.
- Reduction in the number of hosts required to optimizes the cost footprint.
- Potential for shared management and resources co-existing in the NSX-V and NSX-T domains. Additional consideration such as excluding NSX-T components from DFW policy and SLA also apply.

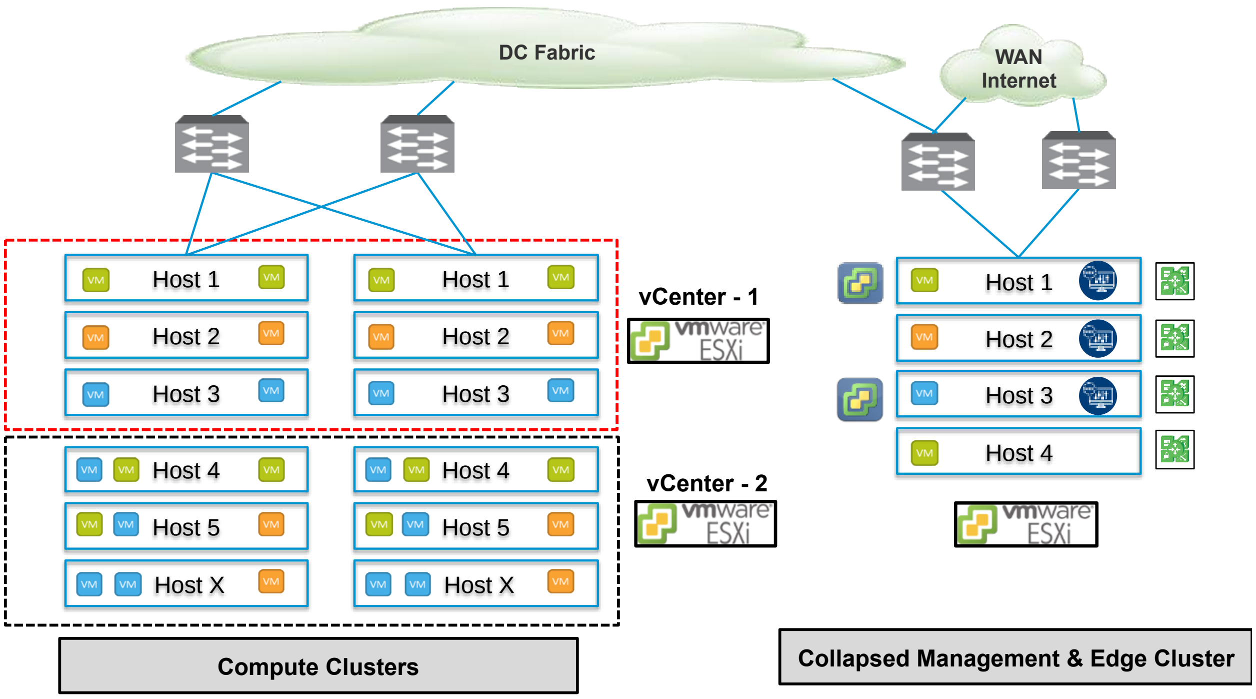


Figure 7-44: Collapsed Management and Edge Resources Design – ESXi Only

The first deployment model, shown in *Figure 7-44: Collapsed Management and Edge Resources Design – ESXi Only* consists of multiple independent vCenter managed compute domains. Multiple vCenters can register with the NSX-T Manager. These vCenter instances are not restricted to a common version and can offer capabilities not tied to NSX-T. The NSX-T can provide consistent logical networking and security enforcement independent of the vCenter compute domain. The connectivity is managed by NSX-T by managing independent N-VDS on each hypervisor, enabling the connectivity of workload between distinct vCenter compute VMs.

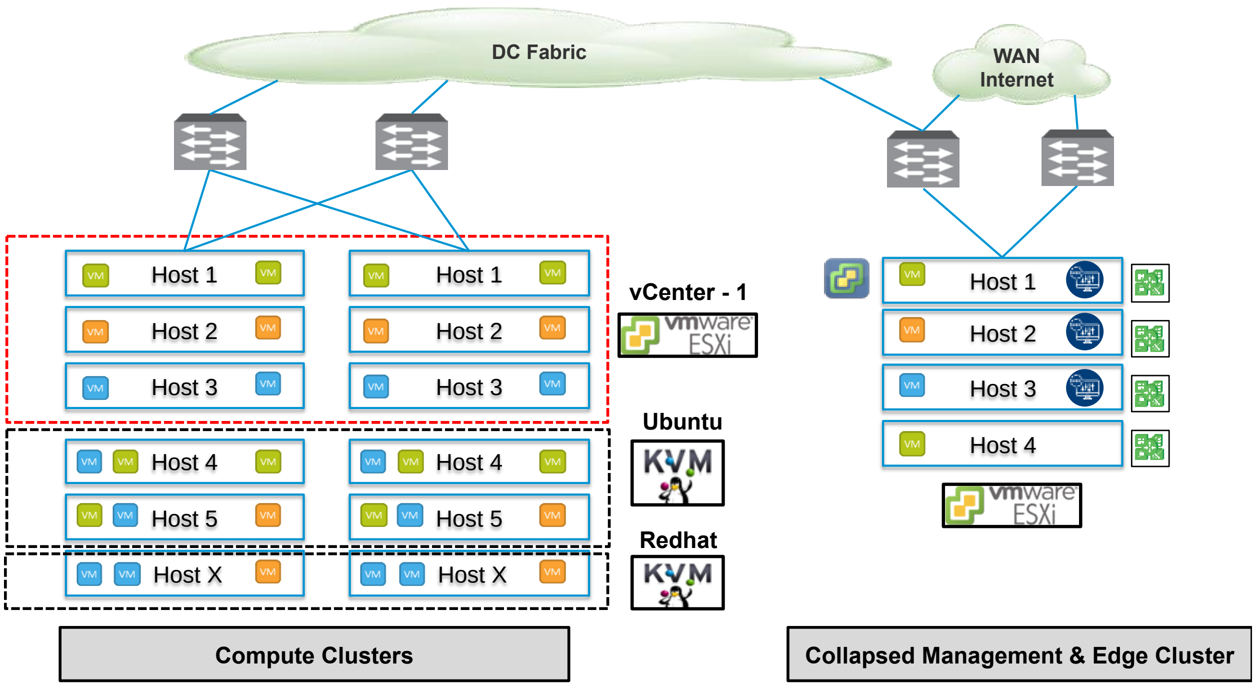


Figure 7-45: Collapsed Management and Edge Resources Design – ESXi & KVM

The second deployment, in *Figure 7-45: Collapsed Management and Edge Resources Design – ESXi & KVM* shows two independent hypervisor compute domains. The first is ESXi-based, the other two are based on KVM hypervisors. As before, each domain is overseen by NSX-T with common logical and security enforcement.

7.5.2.1 Collapsed Management and Edge Cluster

Both designs discussed above have the minimally recommended three ESXi servers for management cluster; however, traditional vSphere best practice is to use four ESXi hosts to allow for host maintenance and maintain the consistent capacity. The following components are shared in the clusters:

- **Management** – vCenter and NSX-T Manager Appliance with vSphere HA enabled to protect NSX-T Manager from host failure and provide resource reservation. NSX-T Manager appliances on separate hosts with an anti-affinity setting and resource reservation.
- **Services** – The Edge cluster is shown with four Edge node VMs but does not describe the specific services present. While this design assumes active/standby Edge nodes to support the Gateway Firewall and NAT services, it does not preclude some other combinations of services.

Where firewall or NAT services are not required, typically active/active (ECMP) services that support higher bandwidth are deployed. A minimum of two Edge nodes is required on each ESXi host, allowing bandwidth to scale to multi-10 Gbps (depending on pNIC speed and Performance Factors for NSX-T Edges optimization). Further expansion is possible by adding additional Edge node VMs, scaling up to a total of eight Edge VMs. For further details, refer to the Edge Node and Services Design considerations. For multi-10 Gbps traffic requirements or line rate stateful services, consider the addition of a dedicated bare metal Edge cluster for specific services workloads. Alternatively, the design can start with distributed firewall micro-segmentation and eventually move to overlay and other Edge services.

Collapsed Management and Edge Resources with 2 pNICs

Compute node connectivity for ESXi and KVM is discussed in the [Compute Cluster Design (ESXi/KVM)]() section. *Figure 7-46: Collapsed Management and Edge on VDS with 2 pNICs* describes the connectivity for shared management and Edge node with 2 pNICs

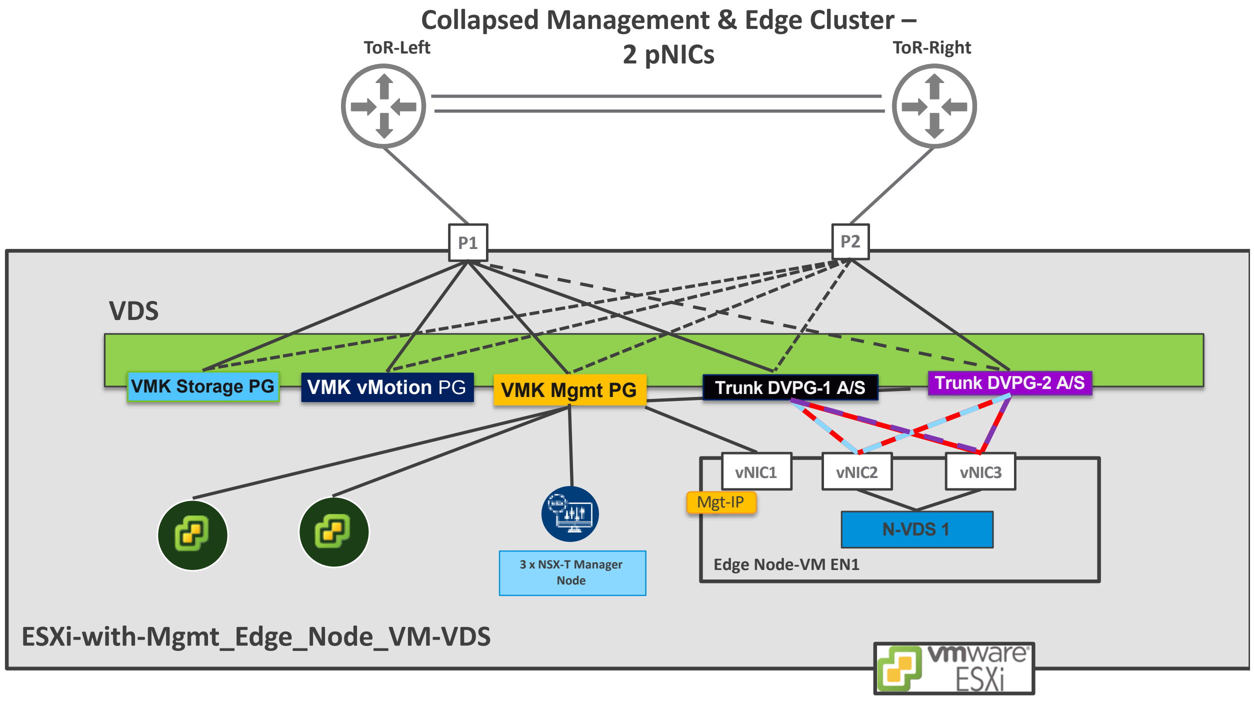


Figure 7-46: Collapsed Management and Edge on VDS with 2 pNICs

This design assumes ESXi hosts have two physical NICs, configured as follows:

- Port “P1” is connected to “ToR-Left” and port “P2” to “ToR-Right”.
- The Edge node VM follows the exact guidance shown in [NSX-T 2.5 Edge node VM connectivity with VDS with 2 pNICs]().
- VDS is configured with pNICs “P1” and “P2”. Related port group assignments include:
  - “Mgt PG” has “P1” active and “P2” standby. Associated with this port group are the management IP address, management and controller elements, and Edge node management vNIC.
  - “vMotion PG” has “P1” active and “P2” standby. The ESXi VMkernel vMotion IP address is associated with this port group.
  - “Storage PG” has “P1” active and “P2” standby. The ESXi VMkernel storage IP address is associated with this port group.
  - “Trunk DVPG-1” has “P1” active and “P2” standby.
  - “Trunk DVPG-2” has “P2” active and “P1” standby.

Design Choices in Collapsed Management and Edge Resources with 4 pNICs

The four pNICs offers flexibility in terms of mixing or dedicating NICs for specific resources. The principal motivation behind four pNICs hosts is to leverage host with denser CPU/memory to build lesser number of hosts for Edge node, while achieving the goals of, bandwidth management, isolation, regulation/compliance control and mixing various clusters such as management and edge. The design choices coming out of requirements for the dedicated compute host with 4 pNICs are discussed in ESXi-Based Compute Hypervisor with Four (or more) pNICs. That design choices are now extended in building a management and Edge node VM connectivity in which one can have following options:

1) Dedicated VDS for each Management and Edge node VM

2) Dedicated VDS for Management and Edge node VM while Dedicated N-VDS for Compute

3) Dedicated N-VDS for each Management and Edge Node VM

One can imaging many other options of arranging the management and Edge node VMs. In this section focus is on option 1 and 2. While option 3 is combined case of combining ESXi-Based Compute Hypervisor with two pNICs and NSX-T 2.5 Edge node VM connectivity with VDS with 2 pNICs however with distinction of management components instead of compute guest VMs.

Dedicated VDS for each Management and Edge node VM

This design choice assumes management components maintains existing VDS for known operational control while dedicating VDS for Edge nod VM. The configuration option for management VDS is shown below *Figure 7-47: Collapsed Management and Edge VM on Separate VDS with 4 pNICs* is left to user preference, however one can build a consistent teaming policy model with Load Balanced SRC ID at the VDS level. The Edge node VM connectivity with dedicated VDS is exactly the same described in NSX-T 2.5 Edge node VM connectivity with VDS with 2 pNICs.

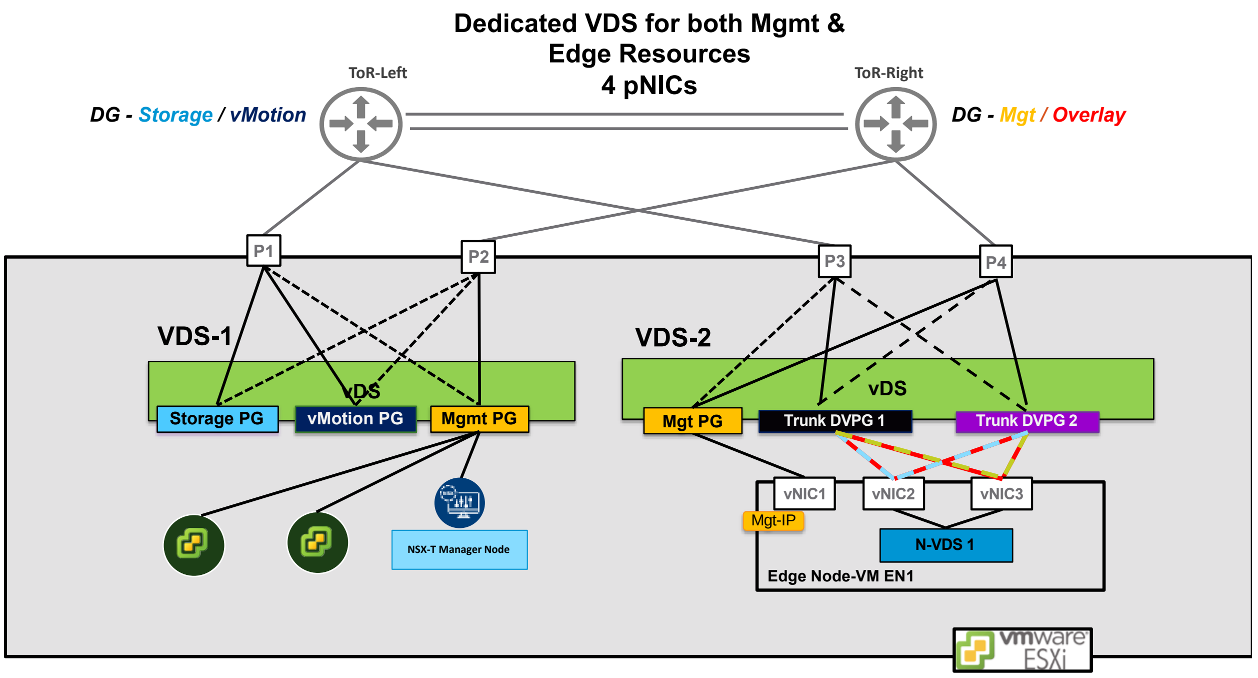


Figure 7-47: Collapsed Management and Edge VM on Separate VDS with 4 pNICs

Dedicated VDS for Management and Edge node VM while Dedicated N-VDS for Compute

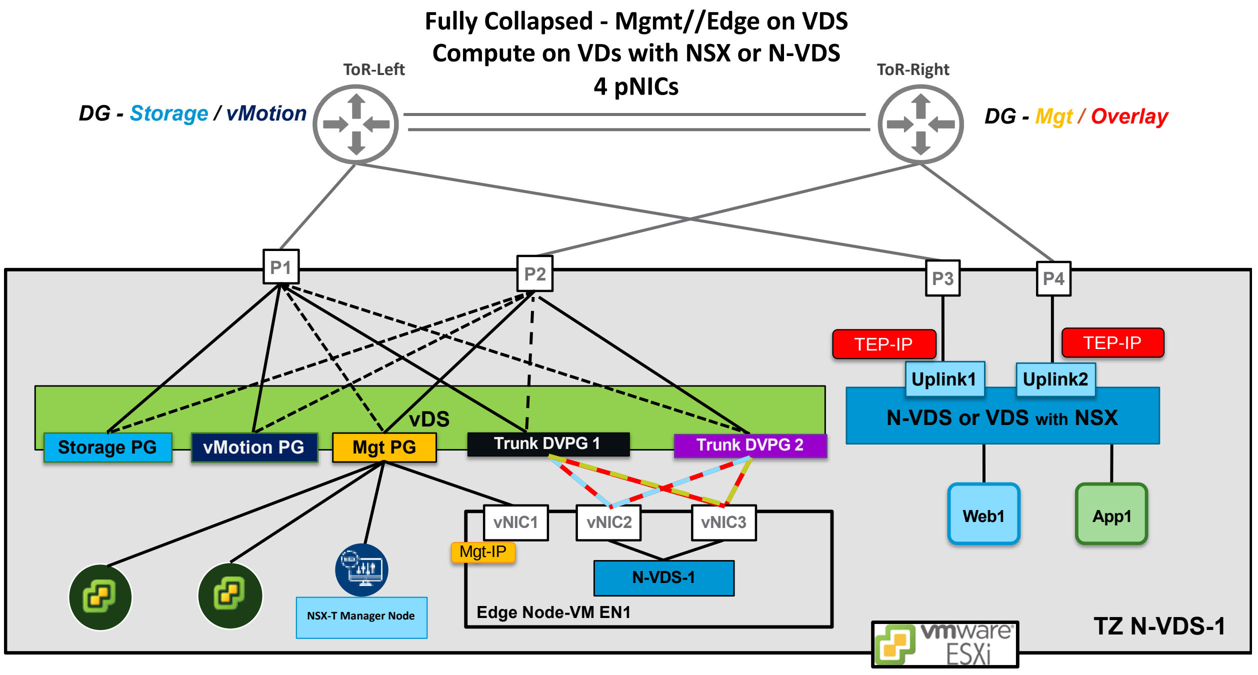


Figure 7-48: Fully Collapsed Design- Mgmt. and Edge on VDS with Compute on N-VDS with 4 pNICs

Above *Figure 7-48: Fully Collapsed Design- Mgmt. and Edge on VDS with Compute on N-VDS with 4 pNICs* is an extension to ESXi-Based Compute Hypervisor with Four (or more) pNICs in which VDS was dedicated for compute infrastructure traffic, while in this option it is dedicated for management cluster component including vCenters, NSX-T management nodes, while other two pNICs is dedicated for compute guest VM necessitating N-VDS or VDS with NSX. This type of configuration commonly referred as fully collapsed cluster design in which all resources are hosted in same cluster (minimum four hosts in case of VSAN). In this option bandwidth and operational control are the main motivator for dedicating pNICs. This design is also a de-facto choice for VxRail based system deployment where first two pNICs are managed by VDS which is controlled by VxRail manager while other two pNICs are dedicated for compute guest VM traffic provisioned via NSX-T Manager. Alternative to above *Figure 7-48: Fully Collapsed Design- Mgmt. and Edge on VDS with Compute on N-VDS with 4 pNICs* design is shown below where Edge VM is deployed on N-VDS. The deployment of Edge VM on N-VDS is discussed in NSX-T 2.5 Edge node VM connectivity with VDS with 2 pNICs. The advantage of design below is that it keeps guest or compute workload traffic local to N-VDS. This comparative choice from *Figure 7-49: Fully Collapsed Design- Mgmt on VDS while Edge with Compute on N-VDS with 4 pNICs* below verses in *Figure 7-48: Fully Collapsed Design- Mgmt. and Edge on VDS with Compute on N-VDS with 4 pNICs* above is based on whether storage traffic on VDS needs to be protected vs compute workload traffic on N-VDS. The NIOC profiles to manage specific type of traffic and higher speed NICs could alleviate this contention, and thus the choice will move to what is the operational control/consistency of managing VDS vs N-VDS.

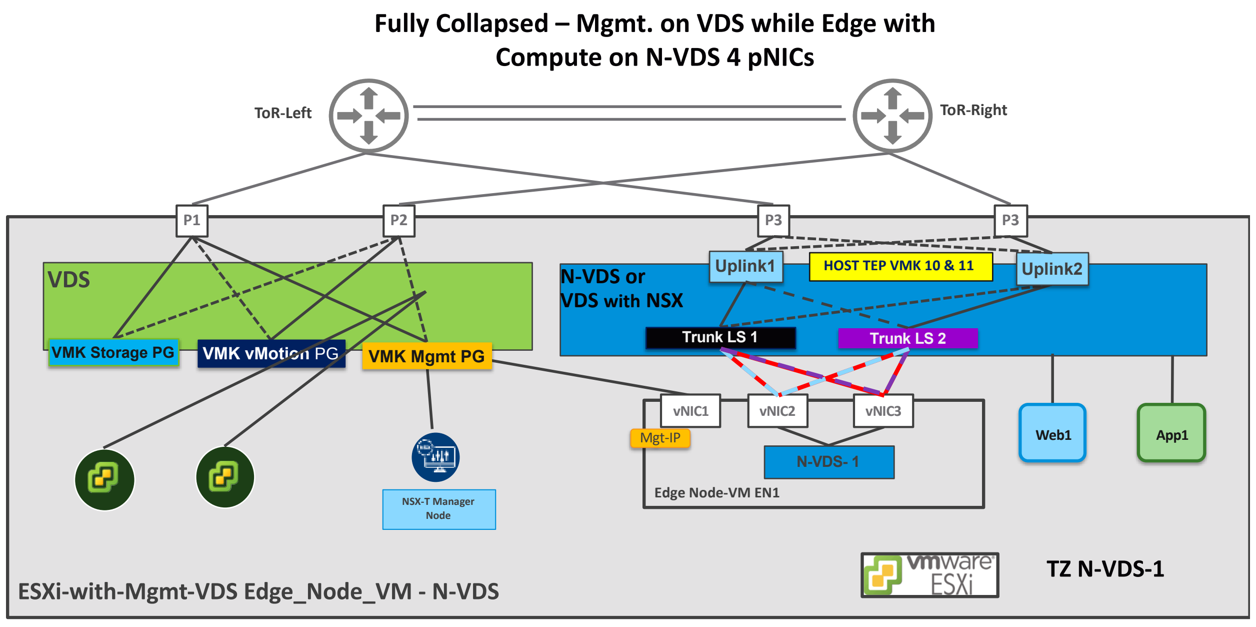


Figure 7-49: Fully Collapsed Design- Mgmt on VDS while Edge with Compute on N-VDS with 4 pNICs

7.5.2.2 Fully Collapsed Single vSphere Cluster with 2 pNICs Host

The case of two pNICs design with fully collapsed cluster (where vCenter, NSX-T management & Edge appliances and workload VMs are in single vSphere cluster) can refer to NSX-T 2.5 Edge node VM connectivity with VDS with 2 pNICs for details on how to build such configuration with N-VDS. Any configuration where Edge node is shared with compute workload requires additional design considerations such as dedicated VLANs for TEP for the host and TEP for the Edge VM. The NSX-T 3.1 removes this restriction of mandating the separate VLANs for host and Edge TEP. Additional consideration for deployment with N-VDS based fully collapsed cluster must be referred on following URL:

https://docs.vmware.com/en/VMware-NSX-T-Data-Center/2.5/installation/GUID-3770AA1C-DA79-4E95-960A-96DAC376242F.html

The similar design can be enabled via VDS with NSX with significant reduction in migration and configuration:

- Does not require migration of VMkernel, keep VMkernel on VDS DVPG
- Deploy NSX Managers and Edge VMs on VDS DVPG eliminating the need of pre-deployment port-configuration changes
- Deploy application VMs on NSX DVPG
- Before NSX-T 3.1, the VLAN for the TEP on the HOST and the TEP on Edge VM must be unique

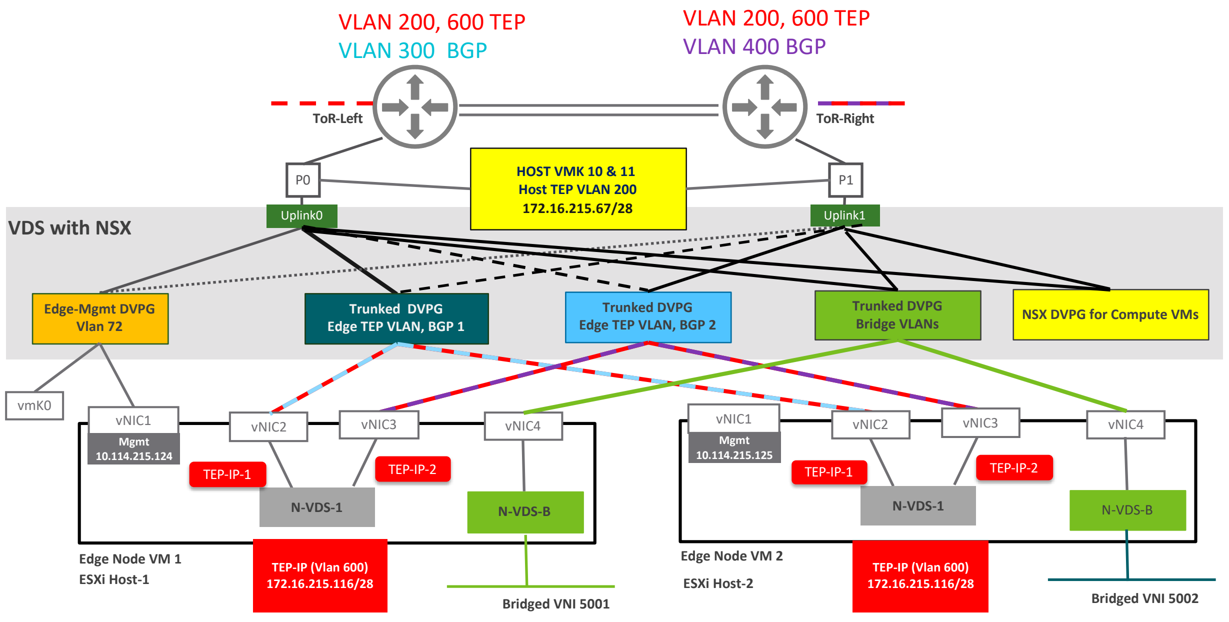


Figure 7-50: Fully Collapsed Cluster with VDS with NSX

7.5.3 Collapsed Compute and Edge Resources Design

The motivation for co-hosting Edge node VMs with compute guest VM in the same host comes from simply avoiding the dedicated resources for the Edge VM. The below *Figure 7-51: Collapsed Edge and Compute Cluster* depicts the Edge and compute VMs coexist on the same host.

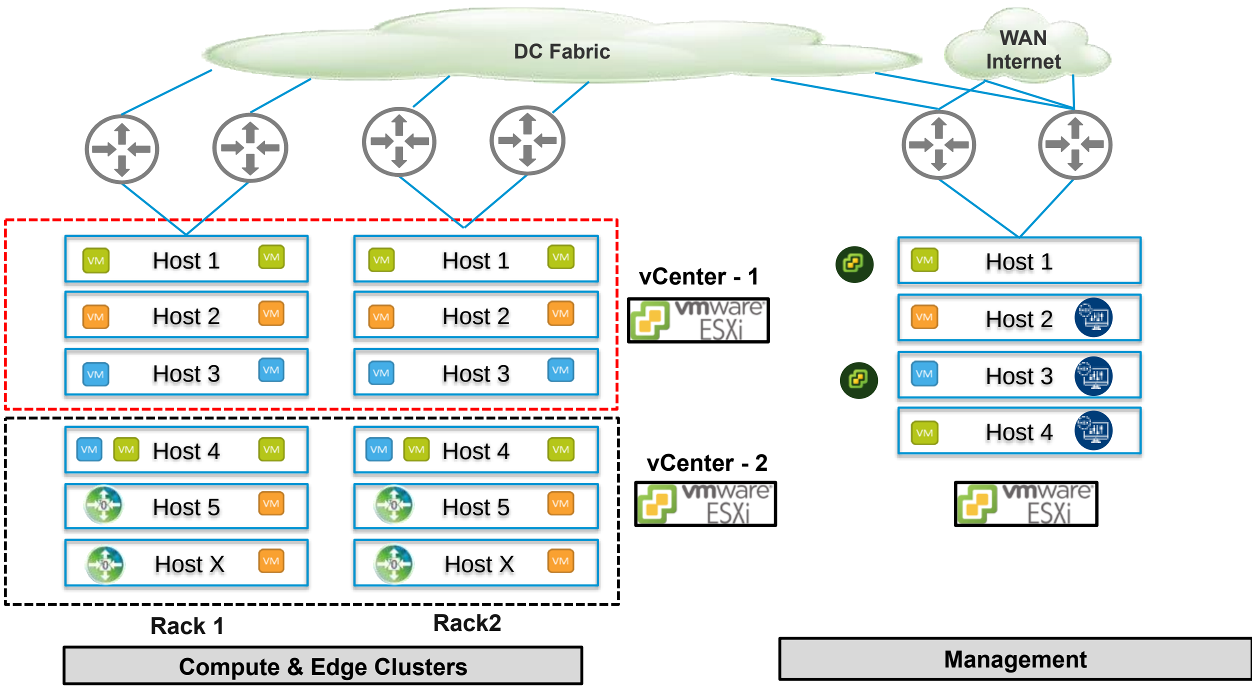


Figure 7-51: Collapsed Edge and Compute Cluster

The core design consideration for co-hosting Edge VM are as follows:

- Shared 2 x 10 Gbps design should have no more than one Edge VM, otherwise either starve compute or Edge traffic, thus Edge VM placement is spread-out leading to expanded failure domain and control points
- Peering just got complicated if one wants to build rack resiliency, it is now on every rack if Edges are spread due to the fact only one Edge VM can be hosted with 2 pNICs design
- Resource reservation that is a must for Edge VM, resources pool design got more complex and anti-affinity rules must be in place, so two Edge VMs do not land on the same host.
- LCM of the host and compute VM requires careful consideration during maintenance, upgrade and HW change
- vMotion the workload and not the Edge node as its not supported with current release
- Shared services mode makes more sense compared to dedicated as more hosts will be utilized for spreading the Edge Node. See NSX-T Edge Resources Design.
- Since Edge is not at fixed location, traffic pattern took the worst turn for both direction – N-S and S-N, for this reason the figure below explicitly shows only two racks configuration intentionally resulting in
  - Doubling hops for traffic for every flow, for/from every Edge due to ECMP
  - Oversubscriptions now has twice the burden

One of traffic pattern resulting from Edge node placement with compute host is that now every Edge VM can receive traffic from every other host and then it must traverse back to physical fabric back to boarder leaf ToRs (typically termination all the external BGP routing from data center). This pattern repeats for every Edge VMs to every other host for each flow. There is multiple slide effect of this, first the host carrying Edge VM may create hot spot in both direction and indirectly affecting applications VMs running only on those hosts. Secondly, it's resulting into double hop traffic pattern compared to centralized location where Edge VMs are connected in the same rack as boarder leaf. This double-hop traffic pattern is shown in below *Figure 7-52: Two Edge Node VMs on Host with N-VDS*.

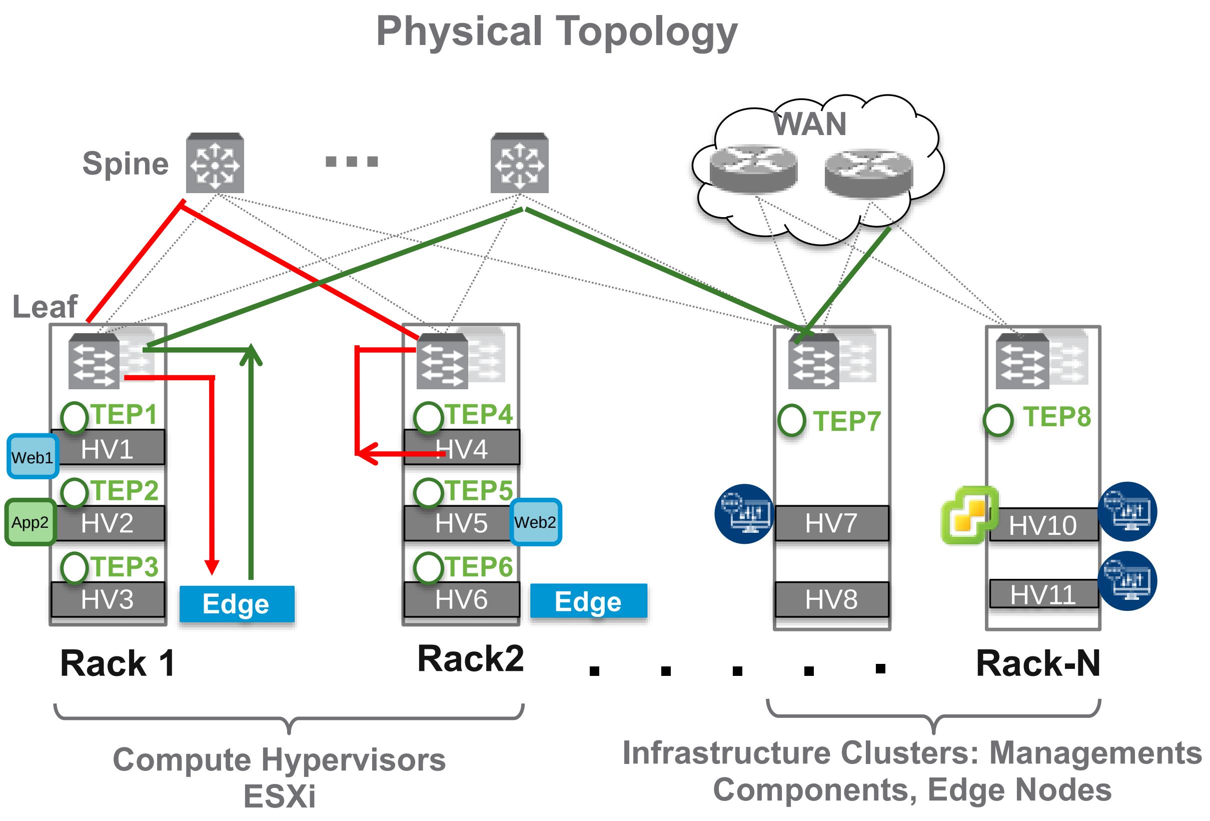


Figure 7-52: Two Edge Node VMs on Host with N-VDS

The recommendation is to not place Edge VM with compute host in a configuration beyond two racks of compute as it will result in suboptimal performance and capacity planning for future growth. Either consider dedicated Edge Nodes cluster or sharing with management with sufficient bandwidth for Edge VMs. In general, this leads to common practice of deploying 4 pNICs host for Edge VMs regardless of where it's hosted, dedicated or shared.

7.5.4 Dedicated Management and Edge Resources Design

This section presents an enterprise scale design with dedicated compute, management, and Edge clusters. The compute cluster design examines both ESXi-only and KVM-only options, each of which contribute to requirements for the associated management and Edge clusters. The initial discussion focuses on recommendations for separate management, compute, and Edge to cover the following design requirements:

- Diversity of hypervisor and requirements as Common Deployment Consideration with NSX-T Components.
- Multiple vCenters managing distinct sets of virtualized workloads
- Compute workload characteristics and variability
- Higher degree of on-demand compute.

- Compliance standards (e.g., PCI, HIPPA, government)
- Automation flexibility and controls
- Multiple vCenters managing production, development, and QA segments
- Migration of workloads across multiple vCenters
- Multi-10G traffic patterns for both E-W and N-S traffic
- Multi-tenancy for scale, services, and separation

7.5.4.1 Enterprise ESXi Based Design

The enterprise ESXi-hypervisor based design deployment may consists of multiple vSphere domains and usually consists of a dedicated management cluster. The NSX-T components that reside in management clusters are NSX-T Managers. The requirements for those components are the same as with the collapsed management/Edge design in the previous section but are repeated to drive the focus that management cluster is ESXi based. Compute node connectivity for ESXi and KVM is discussed in section Compute Cluster Design (ESXi/KVM). For the management cluster, the design presented in *Figure 7-53: Dedicated Compute, Management and Edge Resources Design* has a minimum recommendation for three ESXi hosts. A standard vSphere best practice suggests using four ESXi hosts to allow for host maintenance while maintaining consistent capacity. The following components are shared in the clusters:

- **Management** – vCenter and NSX-T Manager appliance with vSphere HA enabled to protect NSX-T Manager from host failure as well as provide resource reservation.

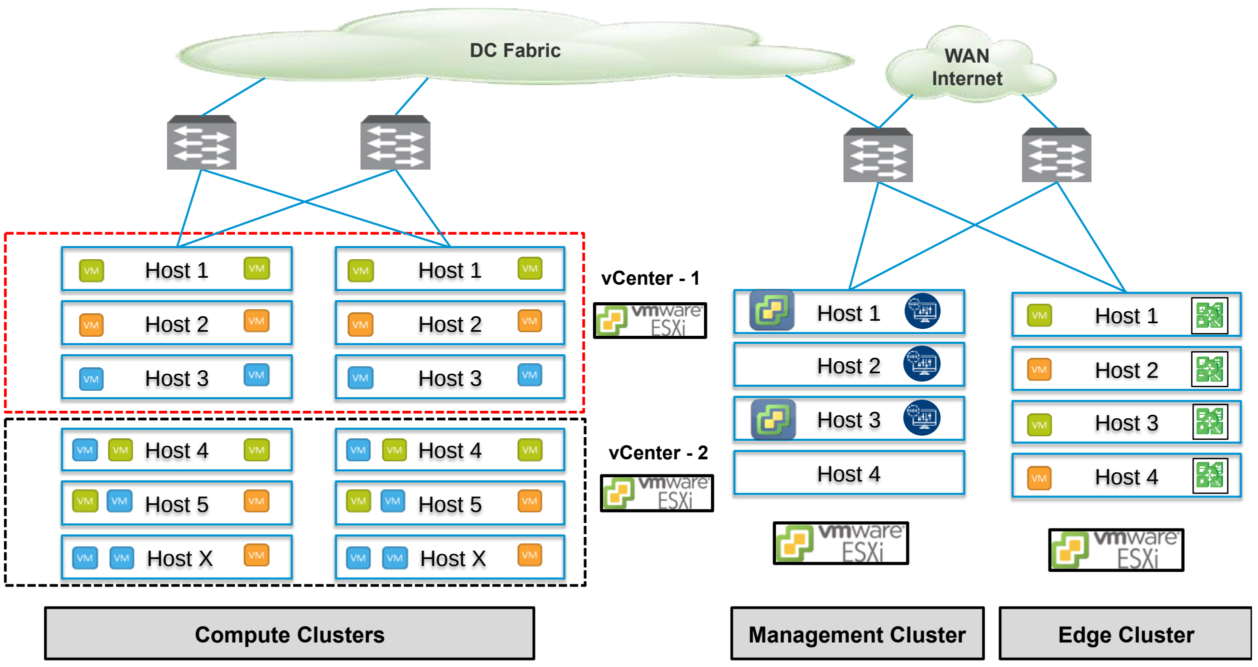


Figure 7-53: Dedicated Compute, Management and Edge Resources Design

The Edge cluster design takes into consideration workload type, flexibility, and performance requirements based on a simple ECMP-based design including services such as NAT/FW/LB. As discussed in Edge Node and Services Design, the design choices for an Edge cluster permit a bare metal and/or VM form factor. A second design consideration is the operational requirements of services deployed in active/active or active/standby mode.

The bare metal Edge form factor is recommended when a workload requires multi-10Gbps connectivity to and from external networks, usually with active/active ECMP based services enabled. The availability model for bare metal is described in Bare metal Edge Design and may require more than one Edge cluster depending on number of nodes required to service the bandwidth demand. Additionally, typical enterprise workloads may require services such as NAT, firewall, or load balancer at high performance levels. In these instances, a bare metal Edge can be considered with Tier-0 running in active/standby node. A multi-tenant design requiring various types of Tier-0 services in different combinations is typically more suited to a VM Edge node since a given bare metal node can enable only one Tier-0 instance. *Figure 7-54: Dedicated Management and Edge Resources Design – ESXi Only & Mix of Edge Nodes* displays multiple Edge clusters – one based on the Edge node VM form factor and other bare metal – to help conceptualize the possibility of multiple clusters. The use of each type of cluster will depend on the selection of services and performance requirements, while as multi-tenancy flexibility will provide independent control of resources configurations.

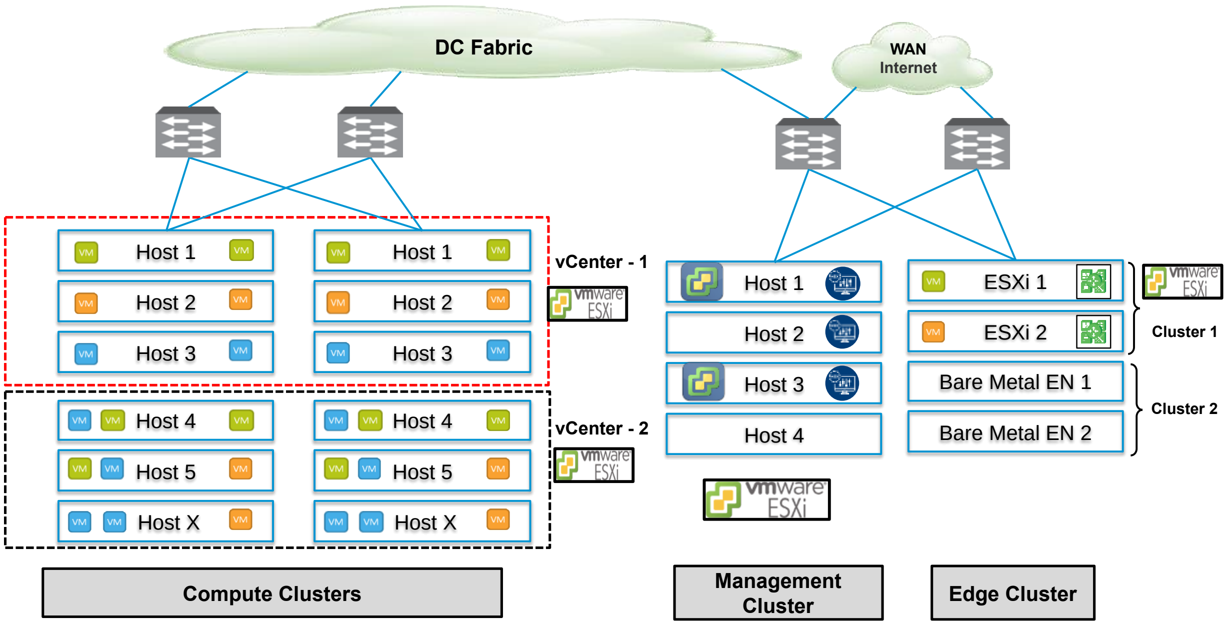


Figure 7-54: Dedicated Management and Edge Resources Design – ESXi Only & Mix of Edge Nodes

The VM Edge form factor is recommended for workloads that do not require line rate performance. It offers flexibility of scaling both in term of on-demand addition of bandwidth as well speed of service deployment. This form factor also makes the lifecycle of Edge services practical since it runs on the ESXi hypervisor. This form factor also allows flexible evolution of services and elastic scaling of the number of nodes required based on bandwidth need. A typical deployment starts with four hosts, each hosting Edge VMs, and can scale up to eight nodes. The VM Edge Node section describes physical connectivity with a single Edge node VM in the host, which can be expanded to additional Edge node VMs per host. If there are multiple Edge VMs deployed in a single host that are used for active/standby services, the design will require more than one Edge Cluster to avoid single point of failure issues.

Some use cases may necessitate multiple Edge clusters comprised of sets of bare metal or VM Edge nodes. This may be useful when Tier-1 requires a rich variety of services but has limited bandwidth requirements while Tier-0 logical routers require the performance of bare metal. Another example is separation of a service provider environment at Tier-0 from a deployment autonomy model at Tier-1.

Such model may be required for a multi-tenant solution in which all Tier-0 logical routers are deployed in a bare metal cluster while Tier-1 is deployed with Edge node VMs based on the requirement for low-bandwidth services. This would also provide complete control/autonomy for provisioning of Edge tenant services while Tier-0 offered static resources (e.g., provider Edge services).

7.5.4.2 Enterprise KVM Design

The enterprise KVM hypervisor-based design assumes all the components – management, Edge, and compute – are deployed with KVM as the base hypervisor. It relies on the KVM-based hypervisor to provide its own availability, agility and redundancy; thus, it does not cover ESXi-centric capabilities including high availability, resource reservation, or vMotion.

Compute node connectivity for ESXI and KVM is discussed in the section [Compute Cluster Design (ESXi/KVM)](#).

For the management cluster, this design recommends a minimum of three KVM servers. The following components are shared in the cluster:

- **Management** – vCenter and NSX-T Manager appliance with an appropriate high availability feature enabled to protect the NSX-T Manager from host failure as well as providing resource reservation.

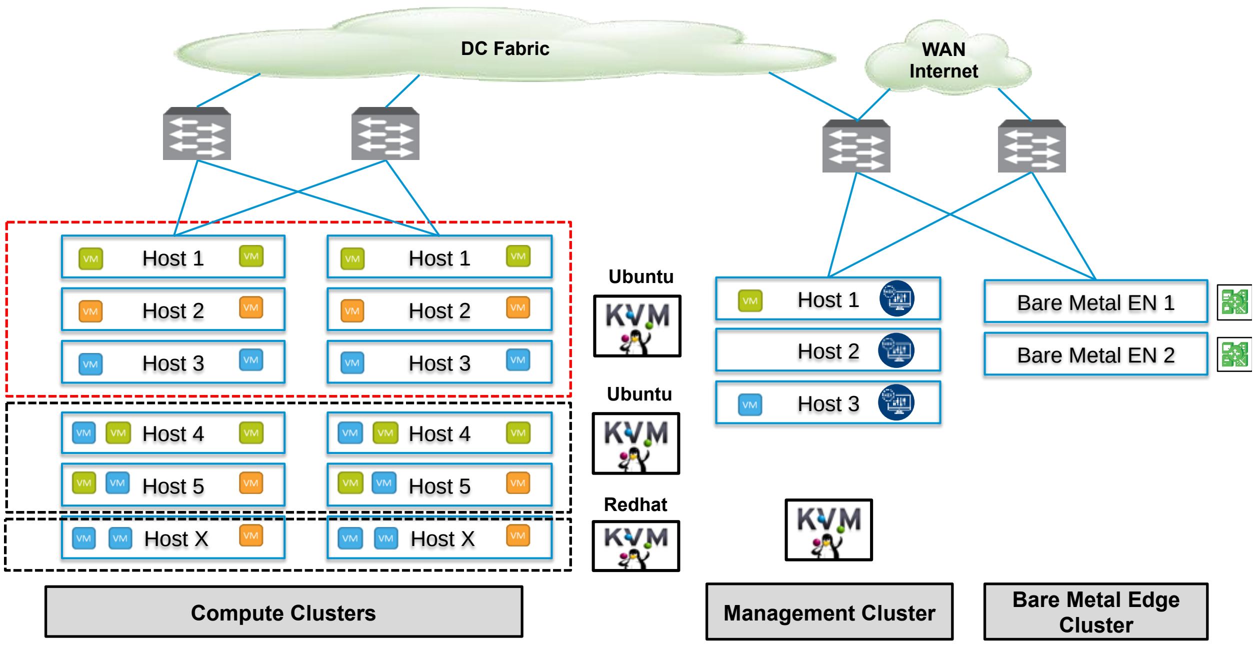


Figure 7-55: Dedicated Management and Edge Resources Design – KVM Only

With KVM as the only hypervisor, the bare metal Edge node is the only applicable form factor. The bare metal cluster considerations are the same as discussed in ESXi design example.

8 NSX-T Performance & Optimization

8.1 Typical Data Center Workloads

Workloads in the data center are typically TCP-based. Generally, 80% of the traffic flows within the data center are east/west, that is, communication between various compute nodes. The remaining 20% is north/south, that is, communication in and out of the data center. The following *Figure 8-1: Data Center Traffic Pattern with NSX-T* shows the typical traffic flow distribution:

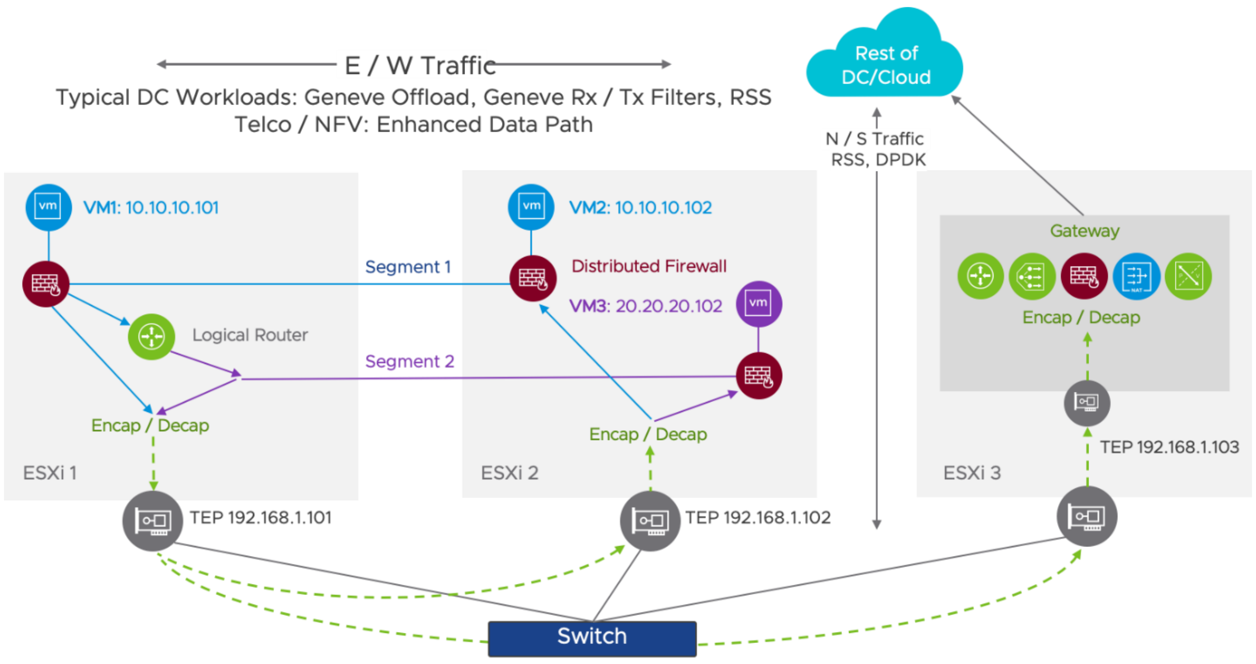


Figure 8-1: Data Center Traffic Pattern with NSX-T

Because of this underlying data center framework, this chapter primarily focuses on performance in terms of throughput for TCP-based workloads. There are some niche workloads such as NFV, where raw packet processing may be ideal, and the enhanced version of N-VDS called N-VDS (E) was designed to address these requirements. Check out the last part of this section for more details on N-VDS (E).

8.2 Next Generation Encapsulation - Geneve

Geneve, a draft RFC in the IETF standard body co-authored by VMware, Microsoft, Red Hat, and Intel, grew out of a need for an extensible protocol for network virtualization. With Geneve the new framework for overlay/network virtualization, understanding Geneve is foundational to rest of this chapter as the rest of the optimizations to be discussed revolve around Geneve.

With its options field length specified for each packet within the Geneve header, Geneve allows packing the header with arbitrary information into each packet. This flexibility offered by

Geneve opens up doors for new use cases, as additional information may be embedded into the packet, to help track the packets path or for in depth packet flow analysis.

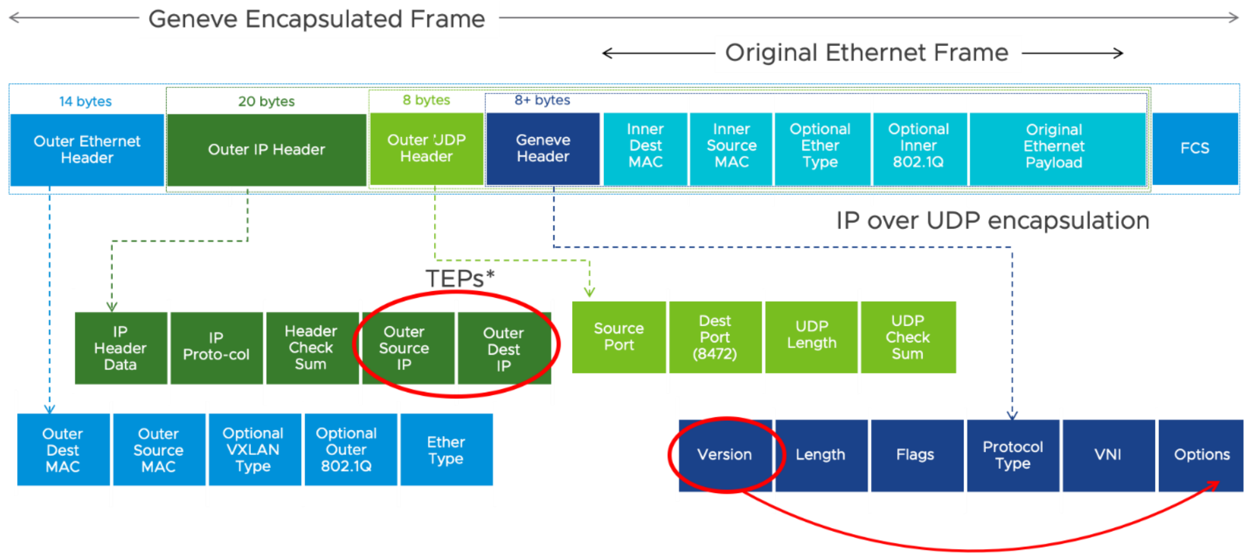


Figure 8-2: Geneve Header

The above *Figure 8-2: Geneve Header* shows the location of the Length and Options fields within the Geneve header and also shows the location of TEP source and destination IP's.

For further insight into this topic, please check out the following blog post: https://octo.vmware.com/Geneve-vxlan-network-virtualization-encapsulations/

8.3 Geneve Offload

Geneve Offload is simply TCP Segmentation Offload (TSO) tuned to understand Geneve headers. Since Geneve is not TCP traffic, NIC cards need to be aware of Geneve headers to perform TCP Segmentation Offload type functionality on the Geneve segments. In addition, guest VMs need to enable TSO, the default behavior with most modern operating systems.

TCP Segmentation Offload (TSO): TCP Segmentation offload is a well-established TCP optimization scheme of relatively long duration that allows large segments to pass through the TCP stack, instead of smaller packets as enforced by the MTU on the physical fabric.

8.3.1 (TSO) applicability to Geneve Overlay Traffic

In the context of Geneve, NICs are aware of the Geneve headers and perform TSO taking Geneve headers into consideration. The following *Figure 8-3: NIC Based Geneve Offload - TSO* shows how the VM would transmit 64K segments, such as switching, routing and firewall and the ESX TCP Stack, which go through the NSX-T Components as 64K segments. NIC cards take care of chopping the segments down to MTU-sized packets before moving them on to the physical fabric.

TSO's primary benefit is in reducing CPU cycles. This benefit could help provide more cycles for actual workloads and also consequently marginally drive network performance upwards.

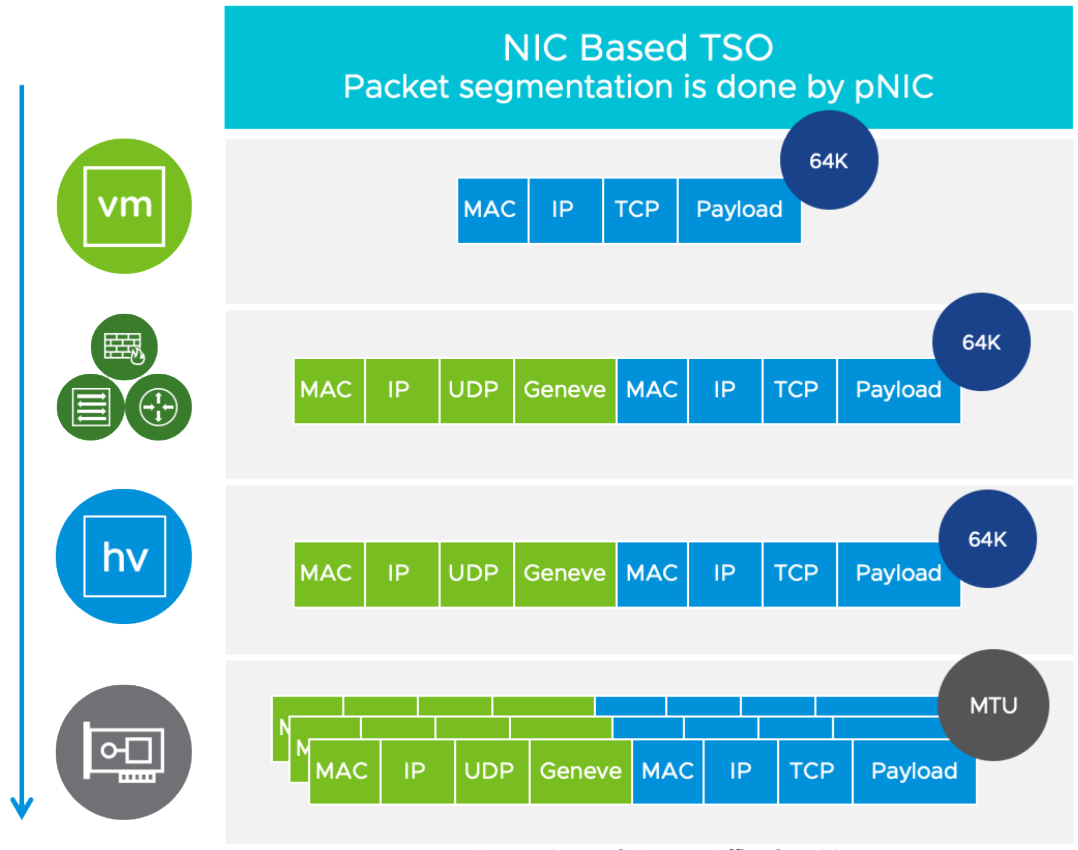


Figure 8-3: NIC Based Geneve Offload - TSO

8.3.2 NIC Supportability with TSO for Geneve Overlay Traffic

In cases where the NIC card does not support TSO for Geneve overlay traffic, TSO is done in software by the hypervisor just before moving the MTU-sized packets to the NIC card. Thus, NSX-T components are still able to leverage TSO.

The following *Figure 8-4: Software/CPU Based Geneve Offload - TSO* shows the process where the hypervisor divides the larger TSO segments to MTU-sized packets.

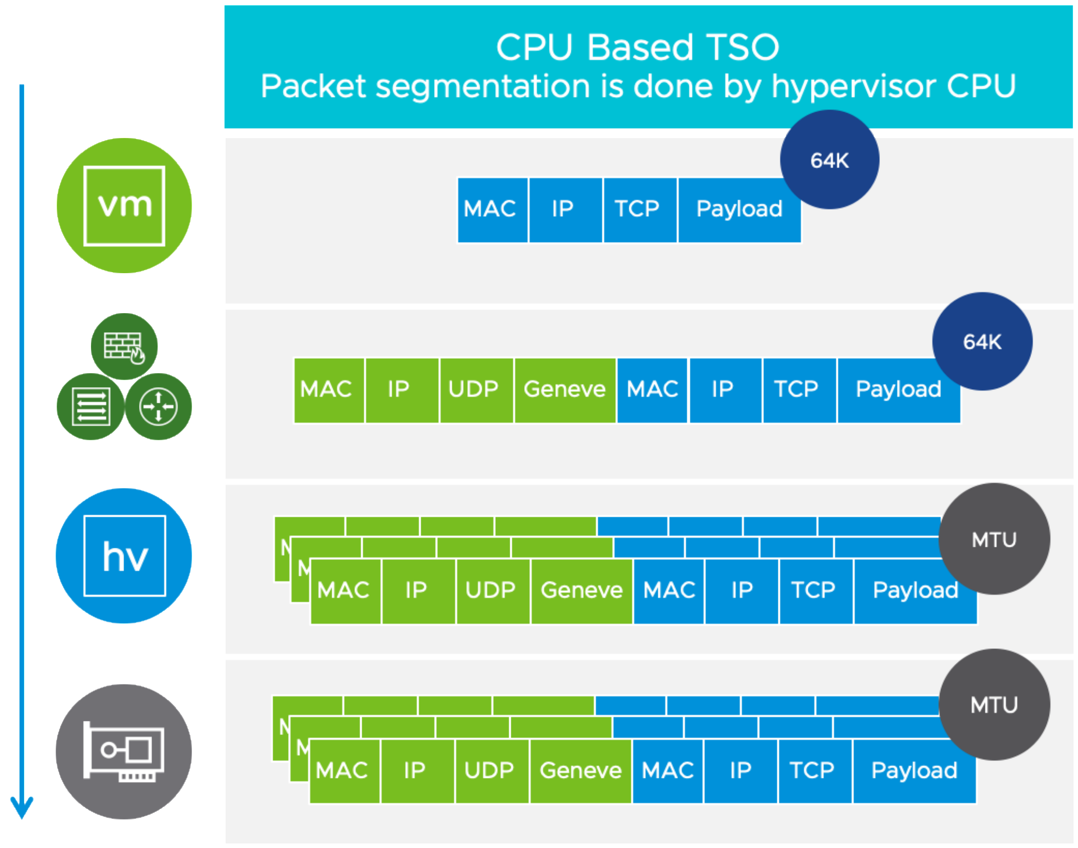

CPU Based TSO
Packet segmentation is done by hypervisor CPU
vm
hv
64K
MAC IP TCP Payload
64K
MAC IP UDP Geneve MAC IP TCP Payload
MTU
MAC IP UDP Geneve MAC IP TCP Payload
MTU
MAC IP UDP Geneve MAC IP TCP Payload

Figure 8-4: Software/CPU Based Geneve Offload - TSO

8.4 NIC Card Geneve Offload Capability

8.4.1 VMware's IO Compatibility Guide

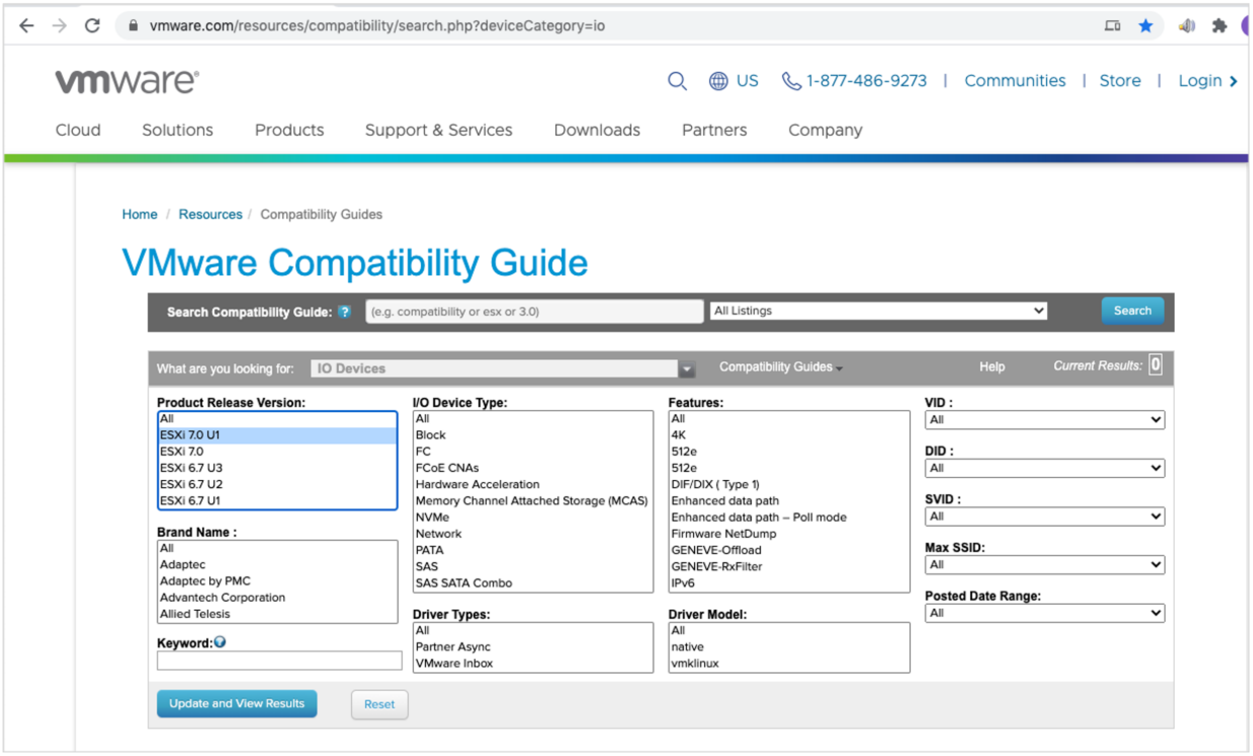
VMware's IO compatibility guide is a publicly accessible online tool:

https://www.vmware.com/resources/compatibility/search.php?deviceCategory=io

And VMware's IO compatibility guide is the single source of truth to confirm whether a particular card is Geneve-offload capable. It is important to note availability of Geneve offload capability in the NIC helps decrease CPU cycles and increase throughput. Hence, deploying NICs with Geneve compatibility does have marginal performance implications. However, in cases where the NIC does not have Geneve capability, ESX automatically falls back to software based Geneve offload mode. While NIC-based offload is ideal, software-based offload still helps reduce the CPU cycles spent for NSX components.

The following section show the steps to check whether a card, Intel 810s in this case, supports Geneve offload.

1. Access the online tool:
   https://www.vmware.com/resources/compatibility/search.php?deviceCategory=io



VMware Compatibility Guide

Search Compatibility Guide: (e.g. compatibility or esx or 3.0) All Listings

What are you looking for: IO Devices

Current Results: 0

Product Release Version:
All
ESXi 7.0 U1
ESXi 7.0
ESXi 6.7 U3
ESXi 6.7 U2
ESXi 6.7 U1

Brand Name :
All
Adaptec
Adaptec by PMC
Advantech Corporation
Allied Telesis

Keyword:

I/O Device Type:
All
Block
FC
FCoE CNAs
Hardware Acceleration
Memory Channel Attached Storage (MCAS)
NVMe
Network
PATA
SAS
SAS SATA Combo

Driver Types:
All
Partner Async
VMware Inbox

Features:
All
4K
512e
512e
DIF/DIX (Type 1)
Enhanced data path
Enhanced data path – Poll mode
Firmware NetDump
GENEVE-Offload
GENEVE-RxFilter
IPv6

Driver Model:
All
native
vmklinux

VID : All

DID : All

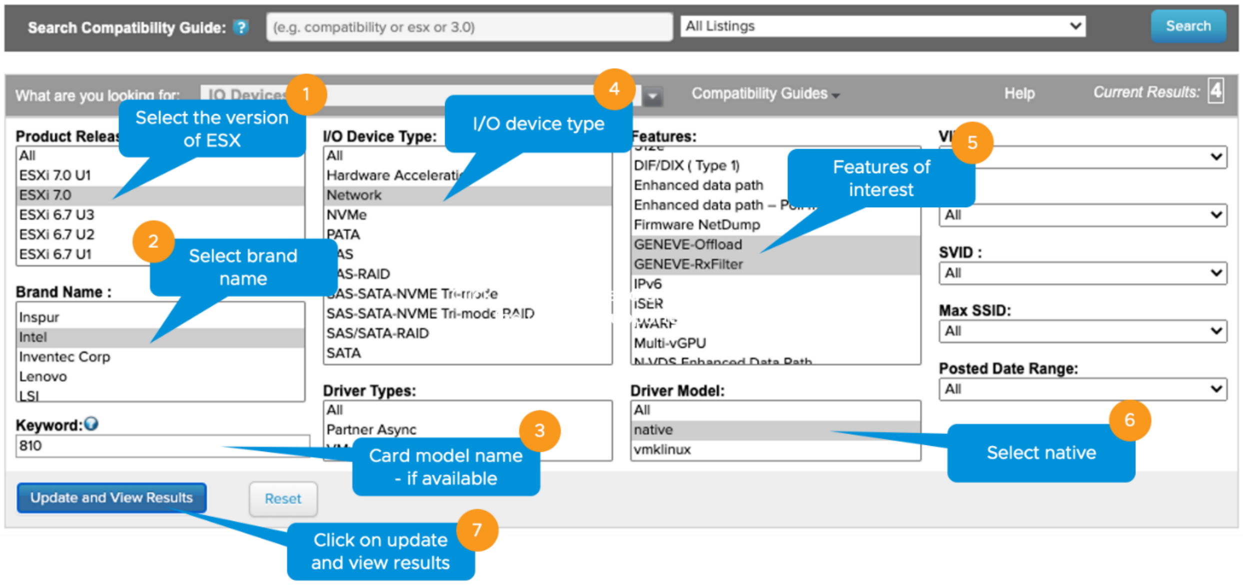
SVID : All

Max SSID: All

Posted Date Range: All

Figure 8-5: VMware Compatibility Guide for I/O

2. Specify the
    1. Version of ESX
    2. Vendor of the NIC card
    3. Model if available
    4. Select Network as the IO Device Type
    5. Select Geneve Offload and Geneve Rx Filters (more on that in the upcoming section) in the Features box
    6. Select Native
    7. Click “Update and View Results”


1
Select the version of ESX
2
Select brand name
3
Card model name - if available
4
I/O device type
5
Features of interest
6
Select native
7
Click on update and view results

Search Compatibility Guide: (e.g. compatibility or esx or 3.0) All Listings Search

What are you looking for: IO Devices Compatibility Guides Help Current Results: 4

Product Release: All, ESXi 7.0 U1, ESXi 7.0, ESXi 6.7 U3, ESXi 6.7 U2, ESXi 6.7 U1

Brand Name : Inspur, Intel, Inventec Corp, Lenovo, LSI

Keyword: 810

I/O Device Type: All, Hardware Acceleration, Network, NVMe, PATA, SAS, SAS-RAID, SAS-SATA-NVME Tri-mode, SAS-SATA-NVME Tri-mode RAID, SAS/SATA-RAID, SATA

Driver Types: All, Partner Async, VMware Inbox

Features: DIF/DIX (Type 1), Enhanced data path, Enhanced data path – Poll, Firmware NetDump, GENEVE-Offload, GENEVE-RxFilter, IPv6, iSER, iWARP, Multi-vGPU, N-VDS Enhanced Data Path

Driver Model: All, native, vmklinux

SVID : All

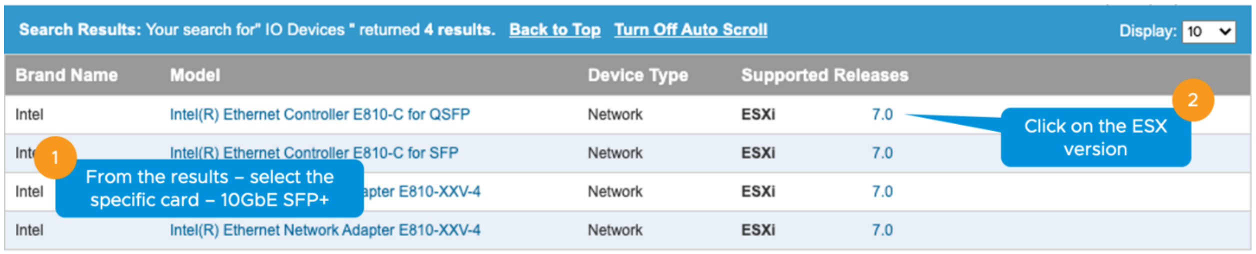
Max SSID: All

Posted Date Range: All

Update and View Results Reset

Figure 8-6: Steps to Verify Compatibility – Part 1

3. From the results, click on the ESX version for the concerned card. In this example, ESXi version 7.0 for Intel E810-C with QSFP ports:

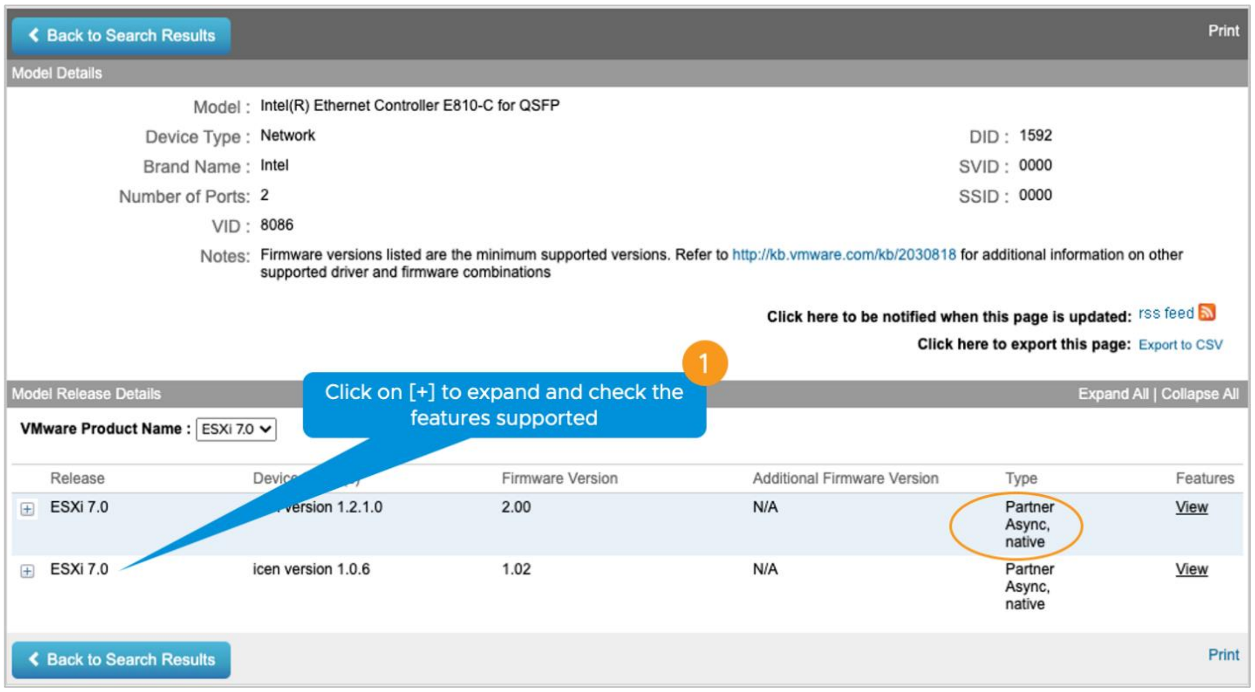


Search Results: Your search for" IO Devices " returned 4 results. Back to Top Turn Off Auto Scroll Display: 10

Brand Name	Model	Device Type	Supported Releases	
Intel	Intel(R) Ethernet Controller E810-C for QSFP	Network	ESXi	7.0
Intel	Intel(R) Ethernet Controller E810-C for SFP	Network	ESXi	7.0
Intel	Intel(R) Ethernet Network Adapter E810-XXV-4	Network	ESXi	7.0
Intel	Intel(R) Ethernet Network Adapter E810-XXV-4	Network	ESXi	7.0

Figure 8-7: Steps to Verify Compatibility - Part 2

4. Click on the [+] symbol to expand and check the features supported.


Back to Search Results
Print
Click on [+] to expand and check the features supported
1
Expand All | Collapse All

Model Details

Model :	Intel(R) Ethernet Controller E810-C for QSFP
Device Type :	Network
Brand Name :	Intel
Number of Ports:	2
VID :	8086
DID :	1592
SVID :	0000
SSID :	0000
Notes:	Firmware versions listed are the minimum supported versions. Refer to http://kb.vmware.com/kb/2030818 for additional information on other supported driver and firmware combinations

Click here to be notified when this page is updated: rss feed
Click here to export this page: Export to CSV

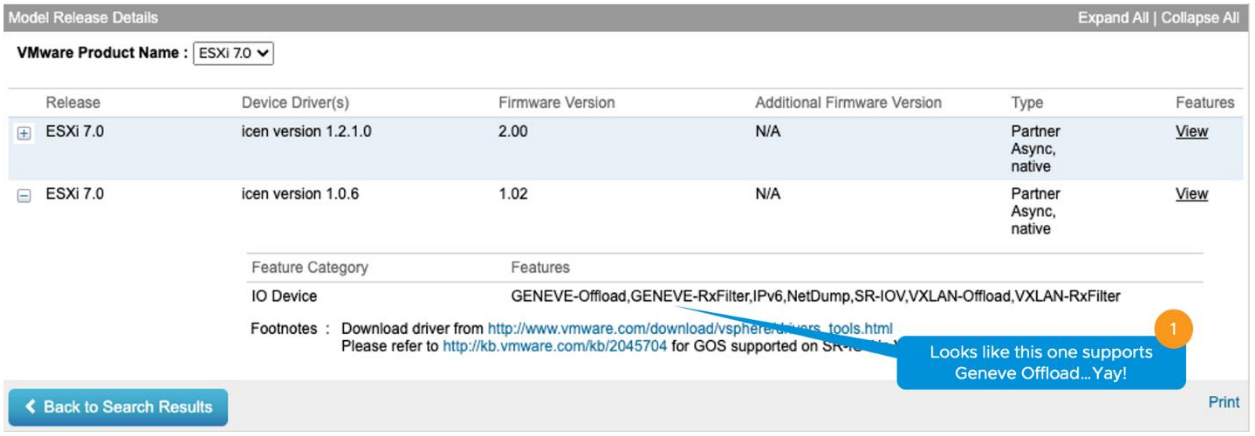
Model Release Details

VMware Product Name : ESXi 7.0

Release	Device Driver(s)	Firmware Version	Additional Firmware Version	Type	Features
ESXi 7.0	version 1.2.1.0	2.00	N/A	Partner Async, native	View
ESXi 7.0	icen version 1.0.6	1.02	N/A	Partner Async, native	View

Figure 8-8: Steps to Verify Compatibility - Part 3

5. Make sure the concerned driver actually has the “Geneve-Offload and Geneve-Rx Filters” as listed features.


Expand All | Collapse All
Looks like this one supports Geneve Offload...Yay!
1
Back to Search Results
Print

Model Release Details

VMware Product Name : ESXi 7.0

Release	Device Driver(s)	Firmware Version	Additional Firmware Version	Type	Features
ESXi 7.0	icen version 1.2.1.0	2.00	N/A	Partner Async, native	View
ESXi 7.0	icen version 1.0.6	1.02	N/A	Partner Async, native	View

Feature Category	Features
IO Device	GENEVE-Offload,GENEVE-RxFilter,IPv6,NetDump,SR-IOV,VXLAN-Offload,VXLAN-RxFilter

Footnotes : Download driver from http://www.vmware.com/download/vsphere/drivers_tools.html
Please refer to http://kb.vmware.com/kb/2045704 for GOS supported on SR-

Figure 8-9: Steps to Verify Compatibility - Part 4

Follow the above procedure to ensure Geneve offload and Geneve Rx Filters are available on any NIC card you are planning to deploy for use with NSX-T. As mentioned earlier, not having Geneve offload will impact performance with higher CPU cycles spent to make up for the lack of software based Geneve offload capabilities.

8.4.2 ESXi-Based Hypervisor

On an ESXi host with a NIC card supporting Geneve-Offload in Hardware with the appropriate supported driver, the following commands can be used to confirm Geneve-Offload is enabled on a pNIC – in this case pNIC vmnic3:

```
[Host-1] vsish -e get /net/pNics/vmnic3/properties | grep
".*Activated.*Geneve"
   Device Hardware Cap Activated:: 0x793c032b ->
VMNET_CAP_SG VMNET_CAP_IP4_CSUM VMNET_CAP_HIGH_DMA
VMNET_CAP_TSO VMNET_CAP_HW_TX_VLAN VMNET_CAP_HW_RX_VLAN
VMNET_CAP_SG_SPAN_PAGES VMNET_CAP_IP6_CSUM VMNET_CAP_TSO6
VMNET_CAP_TSO256k VMNET_CAP_ENCAP VMNET_CAP_Geneve_OFFLOAD
VMNET_CAP_IP6_CSUM_EXT_HDRS VMNET_CAP_TSO6_EXT_HDRS
VMNET_CAP_SCHED
```

CLI 1 Check Geneve Offload Support

Look for the tag "`VMNET_CAP_Geneve_OFFLOAD`", highlighted in red above. This verbiage indicates the Geneve Offload is activated on NIC card vmnic3. If the tag is missing, then it means Geneve Offload is not enabled because either the NIC or its driver does not support it.

8.5 Receive Side Scaling (RSS) and Rx Filters

Readers familiar with software based VxLAN deployment with NSX-V, are likely familiar with the immense performance benefits of RSS, including improving the performance of overlay traffic by four (4) times.

8.5.1 Benefits with RSS

RSS, another long-standing TCP enhancement, enables use of multiple cores on the receive side to process incoming traffic. Without RSS, ESX by default will use only one core to process incoming traffic. Utilizing only one core has a huge impact on the overall throughput as the receiving node then becomes the bottleneck. RSS on the NIC creates multiple queues to process incoming traffic and efficiently uses a core for each queue, with most NIC cards being able to support at least 4 queues. Hence the 4x benefit of using RSS. See *Figure 8-10: RSS* for a visual representation of how this works.

8.5.2 RSS for overlay

While RSS itself in general is in fairly common use today, there are NICs which still may not support RSS for overlay. Hence, our recommendation is to confirm with the NIC vendor whether RSS for overlay traffic is available in hardware, then also confirm with the VMware [Compatibility IO Guide](https://www.vmware.com/resources/compatibility/search.php?deviceCategory=io) (https://www.vmware.com/resources/compatibility/search.php?deviceCategory=io) whether there is a RSS-certified driver.

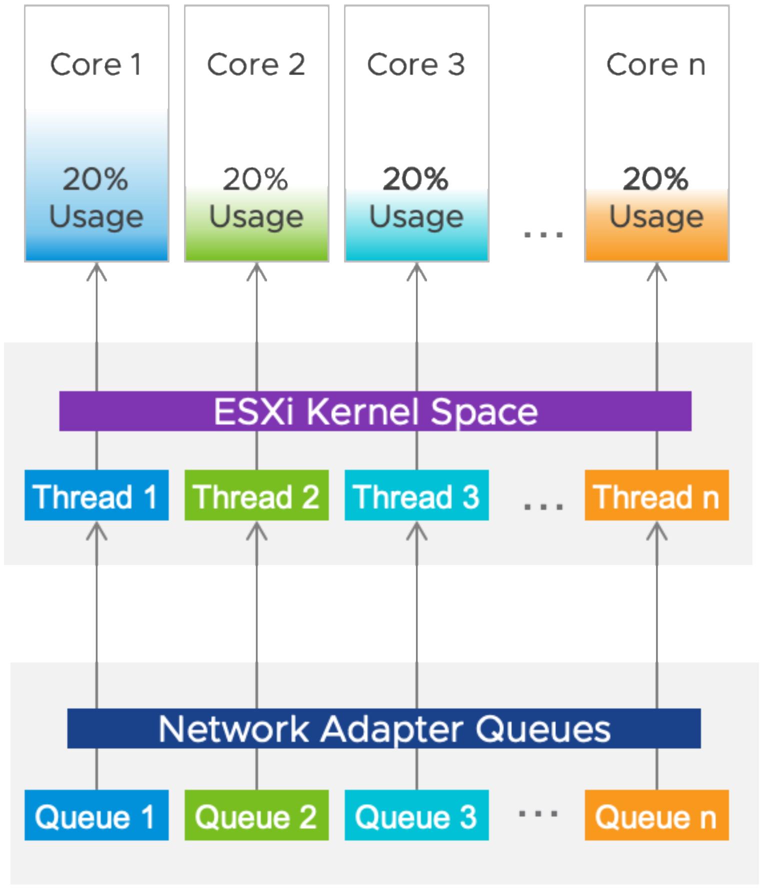


Figure 8-10: RSS

8.5.3 Enabling RSS for Overlay

Every vendor has their own unique mechanism to enable RSS for overlay traffic. There are also cases where the setting used to change RSS is different based on the driver version. Please refer to the concerned vendor documentation for details on enabling RSS for specific NICs.

8.5.4 Checking whether RSS is enabled

Use the "vsish" command to check whether RSS is enabled. The following example shows how to check whether RSS (marked blue) is enabled on NIC vmnic (marked in red).

```
[Host-1] # vsish
/> get /net/pNics/vmnic0/rxqueues/info
rx queues info {
# queues supported:5
# filters supported:126
# active filters:0
Rx Queue features:features: 0x1a0 -> Dynamic RSS Dynamic
Preemptible
```

```
        }
        />
```

CLI 2 Check RSS

8.5.5 RSS and Rx Filters - Comparison

RSS uses the outer headers to hash flows to different queues. Using outer headers of Geneve overlay, especially between two hypervisors, may not be optimal as the only varying parameter is the source port.

The following image shows the fields used by RSS (circled in red) to hash flows across various CPU cores. Since all the fields are from the outer headers, there is a little variability and in the worst-case scenarios the only variable may be the source port.

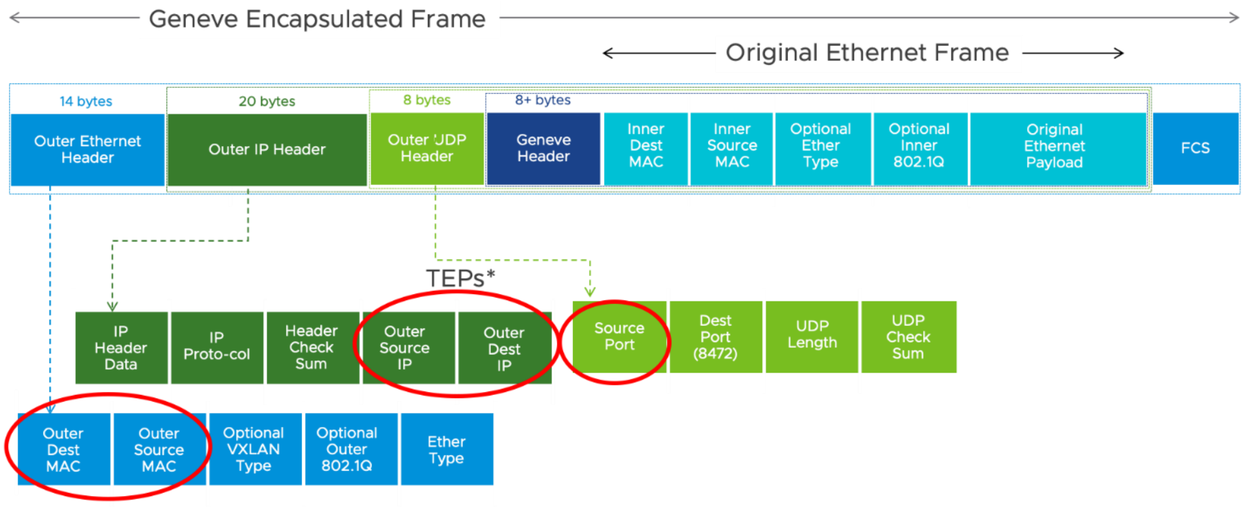


Figure 8-11: RSS: Fields Used for Hashing

To overcome this limitation, the latest NICs (see compatibility guide) support an advanced feature, known as Rx Filters, which looks at the inner packet headers for hashing flows to different queues on the receive side. In the following *Figure 8-12: Rx Filters: Fields Used for Hashing* fields used by Rx Filter are circled in red.

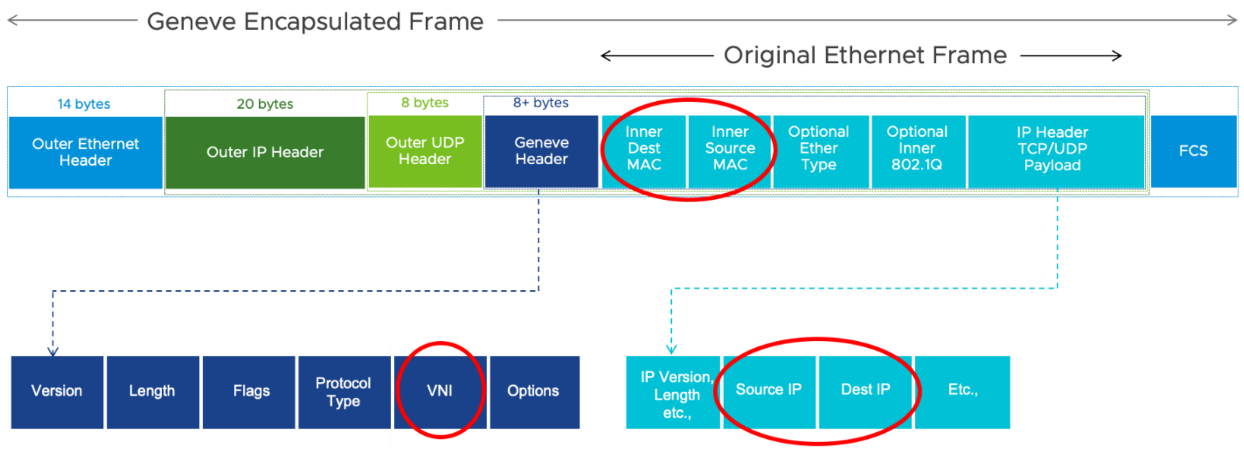


Figure 8-12: Rx Filters: Fields Used for Hashing

Simply put, Rx Filters look at the inner packet headers for queuing decisions. As driven by NSX, the queuing decision itself is based on flows and bandwidth utilization. Hence, Rx Filters provide optimal queuing compared to RSS, which is akin to a hardware-based brute force method.

8.5.6 Checking whether Rx Filters are enabled

Rx Filters are enabled by default on a NIC that supports Rx Filters in hardware and has a driver to use it. Please use the VMware's Compatibility Guide for IO, discussed earlier in this chapter, to confirm whether Rx Filters are available. In VCG for I/O page, select "Geneve-RxFilter", and make sure the right driver is installed on the ESXi host.

On the ESXi host, use the "vsish" command to check whether Rx Filters are enabled. The following example shows how to check whether the NIC vmnic5 (marked in red) has Rx Filters Enabled for Geneve (marked in blue)

Check Whether Rx / Tx Filters are Enabled:

```
[Host-1] vsish
/> cat /net/pNics/vmnic5/rxqueues/info
rx queues info {
   # queues supported:8
   # filters supported:512
   # active filters:0
   # filters moved by load balancer:254
   # of Geneve OAM filters:2
   RX filter classes:Rx filter class: 0x1c -> VLAN_MAC
VXLAN Geneve GenericEncap
```

```
            Rx Queue features:features: 0x82 -> Pair Dynamic
        }
        />
```

CLI 3 Check RxFilters Support

8.5.7 RSS vs Rx Filters for Edge VM

In the case of Edge VMs, the hypervisor does not encapsulate/decapsulate the overlay packets. Instead, the packets are sent along with the overlay headers to the Edge VM's vNIC interfaces. In this case, RSS is the best mechanism available today to hash packets to separate queues. See more on RSS for Edges in the Edge sections.

8.6 Jumbo MTU for Higher Throughput

Maximum Transmission Unit (MTU) denotes the maximum packet size that can be sent on the physical fabric. When setting this configuration on the ESX hosts and the physical fabric, Geneve header size has to be taken into consideration. Our general recommendation is to allow for at least 200 bytes buffer for Geneve headers in order to accommodate the option field for use cases such as service-insertion. As an example, if the VM's MTU is set to 1500 bytes, pNIC and the physical fabric should be set to 1700 or more. See *Figure 8-13: MTU Configuration* on MTU Configuration.

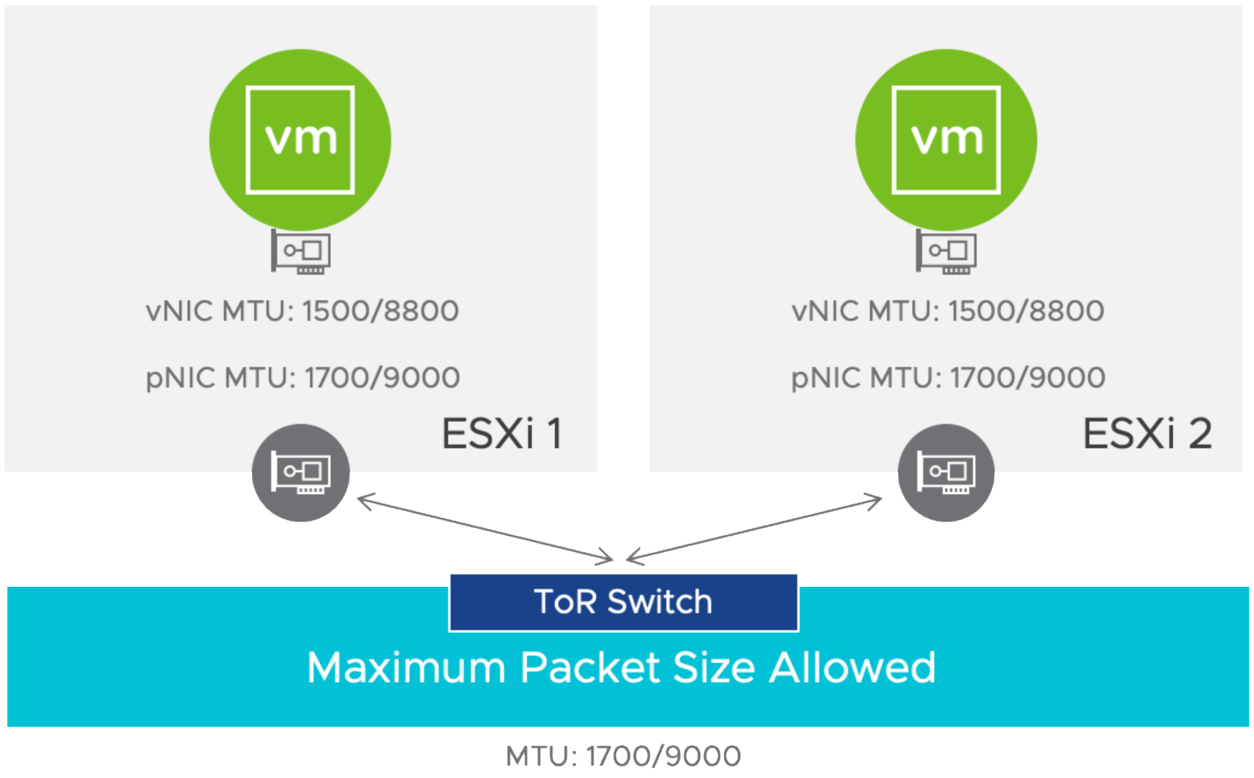


Figure 8-13: MTU Configuration

Why should you care about MTU values? MTU is a key factor for driving high throughput, and this is true for any NIC which supports 9K MTU also known as jumbo frame. The following graph *Figure 8-14: MTU and Throughput* shows throughput achieved with MTU set to 1500 and 8800:

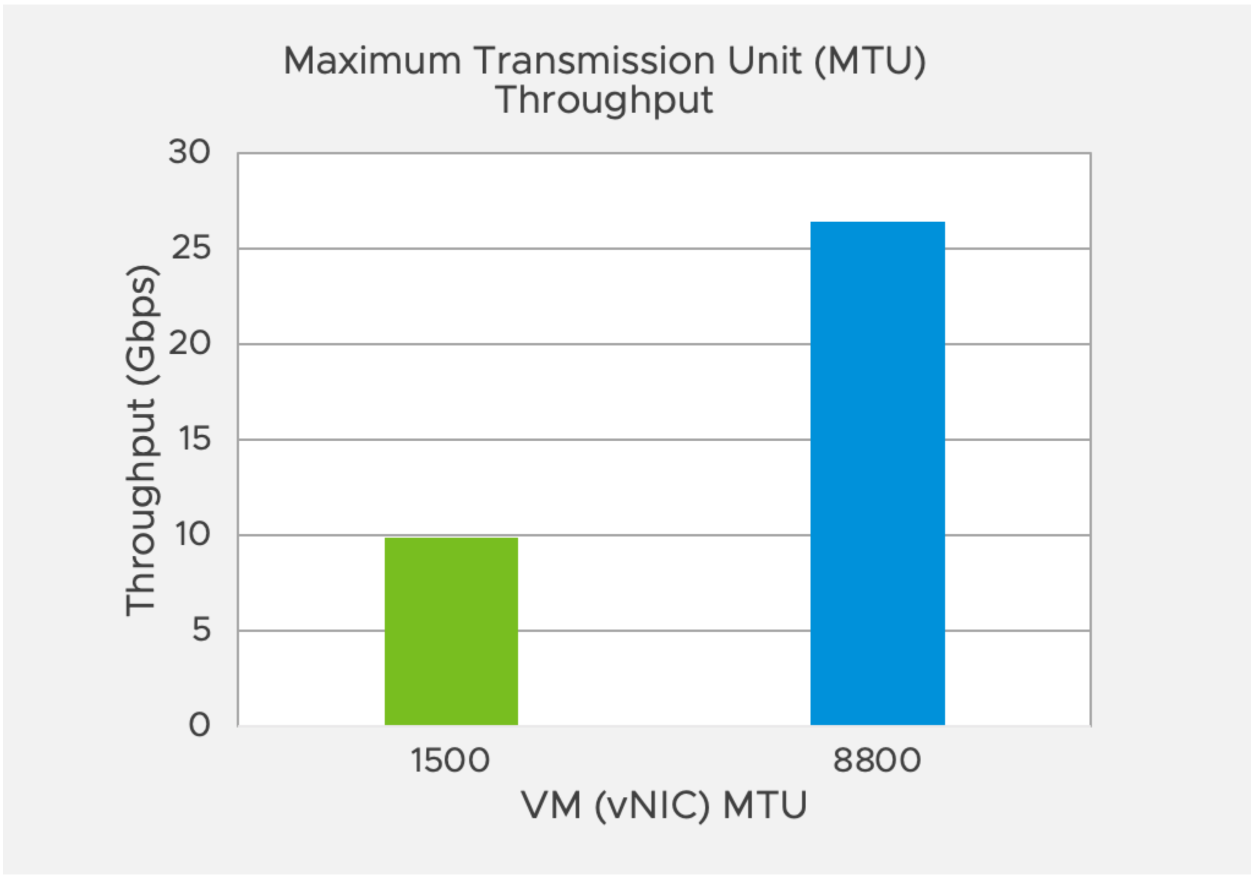


Figure 8-14: MTU and Throughput

Our recommendation for optimal throughput is to set the underlying fabric and ESX host's pNICs to 9000 and the VM vNIC MTU to 8800.

Notes for *Figure 8-14: MTU and Throughput*:

- The above graph represents a single pair of VMs running iPerf with 4 sessions.
- For both VM MTU cases of 1500 and 8800, the MTU on the host was 9000 with demonstrated performance improvements.

8.6.1 Checking MTU on an ESXi host

Use the *esxcfg-nics* command to check the MTU:

```
 [Host-1] esxcfg-nics -l | grep vmnic5
vmnic5  0000:84:00.0 i40en       Up   40000Mbps  Full
```

```
  3c:fd:fe:9d:2b:d0 9000   Intel Corporation Ethernet
 Controller XL710 for 40GbE QSFP+
```

CLI 4 Check MTU on ESXi Host

For the VM, use the commands specific to the operating system for checking MTU. For example, "ifconfig" is one of the commands in Linux to check MTU.

8.7 Single TEP vs Dual TEP

Dual TEP is another method to increase the throughput of a given host. Dual TEP will help achieve twice the throughput of single TEP. The following image compares throughput with Single TEP vs throughput with Dual TEP using Intel® XL710 NICs on servers running on Intel® Xeon® Gold 6252 CPU @ 2.10GHz

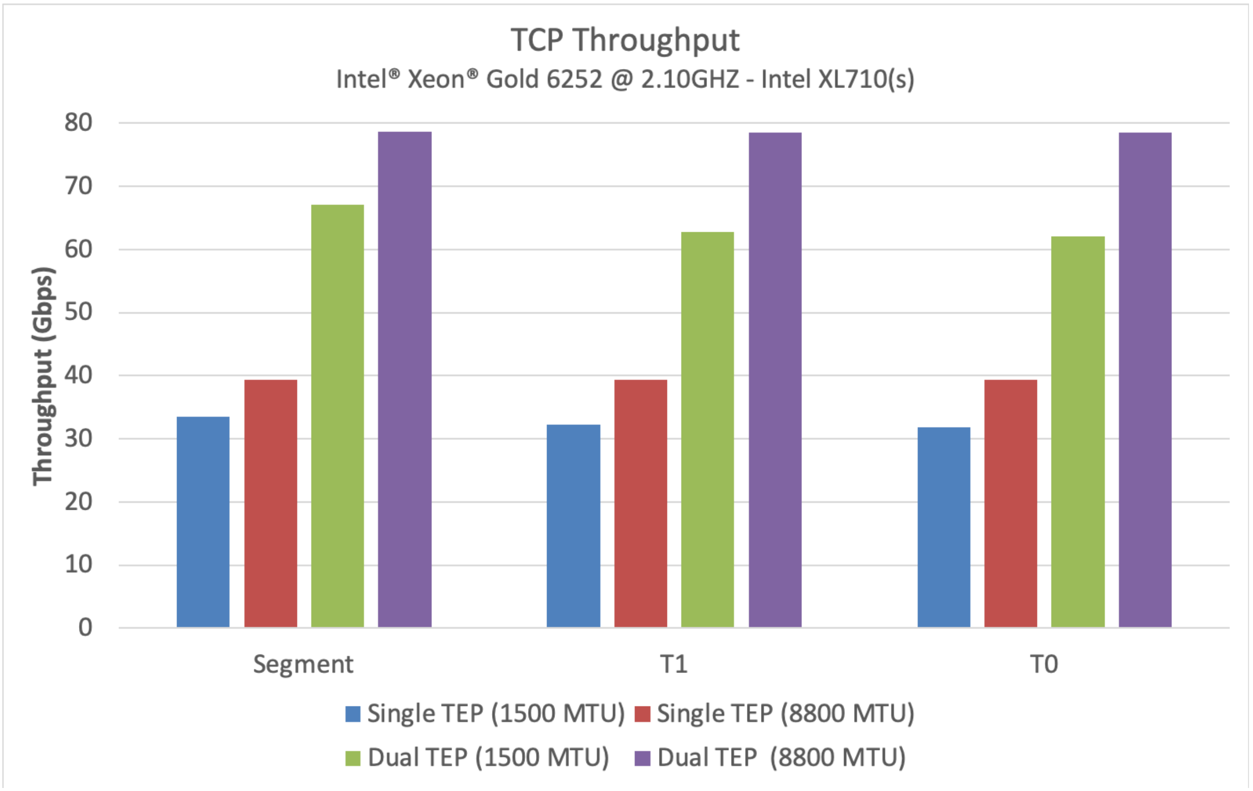


Figure 8-15: Throughput with Single TEP vs Dual TEP with Different MTUs

Note: Intel® XL710s are PCIe Gen 3 x8 lane NICs. On x8 lane NICs, the max throughput is limited to 64Gbps. To achieve the above near-line rate of 80Gbps, 2 x Intel® XL710s must be used.

8.8 NIC Port Speed

The port speed of the NIC, in combination with all the above features, also has a direct impact on the achieved throughput. The following graph shows throughput achieved on an Intel® E810C 100Gbps NIC using 8800 MTU. Thanks to its x16 lane design, this NIC's performance is close to line rate at 100Gbps @ 8800 MTU.

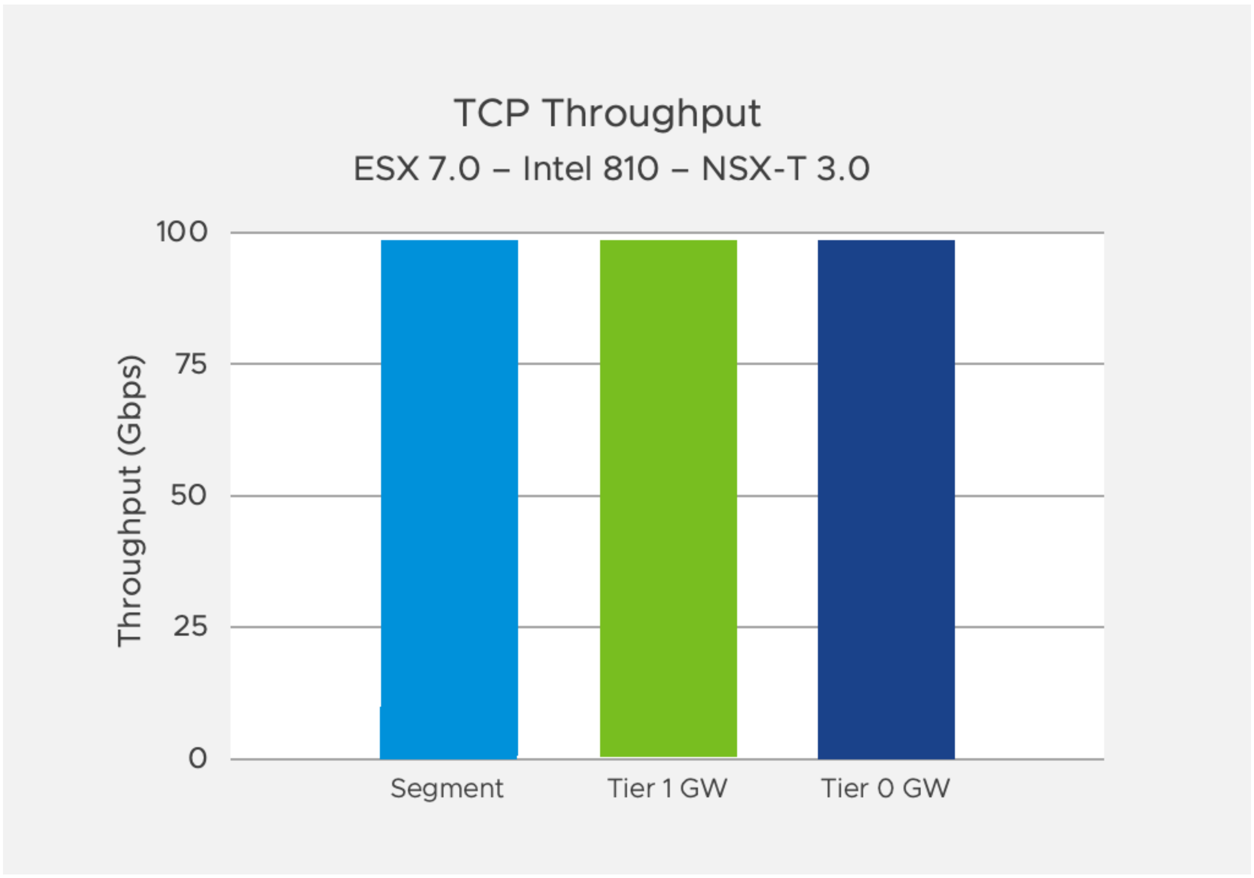


Figure 8-16: Throughput with Intel® E810-C 100Gbps NIC

8.9 PCIe Gen 4

PCIe Gen 4 doubles the bandwidth when compared to PCIe Gen3. Which translates into higher throughput even when using standard 1500 MTU. Following graph shows the throughput on PCIe Gen 4 Platform based on AMD EPYCTM 7F72 @ 3.2 GHz – Single-Socket using PCIe Gen 4 NIC Mellanox ConnectX-6 single port using a standard 1500 MTU.

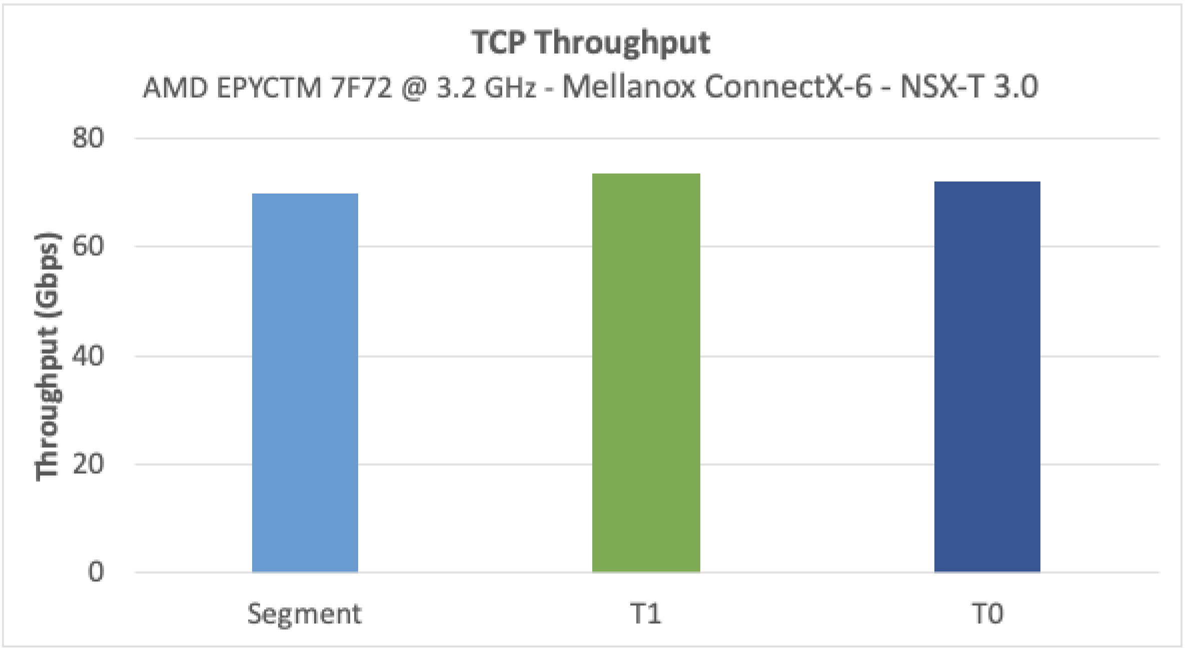


Figure 8-17: Throughput with AMD® EPYCTM 7F72

8.10 Performance Factors for NSX-T Edges

8.10.1 Data Plane Development Kit (DPDK)

Data Plane Development Kit (DPDK) is a set of libraries and drivers to enable fast packet processing on a wide variety of CPU architectures including x86 platforms. DPDK is applicable for both the VM and bare metal Edge form factors, with the VM edge capable of delivering over 20Gbps throughput for standard TCP based DC workloads. Bare metal edge delivers over 35Gbps throughput for the same TCP-based DC workloads. The bare metal Edge form factor also excels at processing small packet sizes ~78 Bytes at near line on a 40Gbps port such as Intel® XL710, which is useful in NFV-style workloads. The following graph *Figure 8-18: Bare Metal Edge Performance Test (RFC2544) with IXIA* shows the performance of bare metal Edge with a standard RFC 2544 test with IXIA.

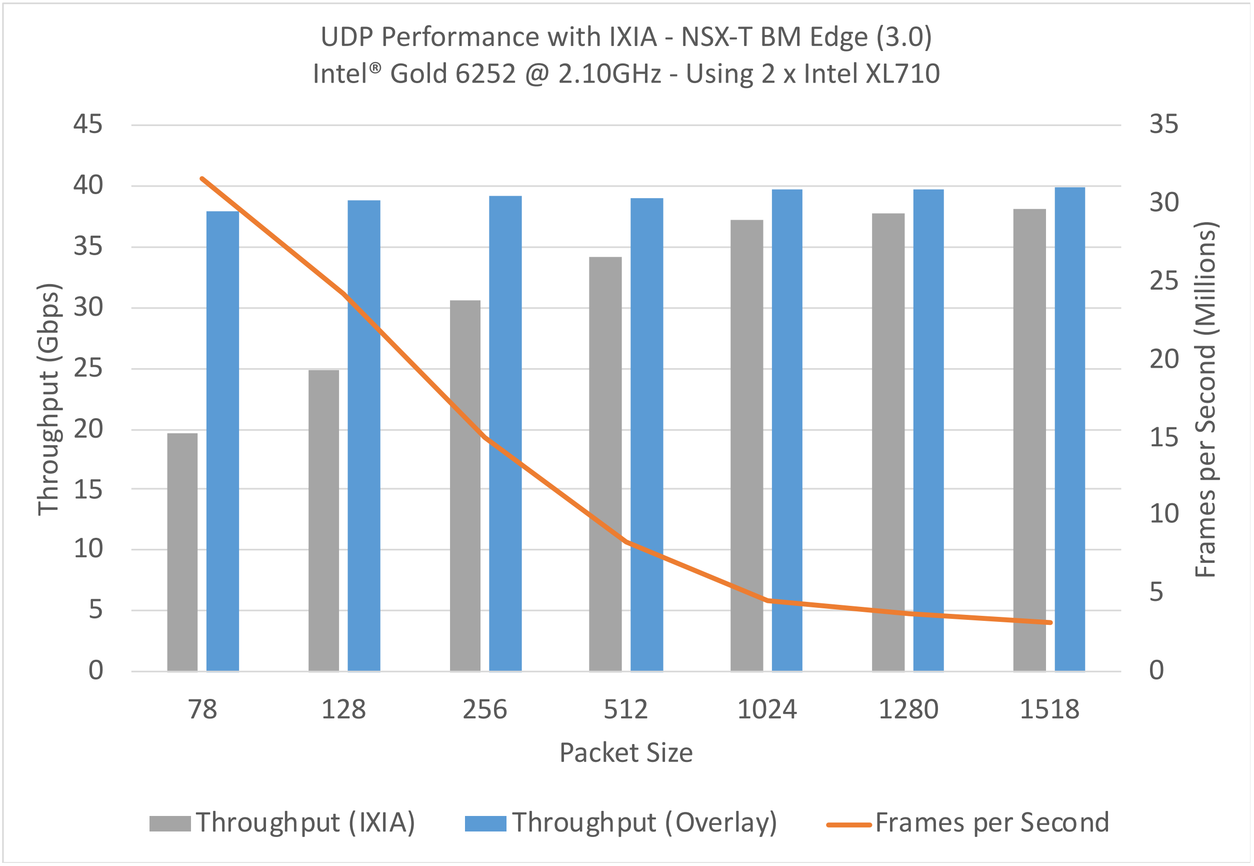


Figure 8-18: Bare Metal Edge Performance Test (RFC2544) with IXIA

Note: For the above test, the overlay lines in blue are calculated by adding throughput reported by IXIA and the Geneve Overlay header size.

8.10.2 SSL Offload

VMware NSX-T bare metal Edges also support SSL Offload. This configuration helps in reducing the CPU cycles spent on SSL Offload and also has a direct impact on the throughput achieved. In the following image, Intel® QAT 8960s are used to show case the throughput achieved with SSL Offload.

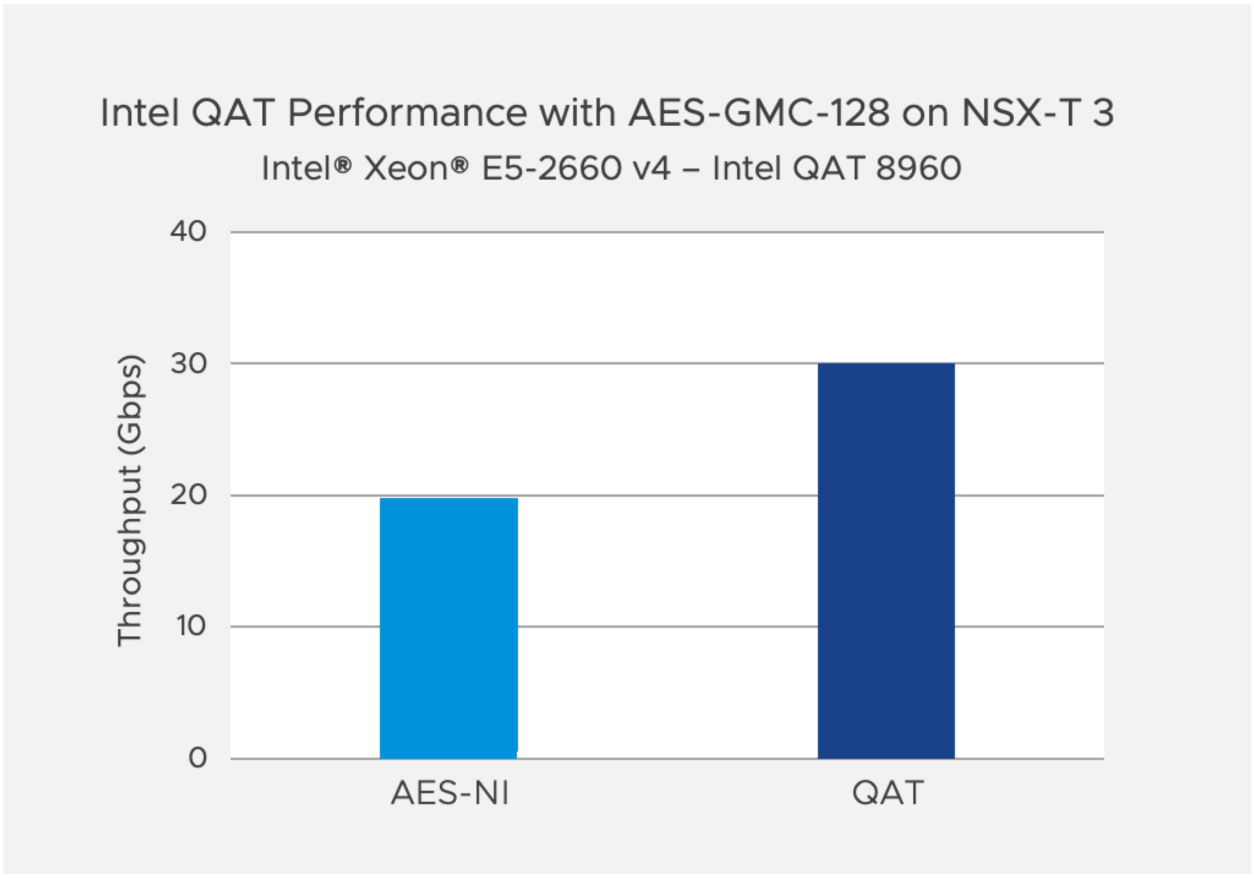


Figure 8-19: Throughput with SSL Offload

8.11 Key Performance Factors

One key to achieve better performance for compute, Edge VM, and bare metal Edge is to ensure having the right set of tools. While DPDK plays a key role, it's not the only factor affecting performance. The combination of DPDK and other capabilities of NIC drivers and hypervisor enhancements will help achieve optimal performance.

8.11.1 Compute Node Performance Factors

For compute clusters, our recommendation is to ensure the following two features are available on your NIC of choice:

1. Geneve Offload
2. Geneve Rx Filters

Geneve Offload helps decrease the CPU usage by offloading the task of dividing TSO segments into MTU-determined packets to the NIC card while also helping to increase throughput. Geneve Rx Filters help increase the number of cores used to process incoming traffic, which is in turn increases performance by a factor of 4x times based on the number of hardware queues available on the NIC. For older cards which do not support Geneve Rx Filters, check whether they at minimum have RSS capability. The following graph shows the throughput achieved with and without using Geneve Rx Filters, 10Gbps vs near line rate:

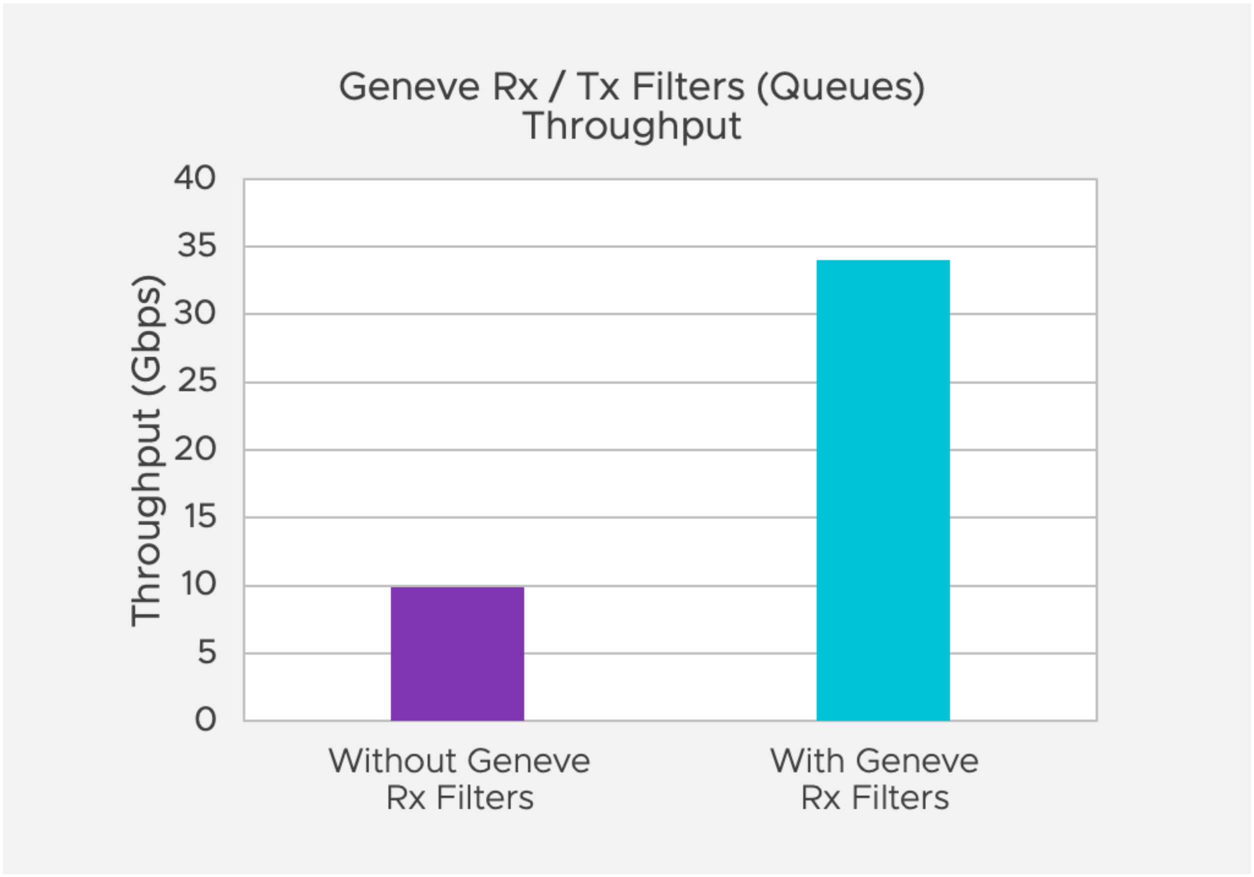


Figure 8-20: Throughput Improvement with Rx Filters

===
Figure 8-20 Note: This test was run with LRO enabled, which is software-supported starting with ESX version 6.5 and higher on the latest NICs which support the Geneve Rx Filter. Thus, along with Rx Filters, LRO contributes to the higher throughput depicted here.
===

8.11.2 VM Edge Node Performance Factors

In the case of edge clusters, DPDK is the key factor for performance. In the case of VM Edge, RSS-enabled NICs are best for optimal throughput.

RSS at pNIC
To achieve the best throughput performance, use an RSS-enabled NIC on the host running Edge VM, and ensure an appropriate driver which supports RSS is also being used. Use the VMware Compatibility Guide for I/O (section 8.4.1) to confirm driver support.

RSS on VM Edge
For best results, enable RSS for Edge VMs. Following is the process to enable RSS on Edge VMs:

1. Shutdown the Edge VM
2. Find the ".vmx" associated with the Edge VM (https://kb.vmware.com/s/article/1714)
3. Change the following two parameters, for the Ethernet devices in use, inside the .vmx file
    a. ethernet3.ctxPerDev = "3"
    b. ethernet3.pnicFeatures = "4"
4. Start the Edge VM

Alternatively, use the vSphere Client to make the changes:

1. Right click on the appropriate Edge VM and click "Edit Settings":

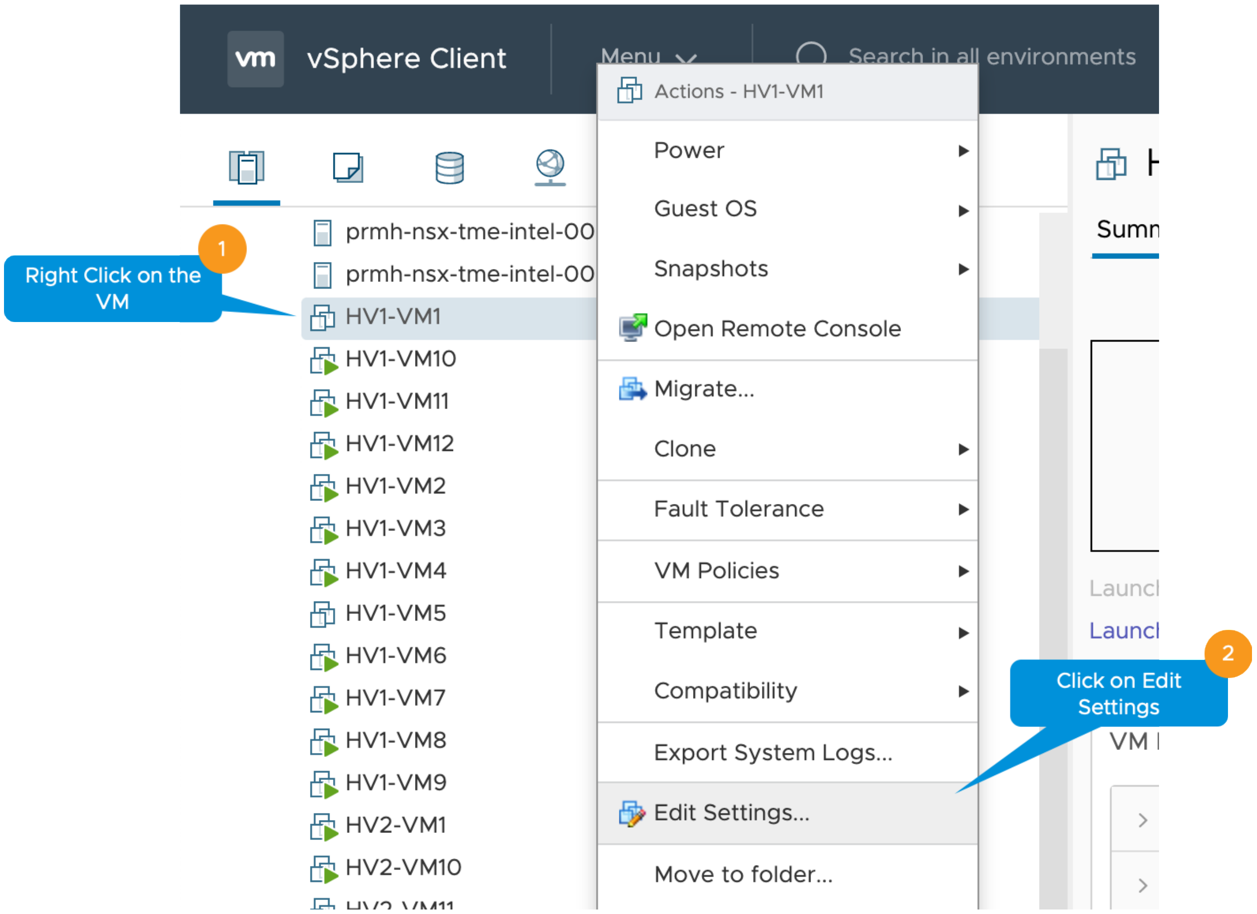
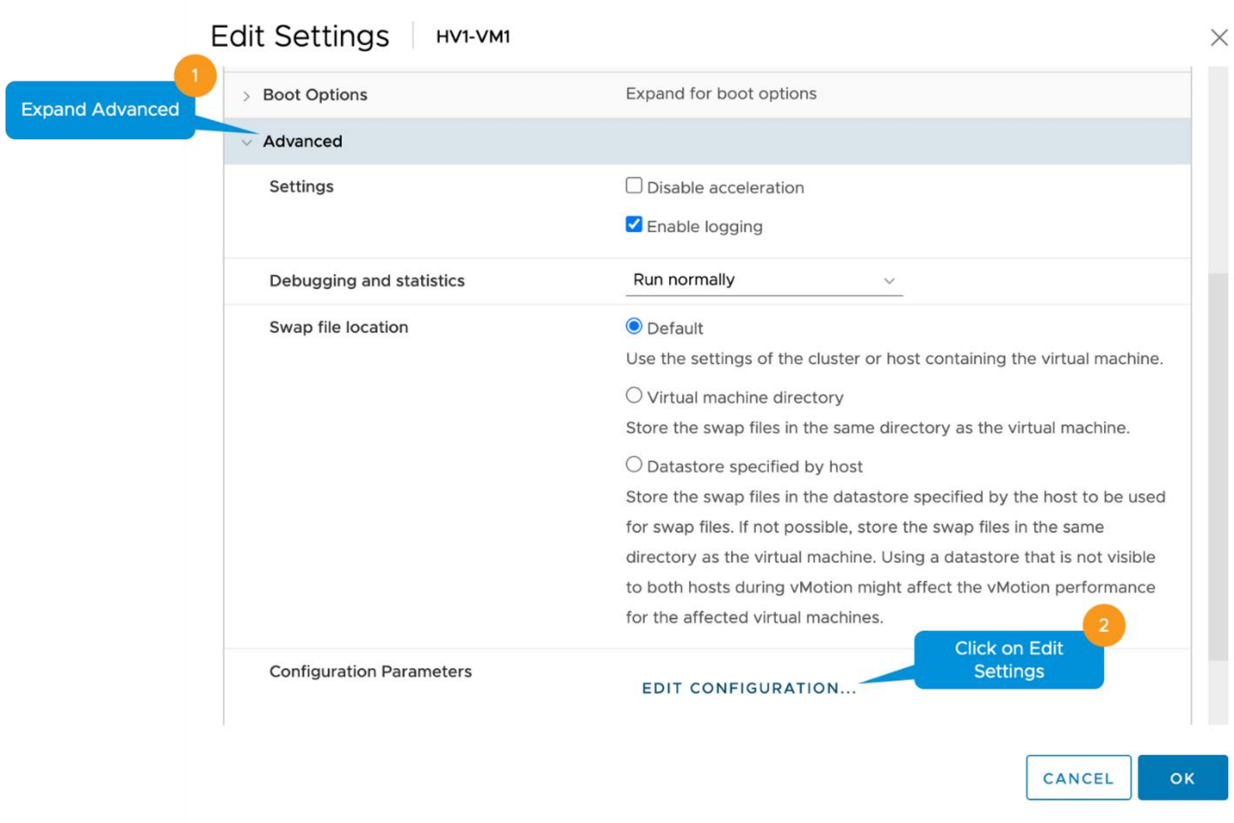


Figure 8-21: Change VM RSS Settings via vSphere Client – Part 1

2. Under “VM Options”, expand “Advanced” and click on “Edit Configuration”:



Settings: ☐ Disable acceleration; ☑ Enable logging

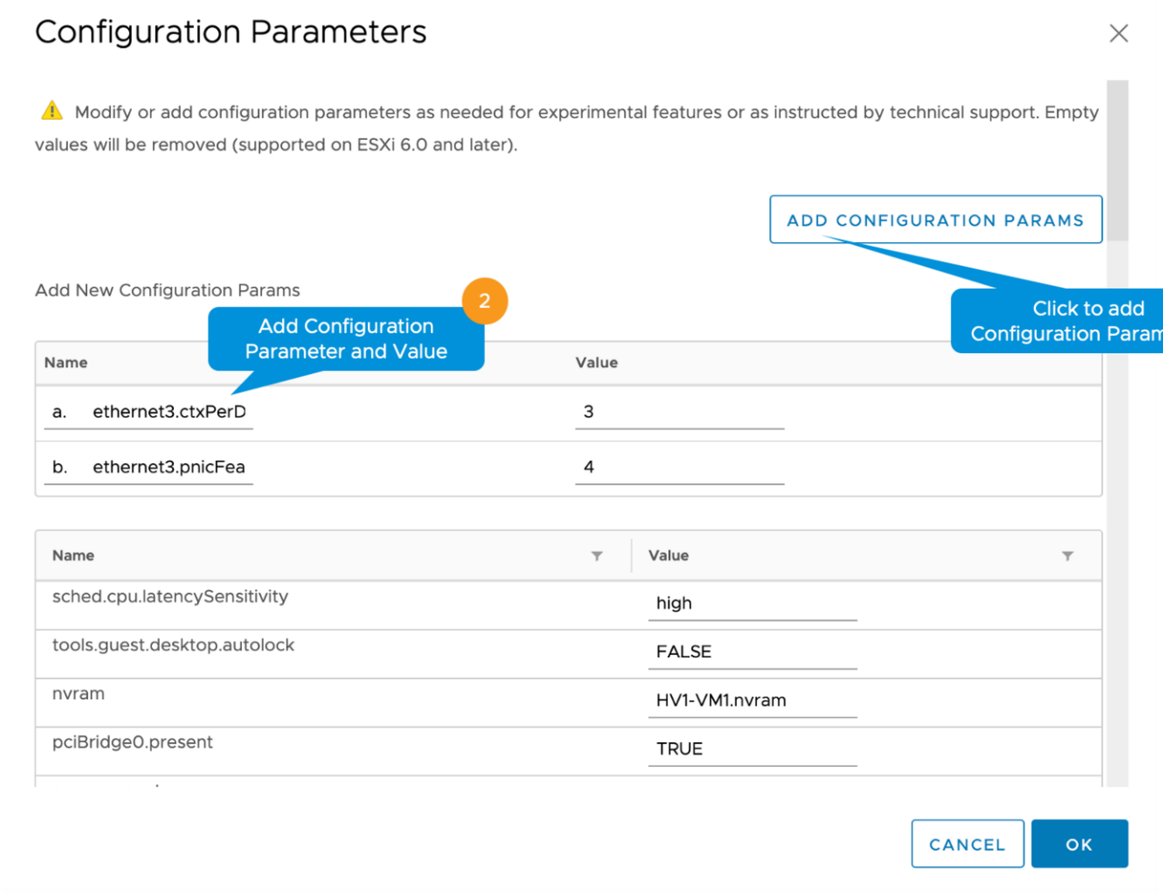
Debugging and statistics: Run normally

Swap file location: ● Default — Use the settings of the cluster or host containing the virtual machine. ○ Virtual machine directory — Store the swap files in the same directory as the virtual machine. ○ Datastore specified by host — Store the swap files in the datastore specified by the host to be used for swap files. If not possible, store the swap files in the same directory as the virtual machine. Using a datastore that is not visible to both hosts during vMotion might affect the vMotion performance for the affected virtual machines.

Configuration Parameters

Figure 8-22: Change VM RSS Settings via vSphere Client – Part 2

3. Add the two configuration parameters by clicking on “Add Configuration” for each item to add:


Configuration Parameters
ADD CONFIGURATION PARAMS
1
Click to add Configuration Parameter
2
Add Configuration Parameter and Value
CANCEL
OK

⚠ Modify or add configuration parameters as needed for experimental features or as instructed by technical support. Empty values will be removed (supported on ESXi 6.0 and later).

Add New Configuration Params

Name	Value
a. ethernet3.ctxPerD	3
b. ethernet3.pnicFea	4

Name	Value
sched.cpu.latencySensitivity	high
tools.guest.desktop.autolock	FALSE
nvram	HV1-VM1.nvram
pciBridge0.present	TRUE

Figure 8-23: Change VM RSS Settings via vSphere Client – Part 3

The following graph *Figure 8-24: RSS for VM Edge* shows the comparison of throughput between a NIC which supports RSS and a NIC which does not. Note: In both cases, even where the pNIC doesn't support RSS, RSS was enabled on the VM Edge:

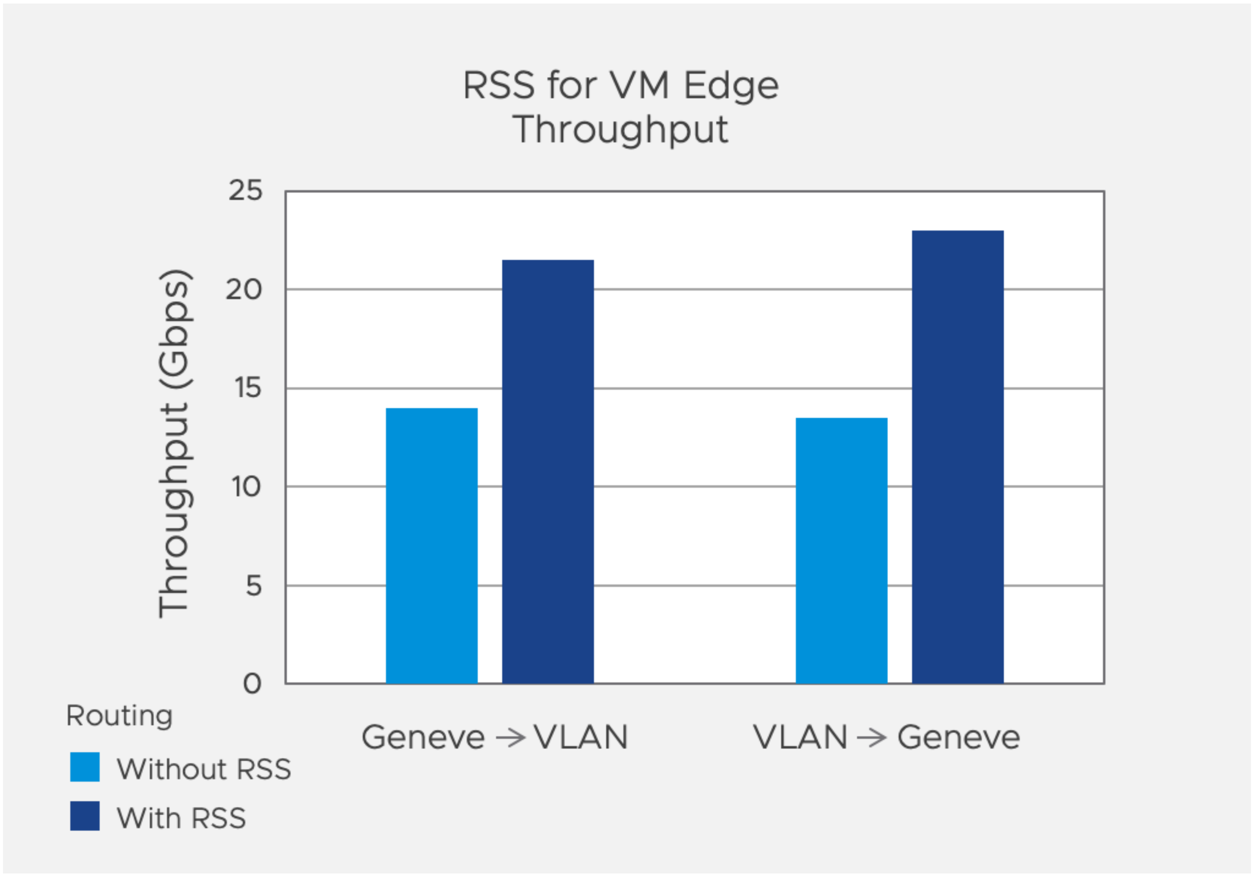


Figure 8-24: RSS for VM Edge

With an RSS-enabled NIC, a single Edge VM may be tuned to drive over 20Gbps throughput. As the above graph shows, RSS may not be required for 10Gbps NICs as they can achieve close to ~15 Gbps throughput even without enabling RSS.

8.11.3 Bare Metal Edge Node Performance Factors

Bare metal Edge has specific requirements dependent on the type of NIC used. Please refer to the NSX-T Installation Guide (https://docs.vmware.com/en/VMware-NSX-T-Data-Center/3.0/installation/GUID-14183A62-8E8D-43CC-92E0-E8D72E198D5A.html) for details on currently supported cards.

While VM and bare metal Edges leverage Data Path Development Kit (DPDK), they differ in deployment. While VM Edge does not have restrictions on the physical NIC which can be used because VMXNET3 provides DPDK functionality for the VM Edge, bare metal Edge does have strict restrictions on the NICs which may be used. (Note however, bare metal Edge nodes do support Intel® QATs for SSL Offload.) Please refer to the relevant hardware requirements section of the NSX-T installation guide for specific details on compatibility.

The following link shows the general system requirements for NSX-T 3.0 components: https://docs.vmware.com/en/VMware-NSX-T-Data-Center/3.0/installation/GUID-14183A62-8E8D-43CC-92E0-E8D72E198D5A.html

From the above page, for requirements specific to the NSX-T bare metal Edge, click on NSX Edge Bare Metal Requirements.

8.11.4 Summary of Performance – NSX-T Components to NIC Features

The following table (*Table 8-1 Summary of Performance Improvements with Various Capabilities*) provides an overall view and guidance on NSX-T components and NIC features per given use case. For common datacenter applications and deployments, Standard N-VDS is the recommendation. Enhanced Data Path is only meant for NFV style workloads with fast packet processing requirements.

Table 8-1 Summary of Performance Improvements with Various Capabilities

	Compute Transport Nodes (N-VDS Standard)	**Compute Transport Nodes ("Enhanced Data Path")**	**ESXi nodes with VM Edges**	**Bare Metal Edge**
Features that Matter	**Geneve-Offload:** To save on CPU cycles **Geneve-RxFilters**: To increase throughput by using more cores and using software based LRO **RSS** (if Geneve-RxFilters does not exist): To increase throughput by using more cores	**N-VDS Enhanced Data Path**: For DPDK-like capabilities	**RSS**: To leverage multiple cores	**DPDK**: Poll mode driver with memory- related enhancements to help maximize packet processing speed **QATs**: For high encrypt/decrypt performance with SSL-offload
Benefits	High Throughput for typical TCP-based DC Workloads	Maximum PPS for NFV style workloads	Maximize Throughput for typical TPC based Workloads with Edge VM VM Tuning + NIC with RSS Support Add/Edit two parameters to the Edge VM's vmx file and restart	Maximum PPS Maximum Throughput even for small packet sizes Maximum encrypt/decrypt performance with SSL Offload Low latency Maximum Scale Fast Failover

8.12 Results

The following section takes a look at the results achievable under various scenarios with hardware designed for performance. First, here are the test bed specs and methodology:

Table 8-2 Specific Configuration of Performance Results

Compute	Virtual Machine	Edge Bare Metal	Test Tools
• CPU: Intel(R) Xeon(R) Gold 6252 CPU @ 2.10GHz • RAM: 192 GB • Hyper Threading: Enabled • MTU: 1700 • NIC: XL710 • NIC Driver: i40e - 1.3.1-18vmw.670.0.0.8169922 • ESXi 6.7	vCPU: 2 RAM: 2 GB Network: VMXNET3 MTU: 1500	CPU: Intel ® Xeon ® E5-2637 v4 3.5Ghz • RAM: 256 GB • Hyper Threading: Enabled • MTU: 1700 • NIC: XL710 • NIC Driver: In-Box	iPerf 2 (2.0.5) with • 4 – 12 VM Pairs • 4 Threads per VM Pair • 30 seconds per test • Average over three iterations

NSX-T Components

- Segments
- T1 Gateways
- T0 Gateways
- Distributed Firewall: Enabled with default rules
- NAT: 12 rules – one per VM
- Bridging
    a. Six Bridge Backed Segments
    b. Six Bridge Backed Segments + Routing

The following graph shows in every scenario above, NSX-T throughput performance stays consistently close to line rate on an Intel® XL710 40Gbps NIC.

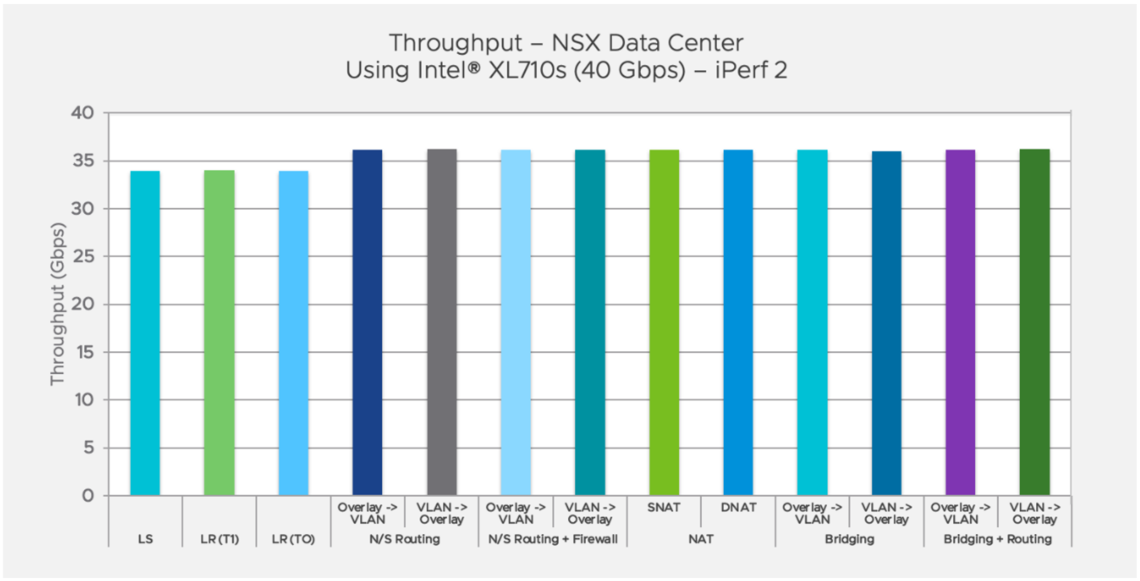


Figure 8-25: Throughput Summary for NSX-T Based Datacenter

8.13 NFV: Raw Packet Processing Performance

TCP-based workloads are generally optimized for throughput and are not sensitive to raw packet processing speed. NFV-style workloads are on the opposite end where the raw packet processing is key. For these specific workloads, NSX-T provides an enhanced version of N-VDS called N-VDS enhanced.

8.13.1 N-VDS Enhanced Data Path

Based on the DPDK-like features such as Poll Mode Driver (PMD), CPU affinity, and optimization and buffer management, N-VDS Enhanced caters to applications requiring high speed raw packet processing, for details on the N-VDS enhanced switch and its application, please refer to the resource below:

8.14 Acceleration with the N-VDS in Enhanced Datapath Mode

https://docs.vmware.com/en/VMware-vCloud-NFV-OpenStack-Edition/3.1/vmware-vcloud-nfv-openstack-edition-ra31/GUID-0695F86B-20AD-4BFB-94E0-5EAF94087758.html?hWord=N4IghgNiBcIHIFoBqARAygAgKIDsAWYOAxgKYAmIAvkA

8.14.1 Poll Mode Driver

One of the recent key changes with DPDK is the addition of Poll Mode Driver (PMD). With the Poll Mode Driver, instead of the NIC sending an interrupt to the CPU once a packet arrives, a core is assigned to poll the NIC to check for packets. This polling procedures eliminates CPU context switching, unavoidable in the traditional interrupt mode of packet processing, resulting in higher packet processing performance.

8.14.2 CPU Affinity and Optimization

With DPDK, dedicated cores are assigned to process packets. This assignment procedure ensures consistent latency in packet processing and enables instruction sets such SSE, which helps with floating point calculations, to be available where needed.

8.14.3 Buffer Management

Buffer management is optimized to represent the packets being processed in simpler fashion with low footprint, assisting with faster memory allocation and processing. Buffer allocation is also Non-uniform memory access (NUMA) aware. NUMA awareness reduces traffic flows between the NUMA nodes, thus improving overall throughput.

Instead of requiring regular packet handlers for packets, Enhanced Datapath uses mbuf, a library to allocate and free buffers resulting in packet-related info with low overhead. As traditional packet handlers have heavy overhead for initialization, mbuf simplifies packet descriptors by decreasing the CPU overhead for packet initialization. To further support the mbuf-based packet, VMXNET3 has also been enhanced. In addition to the above DPDK enhancements, ESX TCP Stack has also been optimized with features such as Flow Cache.

8.14.4 Flow Cache

Flow Cache is an optimization enhancement which helps reduce CPU cycles spent on known flows. With the start of a new flow, Flow Cache tables are immediately populated. This procedure enables follow-up decisions for the rest of packets within a flow to be skipped if the flow already exists in the flow table. Flow Cache uses two mechanisms to figure out fast path decisions for packets in a flow:

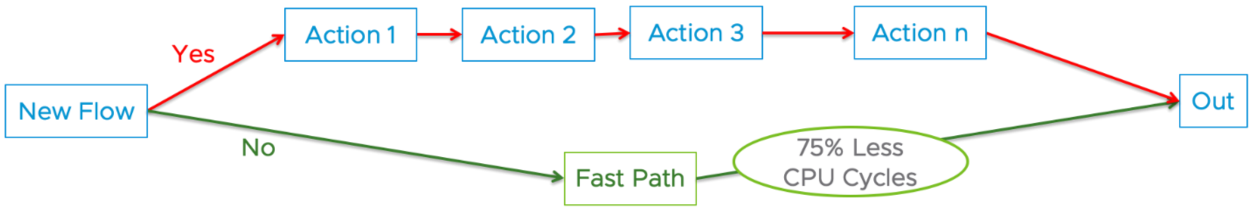
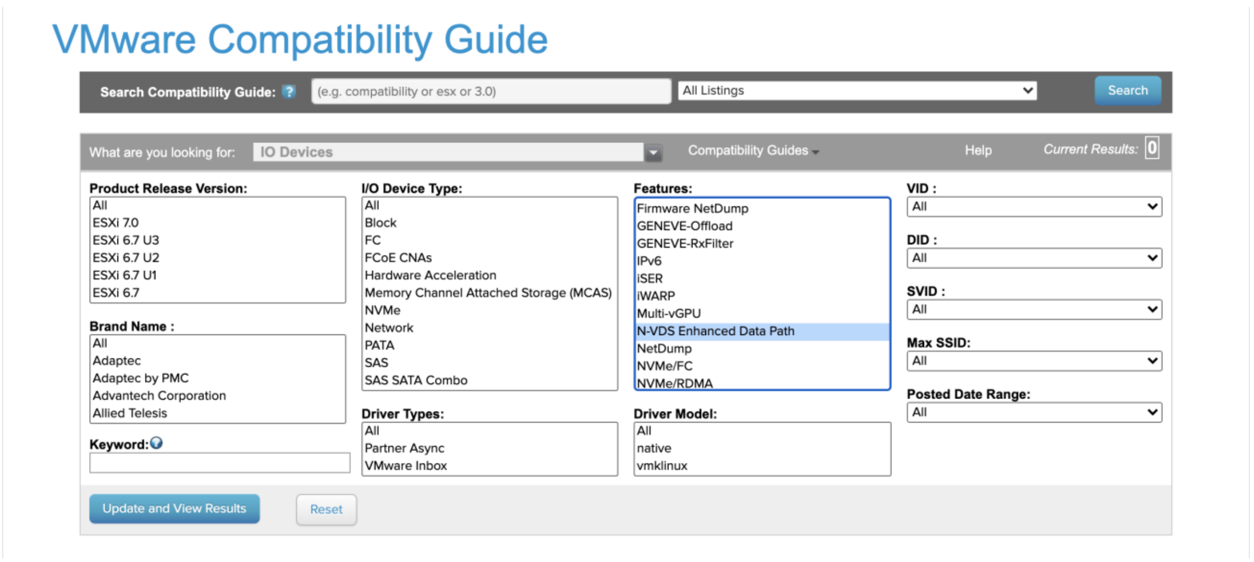


Figure 8-26: Flow Cache Pipeline

If the packets from the same flow arrive consecutively, the fast path decision for that packet is stored in memory and applied directly for the rest of the packets in that cluster of packets.
If packets are from different flows, the decision per flow is saved to a hash table and used to decide the next hop for packets in each of the flows. Flow Cache helps reduce CPU cycles by as much as 75%, a substantial improvement.

8.14.5 Checking whether a NIC is N-VDS Enhanced Data Path Capable

Use the VMware IO Compatibility Guide (VCG I/O) described in the previous sections to find out which cards are N-VDS (E) capable. The feature to look for is “N-VDS Enhanced Data Path” highlighted in blue in the following image:


VMware Compatibility Guide
Search Compatibility Guide:
(e.g. compatibility or esx or 3.0)
All Listings
Search
Compatibility Guides
Help
Update and View Results
Reset

What are you looking for: IO Devices

Current Results: 0

Product Release Version: All, ESXi 7.0, ESXi 6.7 U3, ESXi 6.7 U2, ESXi 6.7 U1, ESXi 6.7

I/O Device Type: All, Block, FC, FCoE CNAs, Hardware Acceleration, Memory Channel Attached Storage (MCAS), NVMe, Network, PATA, SAS, SAS SATA Combo

Features: Firmware NetDump, GENEVE-Offload, GENEVE-RxFilter, IPv6, iSER, iWARP, Multi-vGPU, N-VDS Enhanced Data Path, NetDump, NVMe/FC, NVMe/RDMA

VID : All

DID : All

SVID : All

Max SSID: All

Posted Date Range: All

Brand Name : All, Adaptec, Adaptec by PMC, Advantech Corporation, Allied Telesis

Keyword:

Driver Types: All, Partner Async, VMware Inbox

Driver Model: All, native, vmklinux

Figure 8-27: VMware Compatibility Guide for I/O - Selection Step for N-VDS Enhanced Data Path

==
Note: N-VDS Enhanced Data Path cannot share the pNIC with N-VDS - they both need a dedicated pNIC.
==

8.15 Benchmarking Tools

8.15.1 Compute

On the compute side, our recommendation for testing the software components is to use a benchmarking tool close to the application layer. Application layer benchmarking tools will help take advantage of many features and show the true performance characteristics of the system. While application benchmarking tools are ideal, they may not be very easy to setup and run. In such cases, iPerf is a great tool to quickly setup and check throughput. Netperf is another tool to help check both throughput and latency.

Here is a github resource for an example script to run iPerf on multiple VMs simultaneously and summarize results: https://github.com/vmware-samples/nsx-performance-testing-scripts

8.16 Edges

8.16.1 VM Edge

As VM Edges are designed for typical DC workloads, application layer tools are best for testing VM Edge performance.

8.16.2 Bare Metal Edge

With the Bare Metal Edges, either application layer benchmarking tools or typical network benchmarking and packet generation tools of choice, such as Keysight PathWave (formerly IXIA) or Spirent Network Emulator may be used. One of the challenges with using a hardware benchmarking tool is to find one which includes provision for Geneve encap/decap. Following is a topology with two bare metal edges, each within its own cluster. A segment, aptly called a crosslink segment, connects them both over overlay. PathWave sends and receives only non-overlay packets. However, the segment between the two Edge clusters forces the packets to use overlay. Check the image below for details.

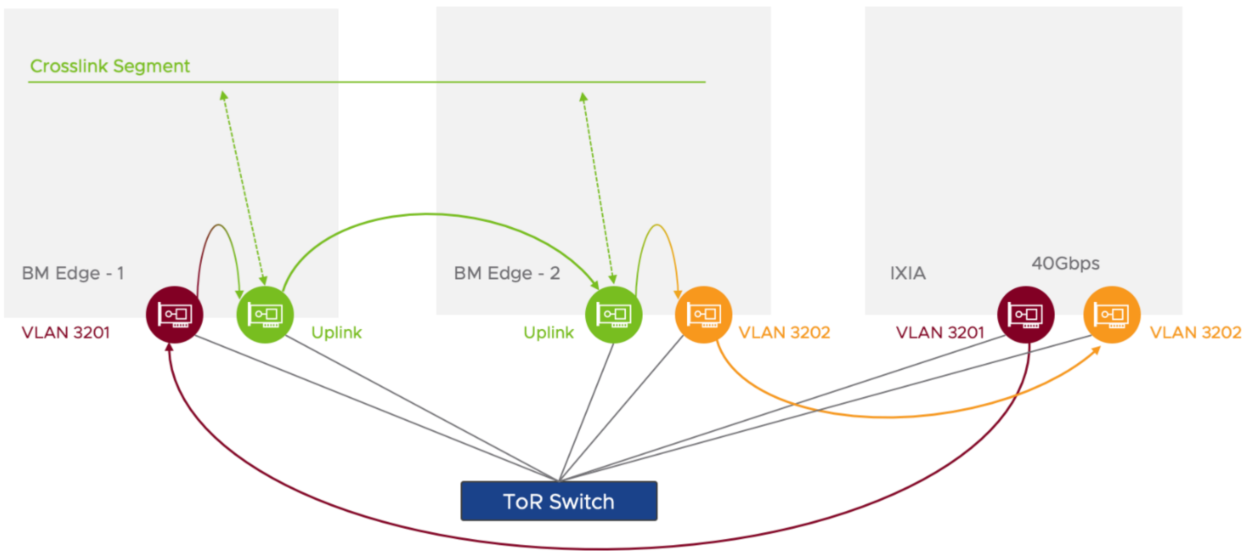


Figure 8-28: Example Topology to Use Geneve Overlay with Hardware IXIA or Spirent

An alternative approach is to use a software tool such as Pktgen (https://github.com/pktgen/Pktgen-DPDK).

8.17 Conclusion

To drive enhanced performance, NSX-T uses a number of features supported in hardware.

On the compute side, these are:

1. Geneve Offload for CPU cycle reduction and marginal performance benefits
2. Geneve Rx Filters, an intelligent queuing mechanism to multiply throughput
3. RSS an older hardware-based queuing mechanism – alternative if Rx Filters are missing
4. Jumbo MTU an age-old trick to enable high throughput on NICs lacking above features
5. NIC port speed
6. Number of NICs – single vs dual TEP
7. PCIe Gen 3 with x16 lane NICs or multiple PCIe Gen 3 x8 NICs
8. PCIe Gen 4

For compute workloads focused on high packet processing rate for primarily small packet sizes, Enhanced Data Path Enabled NICs provide a performance boost.

For the Edges, if its VM Edges, then:

1. NIC cards which support RSS and
2. Enabling RSS on both the pNIC and the Edge VM NIC (vNIC)

For the Bare Metal Edges, leveraging optimal SSL offload performance such as Intel® QAT 8960s and deploying supported hardware from the VMware NSX-T install guide will result in performance gains.

Appendix 1: External References

- Chapter 1
  - NSX-T Installation and Administration Guides – https://docs.vmware.com/en/VMware-NSX-T/index.html
  - NSX Reference Documentation – www.vmware.com/nsx
  - VMware Discussion Community – https://communities.vmware.com/community/vmtn/nsx
  - Network Virtualization Blog – https://blogs.vmware.com/networkvirtualization/
  - NSXCLOUD resources – https://cloud.vmware.com/nsx-cloud
- Chapter 3
  - https://docs.vmware.com/en/VMware-vCloud-NFV-OpenStack-Edition/3.1/vmware-vcloud-nfv-openstack-edition-ra31/GUID-177A9560-E650-4A99-8C20-887EEB723D09.html
  - https://docs.vmware.com/en/VMware-vCloud-NFV-OpenStack-Edition/3.1/vmware-vcloud-nfv-openstack-edition-ra31/GUID-9E12F2CD-531E-4A15-AFF7-512D5DB9BBE5.html
  - https://docs.vmware.com/en/VMware-vCloud-NFV-OpenStack-Edition/3.0/vmwa-vcloud-nfv30-performance-tunning/GUID-0625AE2F-8AE0-4EBC-9AC6-2E0AD222EA2B.html
  - https://www.virtuallyghetto.com/2018/04/native-mac-learning-in-vsphere-6-7-removes-the-need-for-promiscuous-mode-for-nested-esxi.html
- Chapter 4
  - https://kb.vmware.com/s/article/1003806#vgtPoints
  - https://www.vmware.com/pdf/esx3_VLAN_wp.pdf
  - NSX-T Hardware Requirements – https://docs.vmware.com/en/VMware-NSX-T/2.0/com.vmware.nsxt.install.doc/GUID-14183A62-8E8D-43CC-92E0-E8D72E198D5A.html
- Chapter 6
  - More NSX-T LB information can be found in our NSX-T LB https://communities.vmware.com/docs/DOC-40434
- Chapter 7
  - VMware Compatibility Guide - https://www.vmware.com/resources/compatibility/search.php?deviceCategory=io&productid=43696&deviceCategory=io&details=1&keyword=25G&pFeatures=266&page=8&display_interval=10&sortColumn=Partner&sortOrder=Asc&b=1508767551363
  - NSX Edge Bare Metal Requirements - https://docs.vmware.com/en/VMware-NSX-T-Data-Center/2.5/installation/GUID-14C3F618-AB8D-427E-AC88-F05D1A04DE40.html
  - VM-to-VM Anti-affinity Rules – https://docs.vmware.com/en/VMware-vSphere/6.5/com.vmware.vsphere.resmgmt.doc/GUID-7297C302-378F-4AF2-9BD6-6EDB1E0A850A.html

- VM-to-host Anti-affinity Rules – https://docs.vmware.com/en/VMware-vSphere/6.5/com.vmware.vsphere.resmgmt.doc/GUID-0591F865-91B5-4311-ABA6-84FBA5AAFB59.html

Appendix 2: NSX-T API/JSON examples

This appendix gives the actual API & JSON request body for the two examples describe in section 2.3.4 and 2.3.5.

API Usage Example 1- Templatize and deploy 3-Tier Application Topology – API & JSON

API Usage Example 2- Application Security Policy Lifecycle Management - API & JSON

API Usage Example 1- Templatize and deploy 3-Tier Application Topology – API & JSON

The following API & JSON body given an example for deploying 3-Tier Application with Network isolation for each of the Tier, Micro-segmentation White-list policy for each of the workload & Gateway services Load Balancer, NAT & Gateway Firewall.
This API and JSON body do following configuration:
Networking:

1. Create Tier-1 Router and attach to Tier-0
2. Create 3 Segments and attach to Tier-1 Gateway
3. Add NAT Stateful Service

Security:

1. Create Groups App Tier
2. Create Intra-app DFW policy
3. Create Gateway Firewall for Tier-1 GW

Load Balancer:

1. Create LB configuration - Profile, VIP, Pool, Certificates

You can leverage same API & JSON with by toggling "marked_for_delete" flag to true or false to manage life cycle management of entire application topology.

```
curl -X PATCH \
  https://10.114.223.4/policy/api/v1/infra/ \
  -H 'authorization: Basic YWRtaW46Vk13YXJlIW1ncjE5OTg=' \
  -H 'cache-control: no-cache' \
  -H 'content-type: application/json' \
  -H 'postman-token: 140fb7c6-f96c-d23d-ddc6-7bd6288d3e90' \
  -d '{
  "resource_type": "Infra",
  "children": [
    {
      "resource_type": "ChildTier1",
      "marked_for_delete": false,
      "Tier1": {
        "resource_type": "Tier1",
        "id": "DEV-tier-1-gw",
        "description": "DEV-tier-1-gw",
        "display_name": "DEV-tier-1-gw",
        "failover_mode": "NON_PREEMPTIVE",
        "tier0_path":"/infra/tier-0s/DC-01-ENVT-01-TIER-0-GW",
        "route_advertisement_types": [
          "TIER1_CONNECTED",
          "TIER1_STATIC_ROUTES"
        ],
        "children": [
          {
           "resource_type":"ChildLocaleServices",

           "LocaleServices":{

               "resource_type":"LocaleServices",
               "id":  "default",
                "edge_cluster_path": "/infra/sites/default/enforcement-points/default/edge-
clusters/e6d88327-640b-4d33-b0b5-578b1311e7b0"
                }
        },
          {
            "resource_type": "ChildSegment",
            "Segment": {
              "resource_type": "Segment",
              "id": "DEV-RED-web-segment",
              "description": "DEV-RED-web-segment",
              "display_name": "DEV-RED-web-segment",
              "transport_zone_path": "/infra/sites/default/enforcement-points/default/transport-
zones/3a60b876-b912-400d-91b2-bdb0ef602fa0",
              "subnets": [
                {
                  "gateway_address": "10.10.1.1/24"
                }
              ]
            }
          },
          {
            "resource_type": "ChildSegment",
            "Segment": {
              "resource_type": "Segment",
              "id": "DEV-RED-app-segment",
              "description": "DEV-RED-app-segment",
              "display_name": "DEV-RED-app-segment",
            "transport_zone_path": "/infra/sites/default/enforcement-points/default/transport-
zones/3a60b876-b912-400d-91b2-bdb0ef602fa0",
            "subnets": [
              {
                "gateway_address": "10.20.2.1/24"
              }
            ]
          }
        },
        {
          "resource_type": "ChildSegment",
          "Segment": {
            "resource_type": "Segment",
            "id": "DEV-RED-db-segment",
            "description": "DEV-RED-db-segment",
            "display_name": "DEV-RED-db-segment",
            "transport_zone_path": "/infra/sites/default/enforcement-points/default/transport-
zones/3a60b876-b912-400d-91b2-bdb0ef602fa0",
            "subnets": [
              {
                "gateway_address": "10.20.3.1/24"
              }
            ]
          }
        },
        {
           "resource_type": "ChildPolicyNat",
           "PolicyNat": {
           "id": "USER",
           "resource_type": "PolicyNat",
           "children": [
              {
                "resource_type": "ChildPolicyNatRule",
                "PolicyNatRule": {
                   "resource_type": "PolicyNatRule",
                   "id": "DEV-RED-nat-rule-1",
                   "action": "SNAT",
                   "source_network": "10.10.0.0/23",
                   "service": "",
                   "translated_network": "30.30.30.20",
                   "scope": [],
                   "enabled": true,
                   "firewall_match": "BYPASS",
                   "display_name": "DEV-RED-nat-rule-1",
                   "parent_path": "/infra/tier-1s/DEV-tier-1-gw/nat/USER"
                }
          }
        ]
      }
    }
  ]
 }
},
{
  "resource_type": "ChildDomain",
  "marked_for_delete": false,
  "Domain": {
    "id": "default",
    "resource_type": "Domain",
    "description": "default",
    "display_name": "default",
    "marked_for_delete": false,
    "children": [
      {
        "resource_type": "ChildGroup",
        "Group": {
          "resource_type": "Group",
          "marked_for_delete": false,
          "description": "DEV-RED-web-vms",
          "display_name": "DEV-RED-web-vms",
          "id": "DEV-RED-web-vms",
          "expression": [
            {
              "member_type": "VirtualMachine",
              "value": "DEVREDwebvm",
              "key": "Tag",
              "operator": "EQUALS",
              "resource_type": "Condition"
            }
          ]
        }
      },
      {
        "resource_type": "ChildGroup",
        "Group": {
          "resource_type": "Group",
          "marked_for_delete": false,
          "description": "DEV-RED-app-vms",
          "display_name": "DEV-RED-app-vms",
          "id": "DEV-RED-app-vms",
          "expression": [
            {
```

```
        "member_type": "VirtualMachine",
        "value": "DEVREDappvm",
        "key": "Tag",
        "operator": "EQUALS",
        "resource_type": "Condition"
      }
    ]
  }
},
{
  "resource_type": "ChildGroup",
  "Group": {
    "resource_type": "Group",
    "description": "DEV-RED-db-vms",
    "display_name": "DEV-RED-db-vms",
    "id": "DEV-RED-db-vms",
    "expression": [
      {
        "member_type": "VirtualMachine",
        "value": "DEVREDdbvm",
        "key": "Tag",
        "operator": "EQUALS",
        "resource_type": "Condition"
      }
    ]
  }
},
{
  "resource_type": "ChildSecurityPolicy",
  "marked_for_delete": false,
  "SecurityPolicy": {
    "id": "DEV-RED-intra-app-policy",
    "resource_type": "SecurityPolicy",
    "description": "communication map",
    "display_name": "DEV-RED-intra-app-policy",
    "rules": [
      {
        "resource_type": "Rule",
        "description": "Communication Entry",
        "display_name": "any-to-DEV-RED-web",
        "sequence_number": 1,
        "source_groups": [
          "ANY"
        ],
        "destination_groups": [
          "/infra/domains/default/groups/DEV-RED-web-vms"
        ],
        "services": [
          "/infra/services/HTTPS"
        ],
        "action": "ALLOW"
      },
      {
        "resource_type": "Rule",
        "description": "Communication Entry 2",
        "display_name": "DEV-RED-web-to-app",
        "sequence_number": 2,
        "source_groups": [
          "/infra/domains/default/groups/DEV-RED-web-vms"
        ],
        "destination_groups": [
          "/infra/domains/default/groups/DEV-RED-app-vms"
        ],
        "services": [
          "/infra/services/HTTP"
        ],
        "action": "ALLOW"
      },
      {
        "resource_type": "Rule",
        "description": "Communication Entry 3",
        "display_name": "DEV-RED-app-to-db",
        "sequence_number": 2,
        "source_groups": [
          "/infra/domains/default/groups/DEV-RED-app-vms"
        ],
        "destination_groups": [
          "/infra/domains/default/groups/DEV-RED-db-vms"
        ],
        "services": [
          "/infra/services/MySQL"
        ],
        "action": "ALLOW"
      }
    ]
  }
},
{
  "resource_type": "ChildGatewayPolicy",
  "marked_for_delete": false,
  "GatewayPolicy": {
    "resource_type": "GatewayPolicy",
"id": "DEV-RED-section",
"display_name": "DEV-RED-section",
"parent_path": "/infra/domains/default",
"marked_for_delete": false,
"rules": [
 {
  "source_groups": [
       "ANY"
    ],
    "destination_groups": [
       "/infra/domains/default/groups/DEV-RED-web-vms"
    ],
    "services": [
       "/infra/services/HTTPS"
    ],
    "profiles": [
       "ANY"
    ],
    "action": "ALLOW",
    "logged": false,
    "scope": [
       "/infra/tier-1s/DEV-tier-1-gw"
    ],
    "disabled": false,
    "notes": "",
    "direction": "IN_OUT",
    "tag": "",
    "ip_protocol": "IPV4_IPV6",
    "resource_type": "Rule",
    "id": "Any-to-web",
    "display_name": "Any-to-web"
 },
           {
  "source_groups": [
       "ANY"
    ],
    "destination_groups": [
       "/infra/domains/default/groups/DEV-RED-web-vms",
       "/infra/domains/default/groups/DEV-RED-app-vms",
       "/infra/domains/default/groups/DEV-RED-db-vms"
    ],
    "services": [
       "ANY"
    ],
    "profiles": [
       "ANY"
```

```
                ],
                "action": "DROP",
                "logged": false,
                "scope": [
                  "/infra/tier-1s/DEV-tier-1-gw"
                ],
                "disabled": false,
                "notes": "",
                "direction": "IN_OUT",
                "tag": "",
                "ip_protocol": "IPV4_IPV6",
                "resource_type": "Rule",
                "id": "DenyAny",
                "display_name": "DenyAny"
              }
            ]
          }
        }
      ]
    }
  },
  {
    "resource_type": "ChildLBClientSslProfile",
    "marked_for_delete": false,
    "LBClientSslProfile": {
      "resource_type": "LBClientSslProfile",
      "id": "batchSetupClientSslProfile",
      "cipher_group_label": "CUSTOM",
      "session_cache_enabled": true,
      "ciphers": [
        "TLS_ECDHE_RSA_WITH_AES_128_GCM_SHA256",
        "TLS_ECDHE_RSA_WITH_AES_256_GCM_SHA384"
      ],
      "protocols": [
        "TLS_V1_2"
      ]
    }
  },
  {
    "resource_type": "ChildLBServerSslProfile",
    "marked_for_delete": false,
    "LBServerSslProfile": {
      "resource_type": "LBServerSslProfile",
      "id": "batchSetupServerSslProfile",
      "cipher_group_label": "CUSTOM",
      "session_cache_enabled": true,
      "ciphers": [
        "TLS_ECDHE_RSA_WITH_AES_128_GCM_SHA256",
        "TLS_ECDHE_RSA_WITH_AES_256_GCM_SHA384"
      ],
      "protocols": [
        "TLS_V1_2"
      ]
    }
  },
  {
    "resource_type": "ChildLBAppProfile",
    "marked_for_delete": false,
    "LBAppProfile": {
      "resource_type": "LBHttpProfile",
      "id": "batchSetupHttpAppProfile",
      "x_forwarded_for": "INSERT"
    }
  },
  {
    "resource_type": "ChildLBMonitorProfile",
    "marked_for_delete": false,
    "LBMonitorProfile": {
      "resource_type": "LBHttpMonitorProfile",
      "marked_for_delete": false,
      "id": "batchSetupHttpMonitor1",
      "monitor_port": 80,
      "timeout": 5,
      "response_status_codes": [
        200,
        300
      ]
    }
  },
  {
    "resource_type": "ChildLBMonitorProfile",
    "marked_for_delete": false,
    "LBMonitorProfile": {
      "resource_type": "LBHttpsMonitorProfile",
      "id": "batchSetupHttpsMonitor1",
      "monitor_port": 443,
      "timeout": 5,
      "response_status_codes": [
        200
      ]
    }
  },
{
  "resource_type": "ChildLBService",
  "marked_for_delete": false,
  "LBService": {
    "resource_type": "LBService",
    "id": "DEV-RED-LbService",
    "connectivity_path": "/infra/tier-1s/DEV-tier-1-gw",
    "error_log_level": "DEBUG",
    "access_log_enabled": true
  }
},
{
  "resource_type": "ChildLBVirtualServer",
  "marked_for_delete": false,
  "LBVirtualServer": {
    "resource_type": "LBVirtualServer",
    "id": "DEV-RED-VirtualServer1",
    "lb_service_path": "/infra/lb-services/DEV-RED-LbService",
    "ip_address": "30.10.200.1",
    "ports": [
      "443"
    ],
    "pool_path": "/infra/lb-pools/DEV-RED-web-Pool",
    "application_profile_path": "/infra/lb-app-profiles/batchSetupHttpAppProfile",
    "client_ssl_profile_binding": {
      "ssl_profile_path": "/infra/lb-client-ssl-profiles/batchSetupClientSslProfile",
      "default_certificate_path": "/infra/certificates/batchSslSignedCertDEV-RED",
      "client_auth_ca_paths": [
        "/infra/certificates/batchSslCACertDEV-RED"
      ],
      "certificate_chain_depth": 2
    },
    "server_ssl_profile_binding": {
      "ssl_profile_path": "/infra/lb-server-ssl-profiles/batchSetupServerSslProfile",
      "server_auth": "IGNORE",
      "client_certificate_path": "/infra/certificates/batchSslSignedCertDEV-RED",
      "server_auth_ca_paths": [
        "/infra/certificates/batchSslCACertDEV-RED"
      ],
      "certificate_chain_depth": 2
    }
  }
},
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        "marked_for_delete": false,
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        ],
            "algorithm": "ROUND_ROBIN",
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                "ip_revision_filter": "IPV4"
            },
            "snat_translation": {
                "type": "LBSnatDisabled"
            }
      }
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        ],
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        "application_profile_path": "/infra/lb-app-profiles/batchSetupHttpAppProfile"
      }
    },
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        "marked_for_delete": false,
        "active_monitor_paths": [
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        ],
            "algorithm": "ROUND_ROBIN",
            "member_group": {
                "group_path": "/infra/domains/default/groups/DEV-RED-app-vms",
                "ip_revision_filter": "IPV4"
            },
            "snat_translation": {
                "type": "LBSnatDisabled"
            }
        }
      },
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          "marked_for_delete": false,
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P8A==\n-----END CERTIFICATE-----\n"
        }
      },
      {
        "resource_type": "ChildTlsTrustData",
        "marked_for_delete": false,
        "TlsTrustData": {
```

```
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        "marked_for_delete": false,
        "id": "batchSslSignedCertDEV-RED",
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E1cjaLrKBa9ETMSmpXenEQdQvT2vmj69fafvXbBA+2nZPO/6Hmhgnbni+qglM\n0h7BUpf/N
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```

```
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        "private_key": "-----BEGIN RSA PRIVATE KEY-----
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Q2HmEKxuVoK/1tSIiQi4MGI2fbOHeFSZGj+COT3iVKgb\nqmUgs4zwFjVGjm5KrK5FKslfN
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0GUY3sUWVfXFx46qpE7nUR14BJZ7fR9D7TXqlRfb\nwbB3I2an/ozwaLjNnzZ9JjSW4Dmdo
JDKk7XCFMl5BoYNHNu/2rahqt9sJHuKN9BJ\n2kEJEvmxJToYednC33nCZOI9ffxDBhZKN1
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IcNS9uik4eoRmskwW1gjKBywRCUQeGOfsU8pVSZkVmRI6/qcdbua\nR9x37NZ78YEYGFV
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pr6IA2cwGABvhG7zh5adE5Bx8eeNk8QO2\nGaA2eQKBgQDnpBPL0OtVcva1gOIeS41Kaa78
/VxN64fKCdkJNfwr9NUz51u6RMrh\nc2zWaTp3QG062zhdSuUATVJ9kK/NgVT9Afmb21H7
6xE9KY3fztb1SqRCZGMjHeEr\n563mDimPiOPUATWXyZS5/HQSLIRLjJ9+mfBFVFEgFNG
K55pOmyMTaQ==\n-----END RSA PRIVATE KEY-----\n",
        "key_algo": "RSA"
      }
    }
  ]
}'
```

Back to Appendix 2.

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 \
  https://10.114.223.4/policy/api/v1/infra/ \
  -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",
                  "key": "Tag",
                  "operator": "EQUALS",
                  "resource_type": "Condition"
                }
              ]
            }
          },
          {
            "resource_type": "ChildGroup",
            "marked_for_delete": false,
            "Group": {
              "resource_type": "Group",
              "description": "DEV-RED-app-vms",
              "display_name": "DEV-RED-app-vms",
    "id": "DEV-RED-app-vms",
    "expression": [
     {
      "member_type": "VirtualMachine",
      "value": "DEVREDappvm",
      "key": "Tag",
      "operator": "EQUALS",
      "resource_type": "Condition"
     }
    ]
   }
  },
  {
   "resource_type": "ChildGroup",
   "marked_for_delete": false,
   "Group": {
    "resource_type": "Group",
    "description": "DEV-RED-db-vms",
    "display_name": "DEV-RED-db-vms",
    "id": "DEV-RED-db-vms",
    "expression": [
     {
      "member_type": "VirtualMachine",
      "value": "DEVREDdbvm",
      "key": "Tag",
      "operator": "EQUALS",
      "resource_type": "Condition"
     }
    ]
   }
  },
  {
   "resource_type": "ChildSecurityPolicy",
   "marked_for_delete": false,
   "SecurityPolicy": {
    "id": "DEV-RED-intra-tier-1",
    "resource_type": "SecurityPolicy",
    "description": "communication map",
    "display_name": "DEV-RED-intra-tier-1",
    "category": "Environment",
    "rules": [
     {
      "resource_type": "Rule",
      "description": "Communication Entry",
      "display_name": "DEV-RED-web-to-DEV-RED-web",
      "sequence_number": 1,
      "source_groups": [
       "/infra/domains/default/groups/DEV-RED-web-vms"
      ],
      "destination_groups": [
       "/infra/domains/default/groups/DEV-RED-web-vms"
      ],
      "services": [
          "Any"
        ],
        "action": "ALLOW",
        "scope": [
          "/infra/domains/default/groups/DEV-RED-web-vms"
        ]
      },
      {
        "resource_type": "Rule",
        "description": "Communication Entry 2",
        "display_name": "DEV-RED-intra-tier-2",
        "sequence_number": 2,
        "source_groups": [
          "/infra/domains/default/groups/DEV-RED-app-vms"
        ],
        "destination_groups": [
          "/infra/domains/default/groups/DEV-RED-app-vms"
        ],
        "services": [
          "ANY"
        ],
        "action": "ALLOW",
        "scope": [
          "/infra/domains/default/groups/DEV-RED-app-vms"
        ]
      },
      {
        "resource_type": "Rule",
        "description": "Communication Entry 3",
        "display_name": "DEV-RED-intra-tier-3",
        "sequence_number": 3,
        "source_groups": [
          "/infra/domains/default/groups/DEV-RED-db-vms"
        ],
        "destination_groups": [
          "/infra/domains/default/groups/DEV-RED-db-vms"
        ],
        "services": [
          "Any"
        ],
        "action": "ALLOW",
        "scope": [
          "/infra/domains/default/groups/DEV-RED-db-vms"
        ]
      }
    ]
  }
},
        {
  "resource_type": "ChildSecurityPolicy",
  "marked_for_delete": false,
  "SecurityPolicy": {
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"resource_type": "SecurityPolicy",
"description": "communication map",
"display_name": "DEV-RED-intra-app-policy",
"category": "Application",
"rules": [
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    "description": "Communication Entry",
    "display_name": "any-to-DEV-RED-web",
    "sequence_number": 1,
    "source_groups": [
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    ],
    "destination_groups": [
      "/infra/domains/default/groups/DEV-RED-web-vms"
    ],
    "services": [
      "/infra/services/HTTPS"
    ],
    "action": "ALLOW",
    "scope": [
      "/infra/domains/default/groups/DEV-RED-web-vms"
    ]
  },
  {
    "resource_type": "Rule",
    "description": "Communication Entry 2",
    "display_name": "DEV-RED-web-to-app",
    "sequence_number": 2,
    "source_groups": [
      "/infra/domains/default/groups/DEV-RED-web-vms"
    ],
    "destination_groups": [
      "/infra/domains/default/groups/DEV-RED-app-vms"
    ],
    "services": [
      "/infra/services/HTTP"
    ],
    "action": "ALLOW",
    "scope": [
      "/infra/domains/default/groups/DEV-RED-web-vms",
      "/infra/domains/default/groups/DEV-RED-app-vms"
    ]
  },
  {
    "resource_type": "Rule",
    "description": "Communication Entry 3",
    "display_name": "DEV-RED-app-to-db",
    "sequence_number": 3,
    "source_groups": [
      "/infra/domains/default/groups/DEV-RED-app-vms"
    ],
    "destination_groups": [
              "/infra/domains/default/groups/DEV-RED-db-vms"
            ],
            "services": [
              "/infra/services/MySQL"
            ],
            "action": "ALLOW",
            "scope": [
              "/infra/domains/default/groups/DEV-RED-db-vms",
              "/infra/domains/default/groups/DEV-RED-app-vms"
            ]
          },
          {
            "resource_type": "Rule",
            "description": "Communication Entry 4",
            "display_name": "DEV-RED-deny-any",
            "sequence_number": 4,
            "source_groups": [
              "ANY"
            ],
            "destination_groups": [
              "ANY"
            ],
            "services": [
              "ANY"
            ],
            "action": "DROP",
            "scope": [
              "/infra/domains/default/groups/DEV-RED-db-vms",
              "/infra/domains/default/groups/DEV-RED-app-vms",
              "/infra/domains/default/groups/DEV-RED-web-vms"
            ]
          }
        ]
      }
    }
   ]
  }
 }
 ]
}'
```

Back to Appendix 2.

Appendix 3: NSX-T Failure Domain API Example

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.

1. Create Failure domains.
   POST https://<nsx-mgr>/api/v1/failure-domains/
   Copy the following JSON code into the body of the API call.
   ```
   {
      "display_name": "FD-1"
   }
   ```

2. Add Edge nodes to their failure domains. Change the "failure_domain_id" from system generated default to newly created failure domain using PUT API.

   a. Retrieve the UUID of the Edge node.
      GET https://<nsx-mgr>/ api/v1/transport-nodes/<UUID of Edge node>

   b. Add an Edge node to the failure domain created.
      PUT https://<nsx-mgr>/api/v1/ transport-nodes /<UUID of Edge node>
      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
      }
      ```

3. Enable "Allocation based on Failure Domain" on the Edge cluster level
   a. Retrieve the Edge Cluster configuration by using the following GET API.
      GET https://<nsx-mgr>/api/v1/edge-clusters/
      Copy the output of the body.

   b. Enable the feature on Edge cluster level.
      Modify the following json code into the body of the API call.
      PUT https://<nsx-mgr>/api/v1/edge-clusters/
      ```
      "allocation_rules": [FD1],
      ```

   c. Validate by creating a Tier-1 Gateway

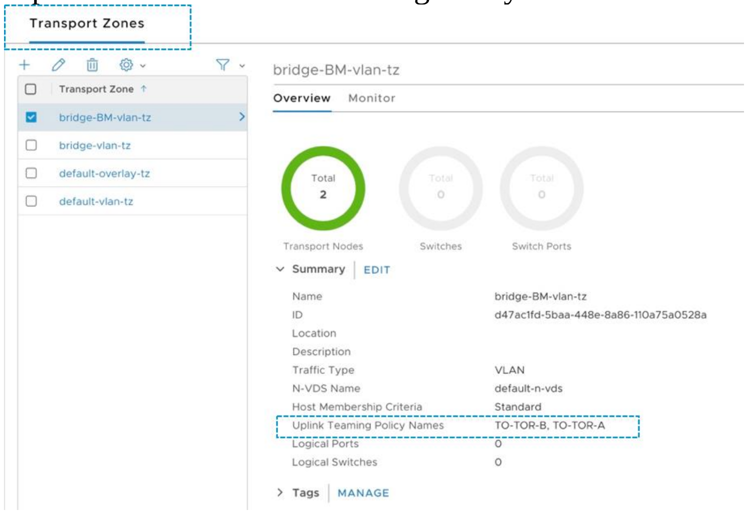
A user can also enforce that all active Tier-1 SRs are placed in one failure domain. This configuration is supported for Tier-1 gateway in preemptive mode only.

```
Set preference for a failure domain using “preferred_active_edge_services”
PUT https://<nsx-mgr>/api/v1/failure-domains/
{
   "preferred_active_edge_services ": true
}
```

Appendix 4: Bridge Traffic Optimization to Uplinks Using Teaming Policy

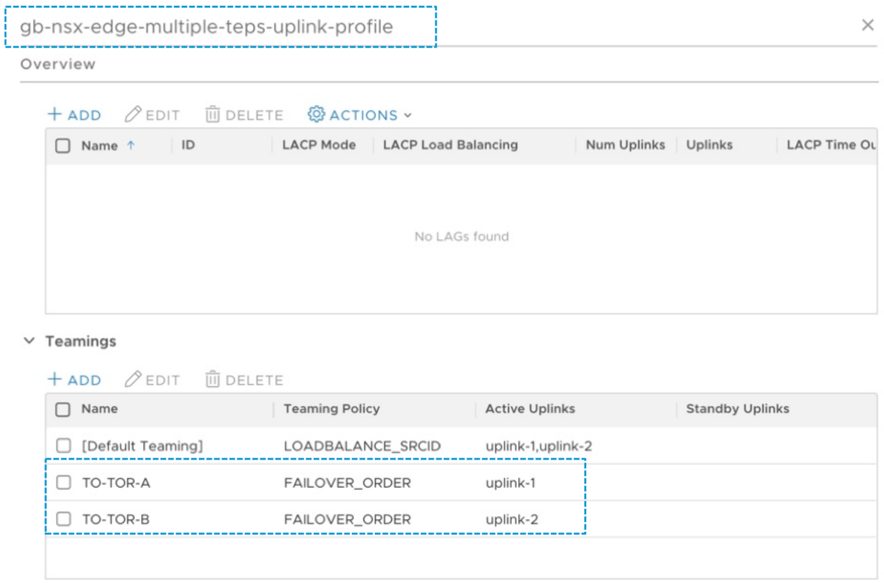
By default, bridge will use the first uplink in N-VDS config. In order to distribute bridge traffic over multiple uplinks user need to map named pinning policy to BridgeEndpoint (VLAN/Segment), with following steps.

Step1: Define Transport Zone with Named Pinning Policy.



Name	bridge-BM-vlan-tz
ID	d47ac1fd-5baa-448e-8a86-110a75a0528a
Location	
Description	
Traffic Type	VLAN
N-VDS Name	default-n-vds
Host Membership Criteria	Standard
Uplink Teaming Policy Names	TO-TOR-B, TO-TOR-A
Logical Ports	0
Logical Switches	0

Step2: Define 2 Named teaming Policy in the Edge Uplink Profile, to direct traffic to each of the uplinks.



Name	ID	LACP Mode	LACP Load Balancing	Num Uplinks	Uplinks	LACP Time Ou

No LAGs found

Name	Teaming Policy	Active Uplinks	Standby Uplinks
[Default Teaming]	LOADBALANCE_SRCID	uplink-1,uplink-2	
TO-TOR-A	FAILOVER_ORDER	uplink-1	
TO-TOR-B	FAILOVER_ORDER	uplink-2	

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/<ID> with parameter "uplink_teaming_policy_name":"<name of the teaming policy from 1 & 2>"

Please refer https://code.vmware.com/apis/547/nsx-t

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
}
```

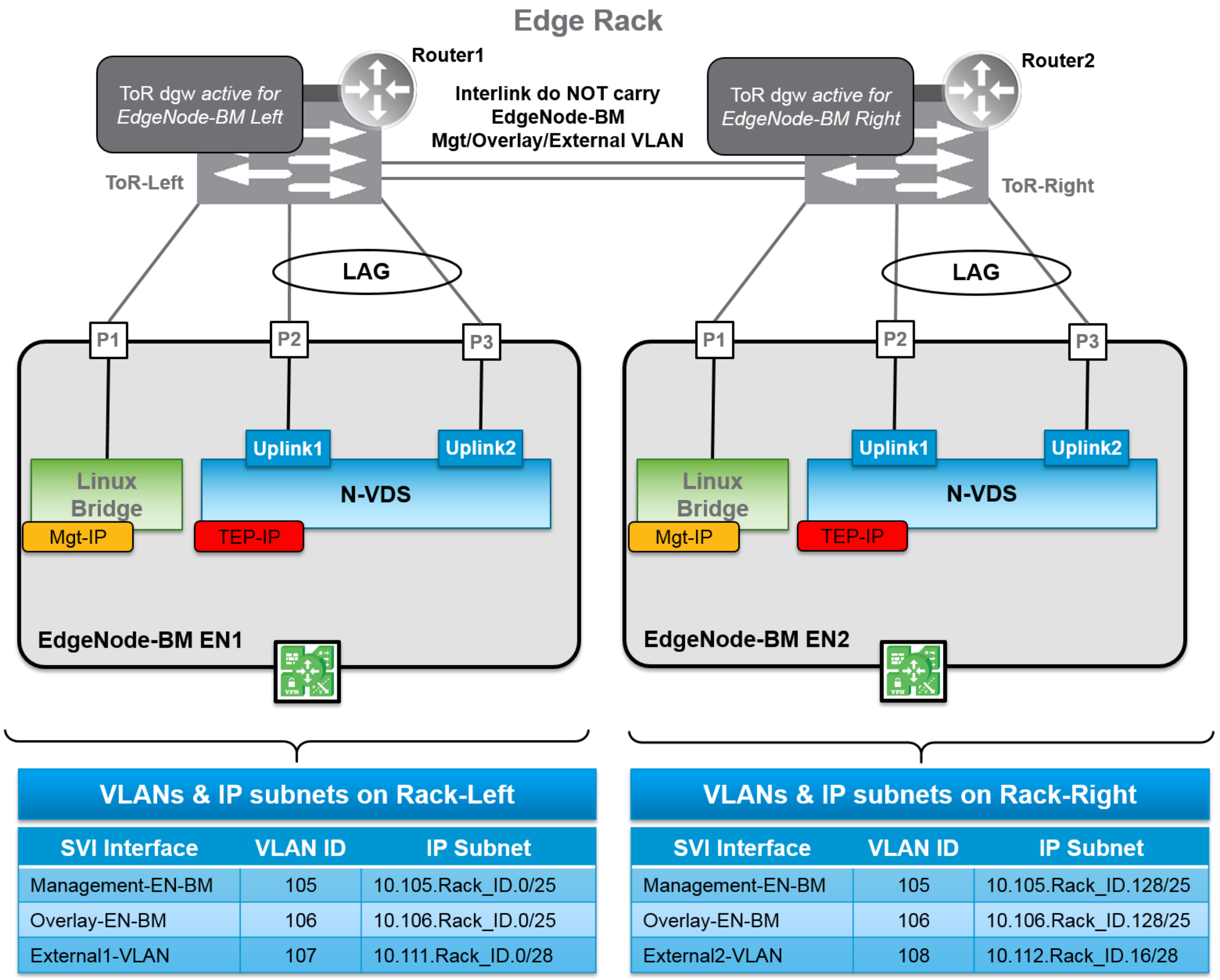
Appendix 5: The Design Recommendation with Edge Node before NSX-T Release 2.5

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.



VLANs & IP subnets on Rack-Left

SVI Interface	VLAN ID	IP Subnet
Management-EN-BM	105	10.105.Rack_ID.0/25
Overlay-EN-BM	106	10.106.Rack_ID.0/25
External1-VLAN	107	10.111.Rack_ID.0/28

VLANs & IP subnets on Rack-Right

SVI Interface	VLAN ID	IP Subnet
Management-EN-BM	105	10.105.Rack_ID.128/25
Overlay-EN-BM	106	10.106.Rack_ID.128/25
External2-VLAN	108	10.112.Rack_ID.16/28

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.

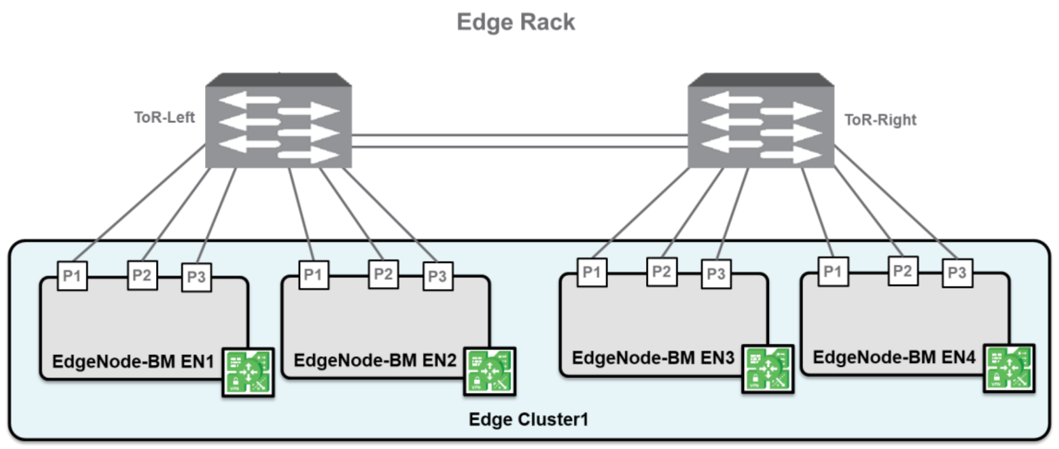


Figure A5-2: One Edge Cluster with 4 Edge Nodes

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.

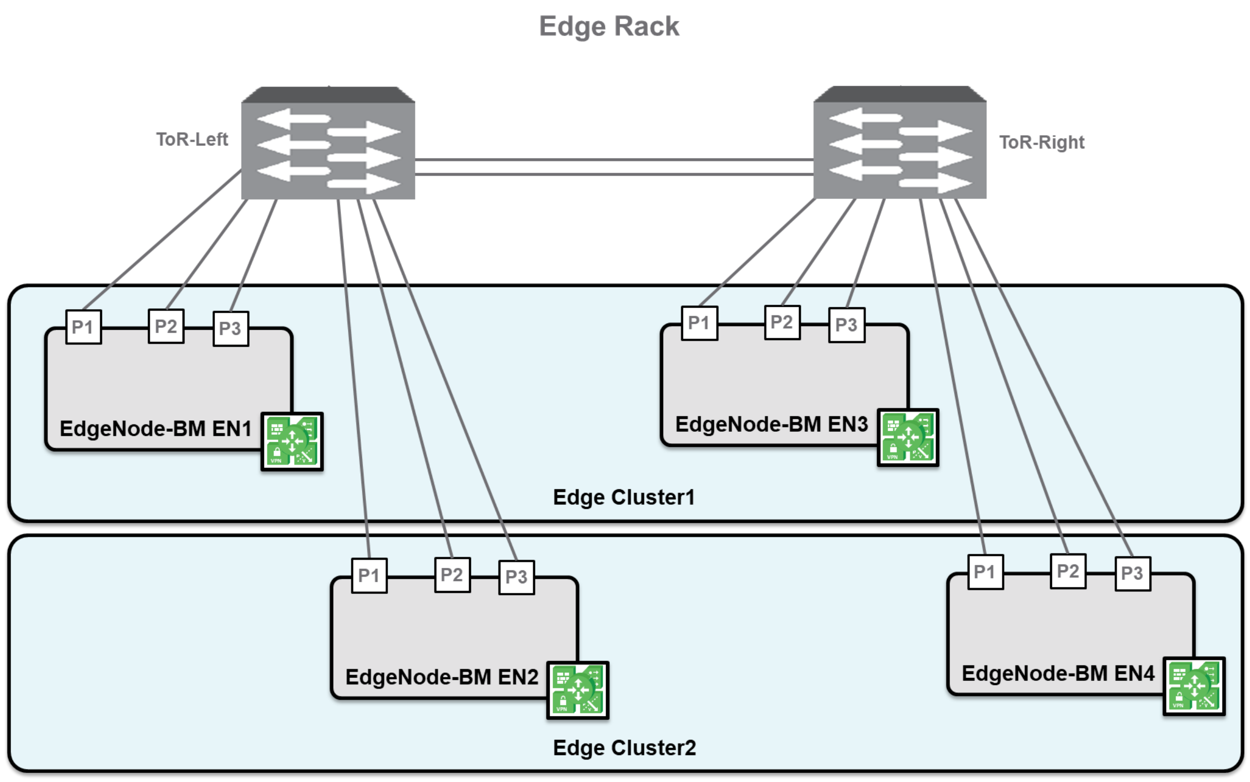


Figure A5-3: Two Edge Clusters with 2 Edge Nodes Each

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.

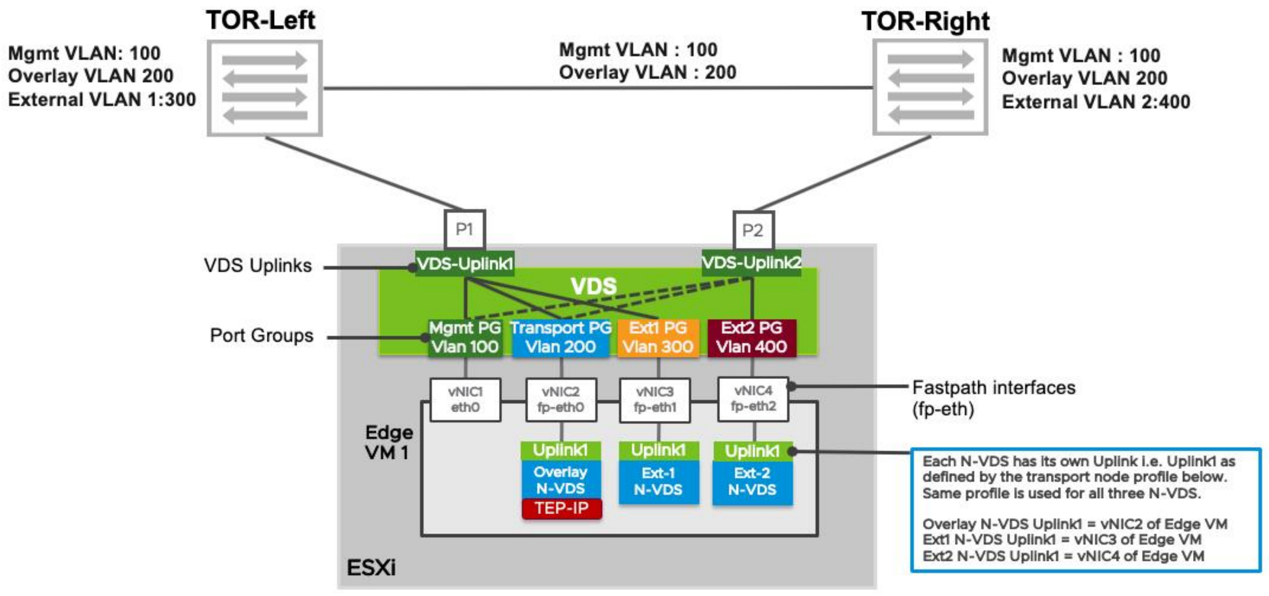


Figure A5-4: Edge Node VM installed leveraging VDS port groups on a 2 pNIC host

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.

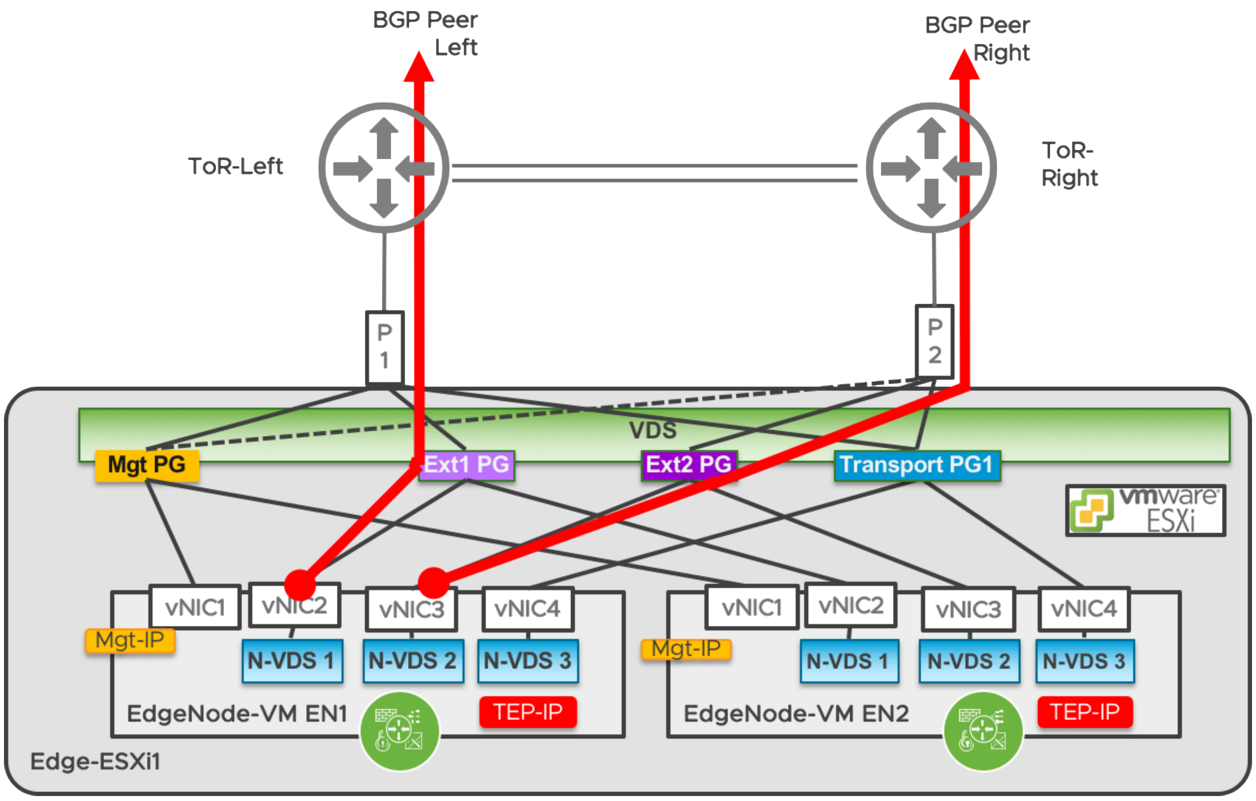
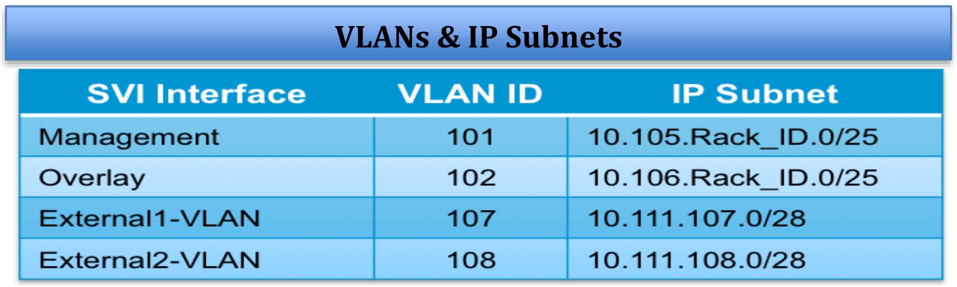


Figure A5-6: 2 pNIC Host with two Edge Node VM



VLANs & IP Subnets

SVI Interface	VLAN ID	IP Subnet
Management	101	10.105.Rack_ID.0/25
Overlay	102	10.106.Rack_ID.0/25
External1-VLAN	107	10.111.107.0/28
External2-VLAN	108	10.111.108.0/28

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.

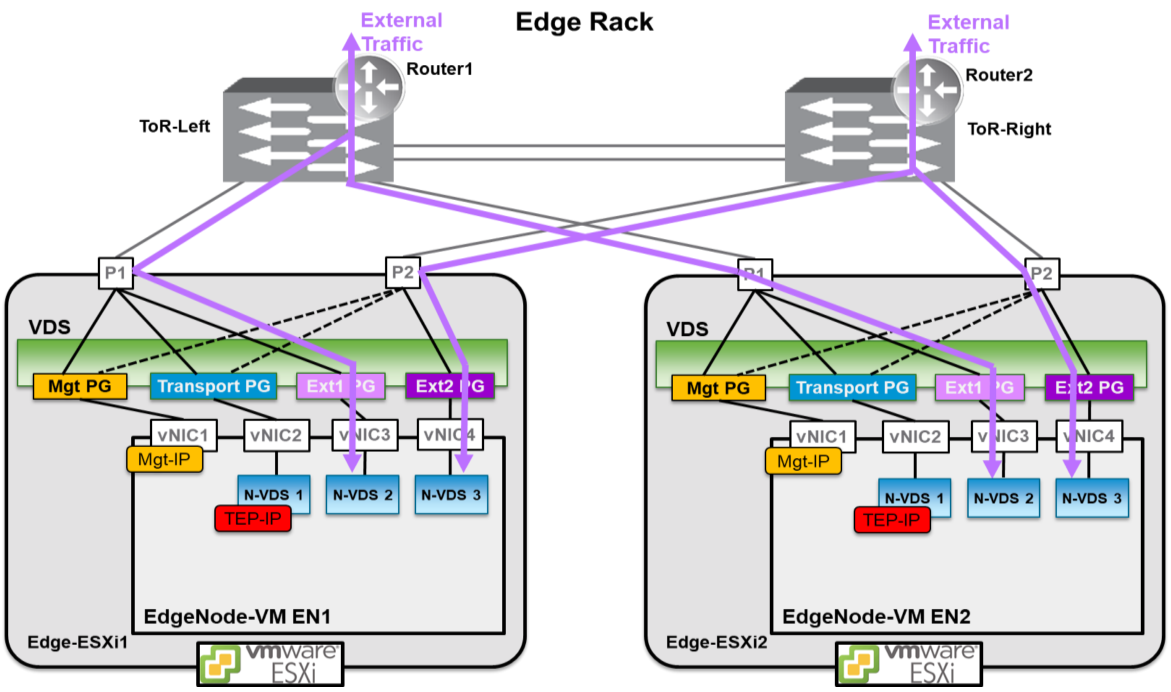


Figure A5-7 Typical Enterprise Edge Node VM Physical View with External Traffic

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.

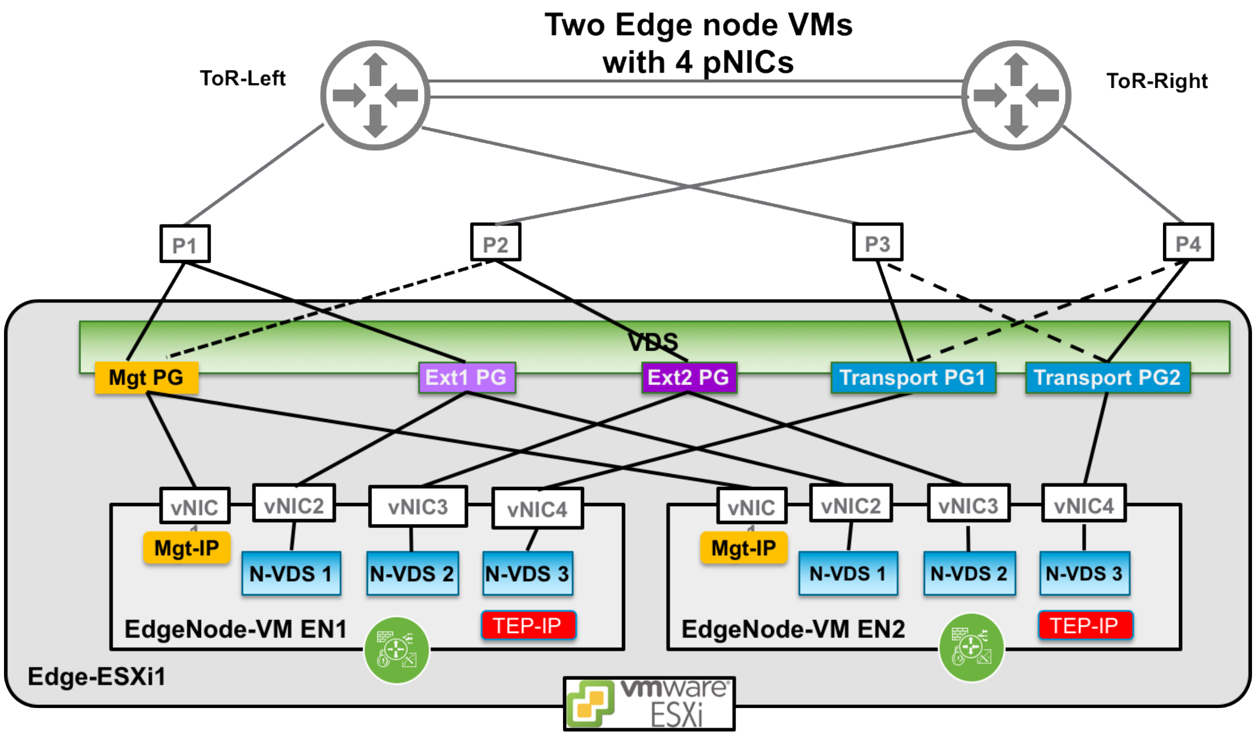


Figure A5-7: Four pNICs Edge Dedicated Host with two Edge nodes

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.