BROCADE

OVERLAYING VIRTUALIZED LAYER 2 NETWORKS OVER LAYER 3 NETWORKS

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ABSTRACT

Cloud computing and virtual machines require significantly more logical networks than traditional data center networks, and past network segmentation techniques such as VLANs cannot scale adequately. Several technologies were developed to enable Layer 2 overlay networks that are tunneled over Layer 3 for scalable cloud network architectures. This presentation will briefly highlight existing challenges, and then introduce Technologies enabling Virtualized L2 overlay networks, brief concept and related deployment case studies

Agenda

- Overview
- Existing Challenges
- Proposed Solutions
  - IETF VxLAN
    - ✓ Concepts & Deployment Case Studies
  - IETF OTV
    - ✓ Concepts & Deployment Case Studies
  - IETF MAC VPN
    - ✓ Concepts & Deployment Case Studies

Overview – Why Overlay Networks ?

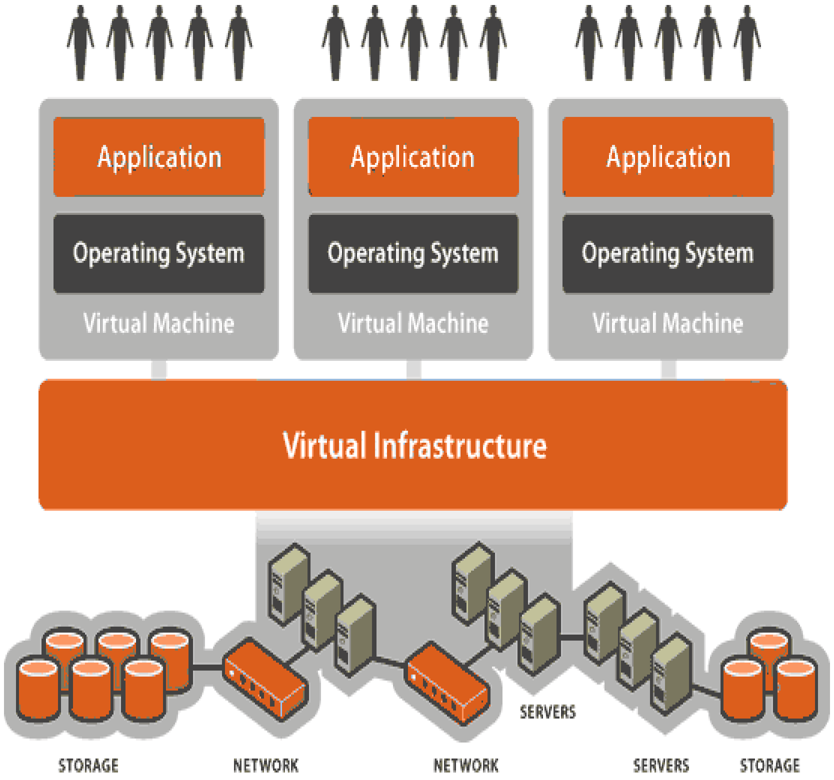
- Increased demand on the physical network infrastructure due to server virtualization

  - Switched Ethernet network needs more MAC address table entries
    - ✓ Due to attachment to hundreds of thousands of virtual machines
    - ✓ Every VM will have its own MAC address
  - VM may be grouped according to their Virtual LAN (VLANs)
    - ✓ Drives requirement of thousands of vlans to partition the traffic according to specific group vlan may belong to

Overview – Why Overlay Networks ?

- **Datacenter hosting multiple tenants each needed its own isolated network domain**
  - ➢ Not economical to realize with dedicated infrastructure
  - ➢ Each tenants may independently assign MAC addresses and vlan IDs leading to potential duplication of these on physical network

- **Network Operators prefers to use IP for interconnection of the physical infrastructure**
  - ➢ To achieve multipath scalability using ECMP
  - ➢ Still want to preserve Layer 2 model for inter-VM connection



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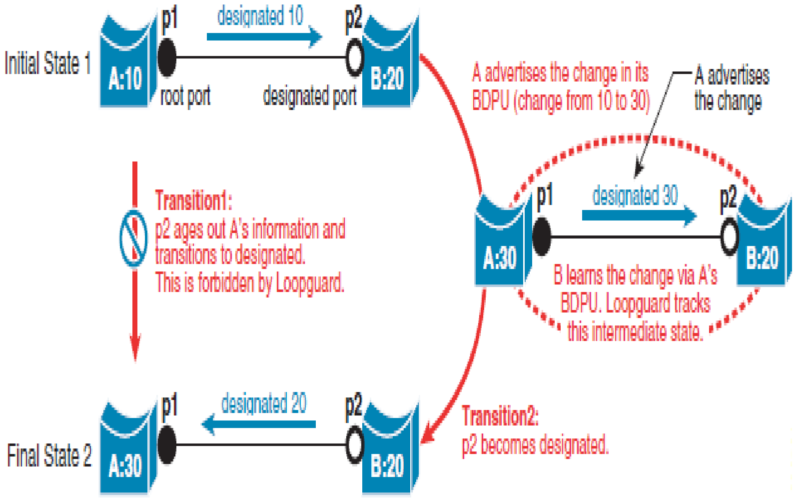
Existing Challenges with Layer 2 DataCenter

- **Limitation imposed by Spanning Tree**
  - Layer 2 networks use STP to avoid loops due to duplicate paths
  - STP will turn off links to avoid the replication and looping of frames
    - ✓ Paying for more ports and links that they can really use – Expensive solution
  - Lack of Multipath support in STP model



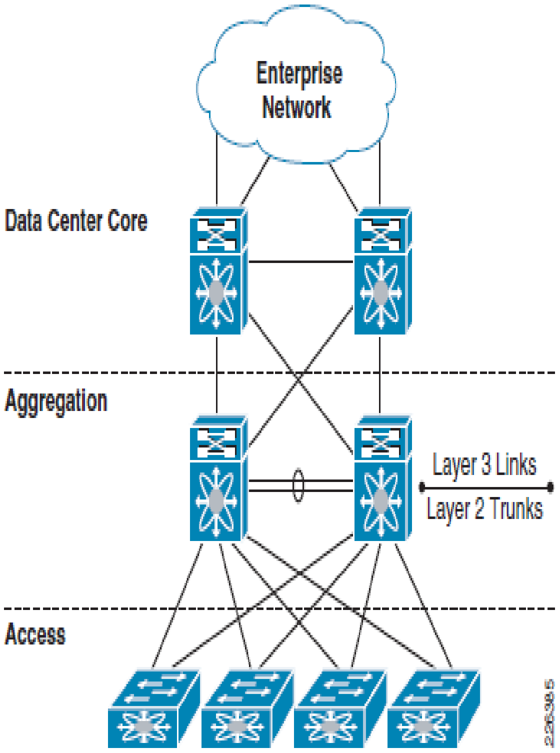
- **Scale with broadcast isolation/security limitation**
  - Layer 2 Datacenter networks use VLANs to provide broadcast isolation
  - A 12 bit VLAN ID is used in the Ethernet frames to divide larger layer 2 networks into broadcast domain
  - 12 bit can only provide unique 4096 vlans as upper limit which is not enough with growing adoption of virtualization
  - Requirement of multitenant environments accelerate the need for larger VLAN limits

Existing Challenges with Layer 2 DataCenter

- **Cross POD expansion – Stretched layer 2 environment**
  - POD consist of one or more rack of servers with associated network and storage connectivity
  - Tenants may start off on a POD and due to expansion, requires servers/VM on other PODs (due to resource availability)
  - Requires Stretched Layer 2 networks to connect Servers / VMs
- **Multi Tenancy with Layer 3 networks**
  - Layer 3 networks are not a complete solution for a multi tenancy
  - There can be IP addressing overlaps between two tenants requires Cloud Provider to isolation of some sort
  - Using IP connectivity excludes customers relying on direct layer 2 or non-IP layer 3 protocols for inter-VM communication.

Existing Challenges with Layer 2 DataCenter

- Inadequate Table Sizes at TOR switch
  - Virtualized environment place additional demands on the MAC table of TOR switches connect to the servers
  - Instead of just one MAC address per server switch has to learn MAC of individual VMs (range in 100s / server)
  - Rack typically host 24 or 48 servers depends on the number of server facing ports which translates to huge number of MACs per rack
  - If table overflows, the switch may stop learning new MACs until idle entries expires leading to flooding of unknown destination frames throughout the network



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VxLAN – Virtual Extensible LAN

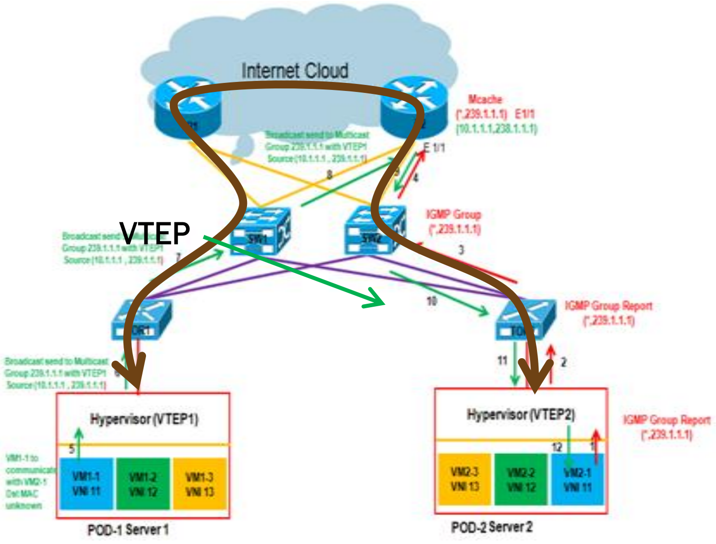
Concept

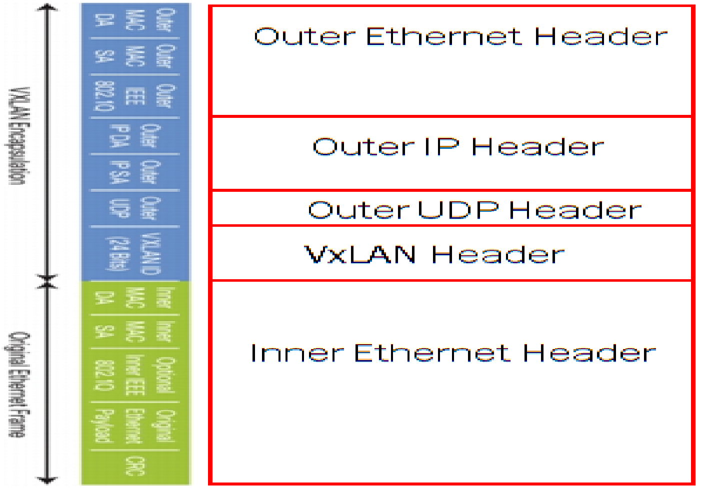
- The VXLAN standard enables overlay networks, focuses on eliminating the constraints of **STP, CAPEX Capacity expansion across racks or server expansion and Inter Host workload mobility** by enabling virtualized workloads to seamlessly communicate or move across server clusters and data.

- VXLAN is simply a MAC-in-UDP encapsulation (encapsulation of an Ethernet L2 Frame in IP) scheme enabling the creation of virtualized L2 subnets that can span physical L3 IP networks

- L2 overlay scheme over L3 transport network

- VXLAN is a tunneling scheme (Hypervisor to Hypervisor) . The VTEPs encapsulate the virtual machine traffic in a VXLAN header as well as strip it off and present the destination virtual machine with the original L2 packet.





Life of a Packet

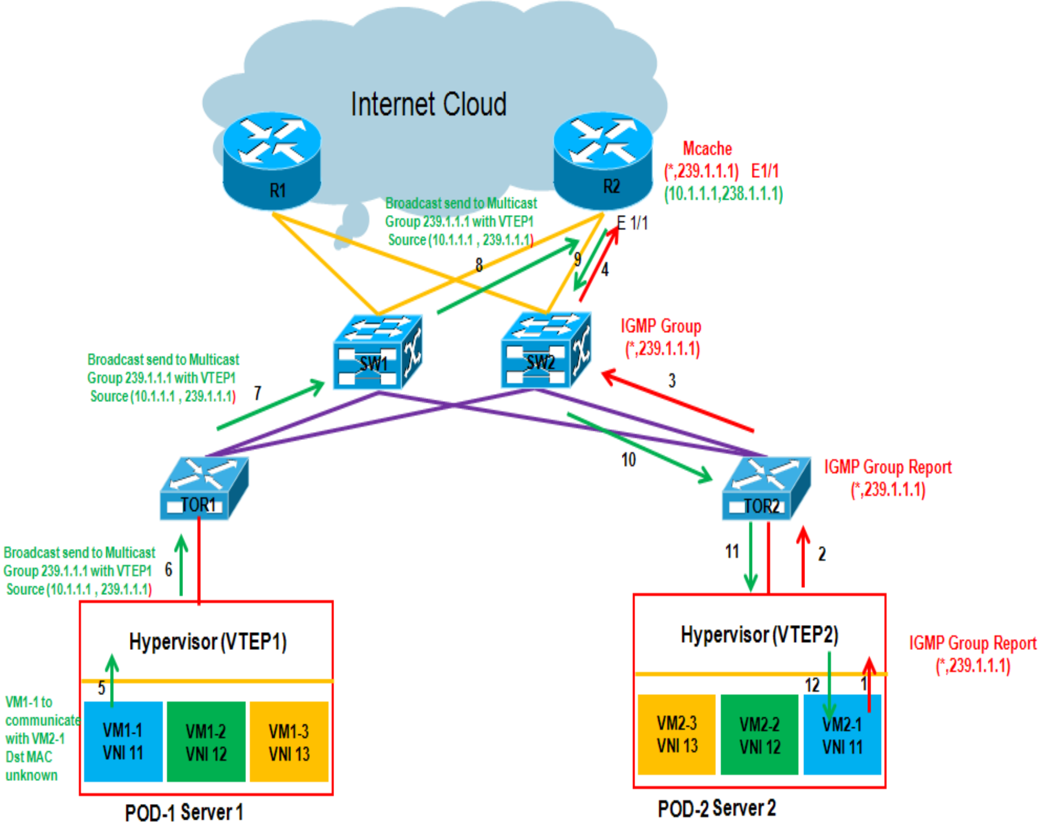
Summary of Data Path communication

- **ARP Resolution between VTEPs hosting VMs**
  - Communication between two VMs happens over IP networks
  - Hence two VMs to communicate with each other needs ARP resolution aka MAC to IP Mapping
  - with VxLAN, Broadcast packets are sent to **IP Multicast group** over which VxLAN overlay network is realized
  - Mapping is created between VLAN VNI and IP multicast group
- **Unicast Communication using MAC-in-UDP Encapsulation**
  - After ARP is resolved VM to VM communication happens over layer 3
  - VTEP slaps encapsulation transparent to communicating VMs

Life of a Packet

Broadcast resolution using Multicast – Packet from VM1-1 to VM2-1

- **Step 1 – Multicast group mapping to VNI**
  - ➢ SW creates VNI and IP multicast group mapping
- **Step 2 – IGMP Group membership report**
  - ➢ VTEP sends IGMP group membership report to upstream switch / router to join/leave the VxLAN related multicast group as needed
- **Step 3 – VTEP initiates ARP request when VM needs to communicate**
  - ➢ Since Multicast tree is build up using step 2
  - ➢ Arp packets destined to multicast group is forwarded to the interested listeners
- **Step 4 – Receiving VTEP will process packet**
  - ➢ Receiving VTEP will learn sending VTEP MAC from received Packet and will send unicast ARP response



Life of a Packet

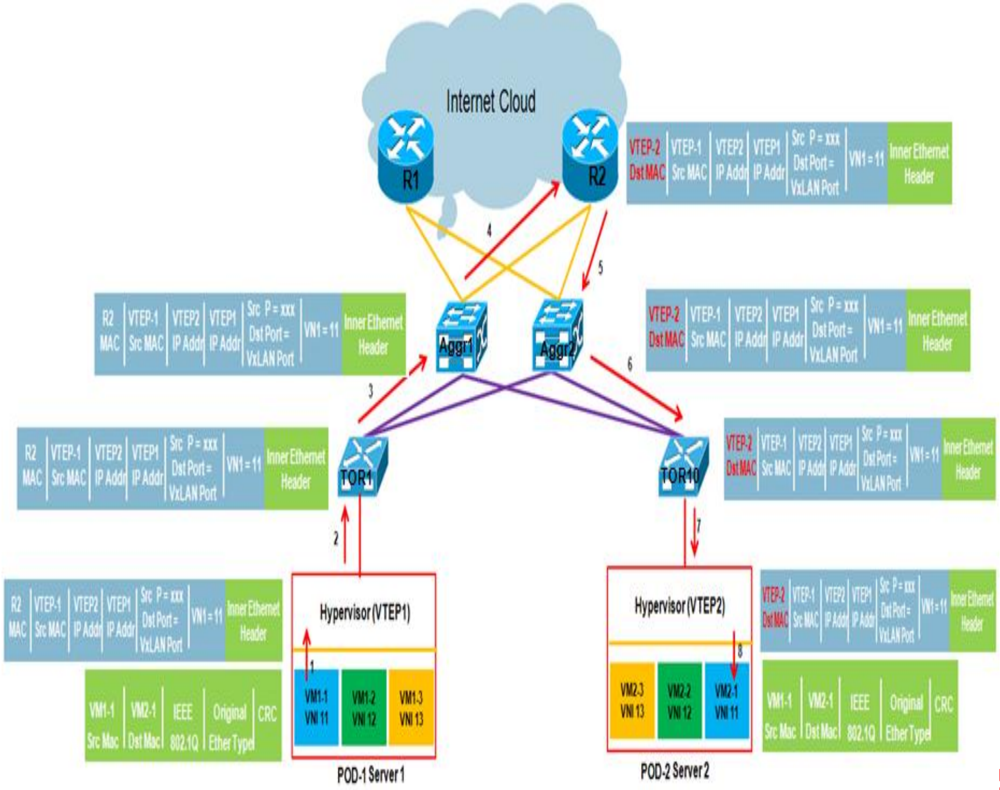
VM to VM communication after ARP resolution – Packet from VM1-1 to VM2-1

- **Step 1**
  - ➢ VM1-1 on server 1 in vlan A in POD-1 wanted to communicate VM1-2 on server 2 in POD-2
  - ➢ Ethernet header is sent from VM1-1 to Hypervisor (VTEP1)

- **Step 2**
  - ➢ Hypervisor (VTEP-1) will slap VxLAN header Comprises of VXLAN , Outer UDP , Outer IP and outer Ethernet header

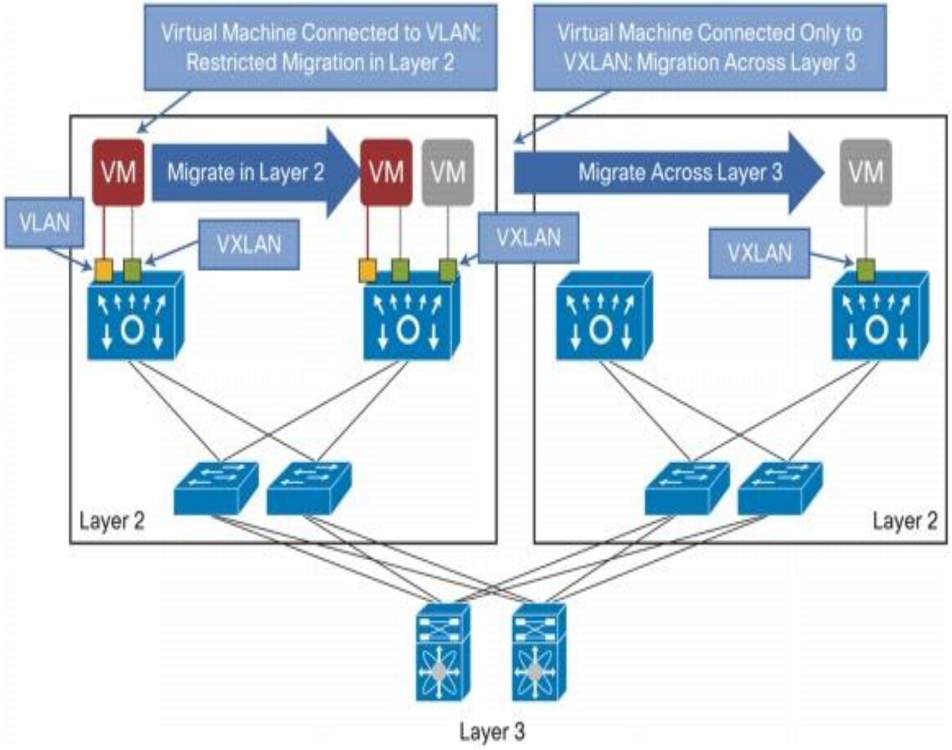
- **Step 3**
  - ➢ Routing device will change the MAC to VTEP-2 destination MAC

- **Step 4**
  - ➢ Destination VTEP-2 will receive the packet , will strip off Outer Ethernet, IP , UDP and VxLAN header and forward packet based on VNI to specific VM (VM2-1 / VNI 11)



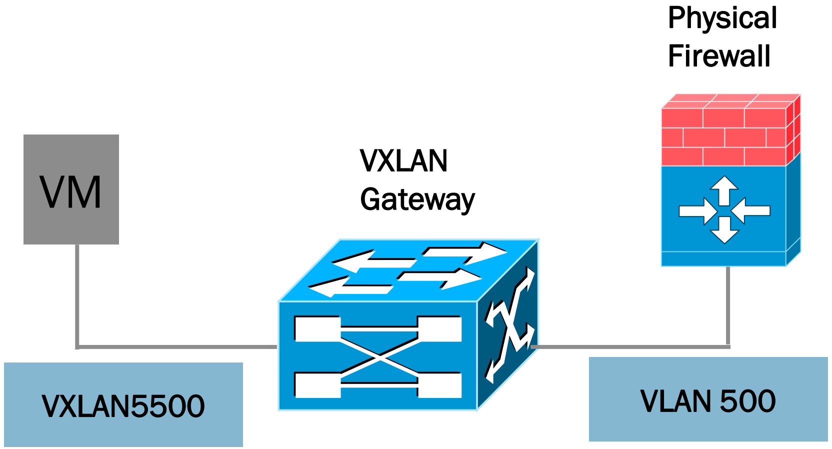
Case 1 : Virtualized servers connected over layer 3 Infrastructure

- Logical networks can be extended among virtual machines placed in different Layer 2 domains
- Flexible, scalable cloud architecture enables addition of new server capacity over Layer 3 networks and accommodates elastic cloud workloads
- If a virtual machine is connected only through VXLAN, then it can migrate across the Layer 3 network (gray virtual machine)
- If a virtual machine is connected to a VLAN (as in the case of the red virtual machine with VLAN, then it is restricted to migration within the Layer 2 domain only



Case 2: VXLAN aware Virtualized servers communicates with legacy servers

- Figure depicts a scenario where VXLAN overlay network need to communicate with nodes on legacy networks which could be VLAN based
- To enable this communication, a Network can include gateways which forwards traffic between VXLAN and non-VXLAN environments
- **The gateway devices could be**
  TOR switches
  Access switches
  Core devices
  WAN edge devices



- **For incoming frames on VXLAN connected interface**

  ✓ The gateway strips out VXLAN header and forwards to a physical port based on destination MAC address on inner ETH Header

- **For incoming frames on non VxVLAN connected interface**

  ✓ The incoming frames from non-VXLAN interfaces are mapped to a specific VXLAN overlay network based on the VLAN ID in the frame

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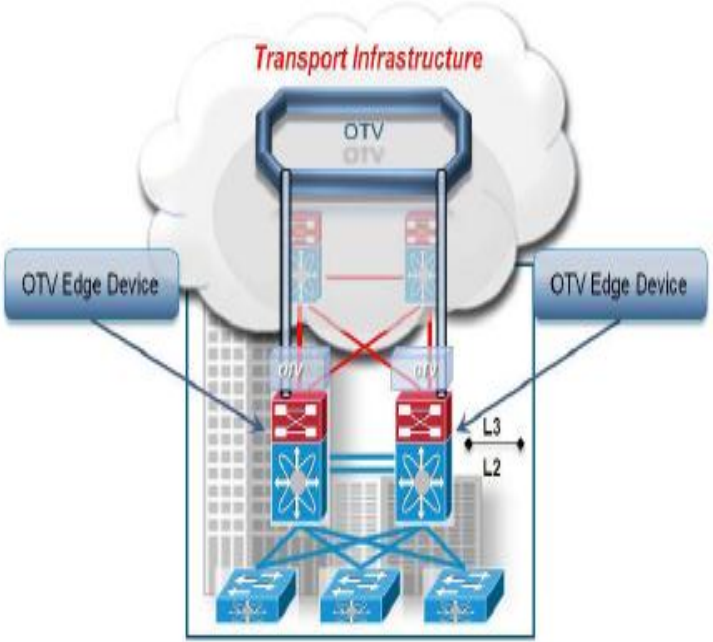
OTV – Overlay Transport Virtualization

Concept

- **MAC Routing**
  - ➢ Control Plane protocol is used to exchange MAC reachability information between network devices providing LAN extension functionality
- **Edge Device**
  - ➢ **Encapsulation:** It receives the Layer 2 traffic for all VLANs that need to be extended to remote locations and dynamically encapsulates the Ethernet frames into IP packets that are then sent across the transport infrastructure.
  - ➢ **Decapsulation:** It receives the IP encapsulated traffic from the transport layer to removes IP encapsulation and expose original ethernet frame



OTV – Overlay Transport Virtualization

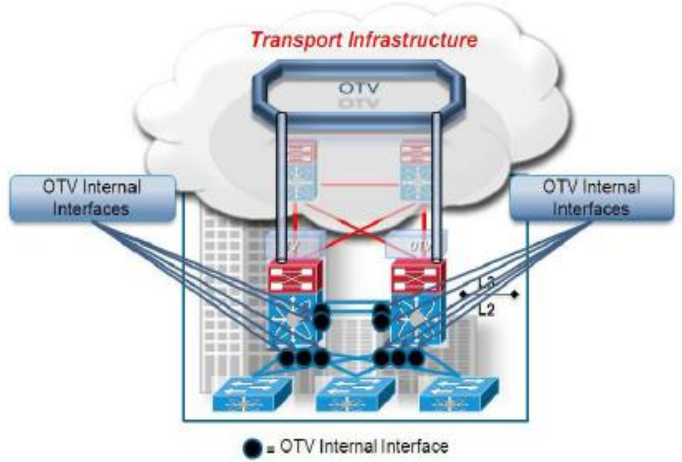
Concept

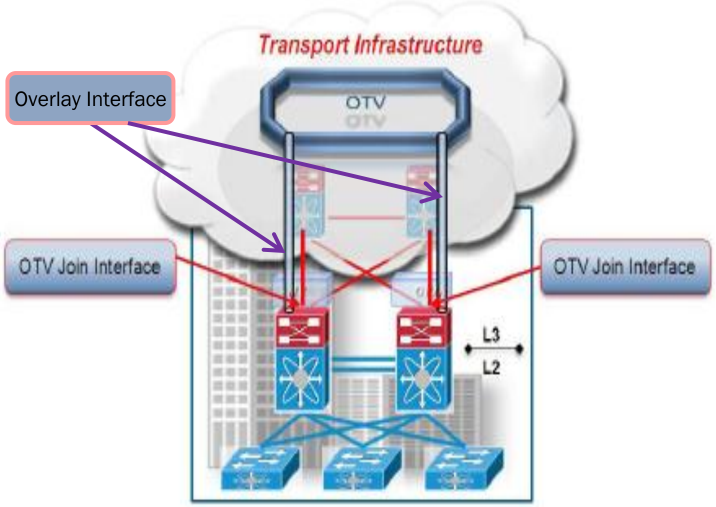
- Interface types

  - **Internal Interface:** Internal interfaces are regular Layer 2 interfaces configured as access or trunk ports

  - **Join Interface:** The Join interface is a Layer 3 entity.
    - "Join" the Overlay network and discover the other remote OTV edge devices.
    - Form OTV adjacencies with the other OTV edge devices belonging to the same VPN.
    - Send/receive MAC reachability information and unicast/multicast traffic

  - **Overlay Interface:**
    - logical multi-access and multicast-capable interface where the entire OTV configuration is applied.
    - Layer 2 frame destined for a remote data center site, the frame is logically forwarded to the Overlay interface to perform the dynamic OTV encapsulation on the Layer 2 packet and send it to the Join interface toward the routed domain.





OTV – Control Plane Functionality

Concept - Multicast Enabled Transport

- Neighbor Discovery

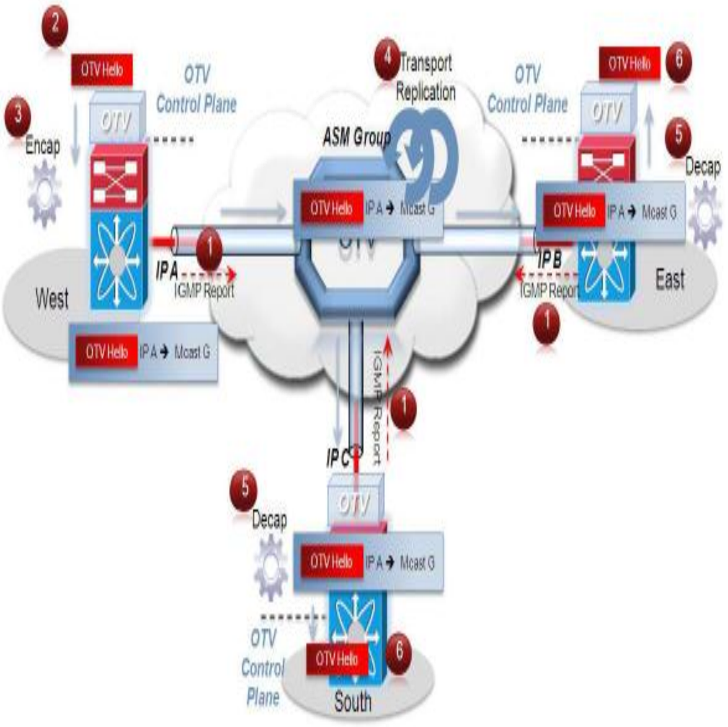
  - **Step-1:** Each OTV edge device sends an IGMP report to join the specific ASM group used to carry control protocol exchanges

  - **Step-2:** The OTV control protocol running on the left OTV edge device generates Hello packets to establish control Plane adjacency

  - **Step-3:** The OTV Hello messages must be OTV-encapsulated, adding an external IP header.

  - **Step-4(a):** The source IP address in the external header is set to the IP address of the Join interface of the edge device,The destination is the multicast address of the ASM group dedicated to carry the control protocol.
  - **Step-4(b):**The resulting multicast frame is then sent to the Join interface toward the Layer 3 network domain which will be optimally replicated by transport layer to reach all OTV edge devices that joined multicast group G

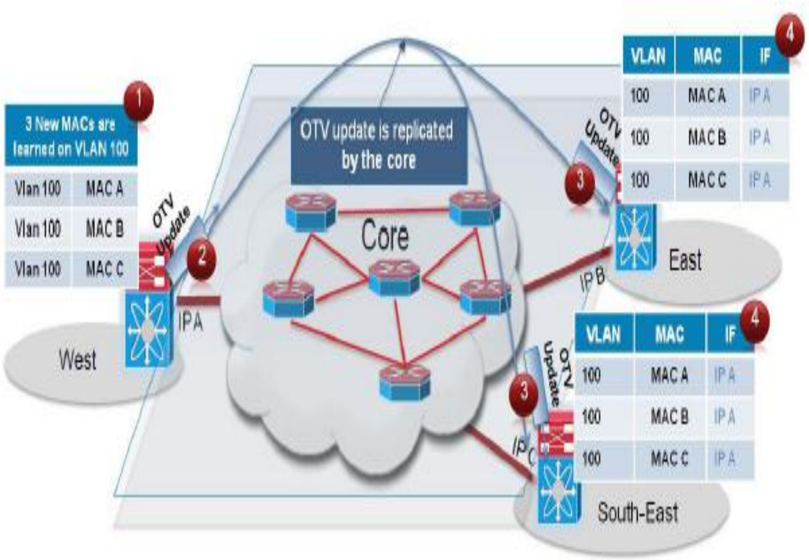
  - **Step 5:** The receiving OTV edge devices decapsulate the packets.



OTV – Control Plane Functionality

Concept - Multicast Enabled Transport

- **MAC Learning**
  - **Step-1:** The OTV edge device in the West data center site learns new MAC addresses (MAC A, B and C on VLAN 100) on its internal interface. This is done via traditional data plan learning.
  - **Step-2:** An OTV Update message is created containing information for MAC A, MAC B and MAC C. The message is OTV encapsulated with the IP destination address of the packet in the outer header is the multicast group G used for control protocol exchanges.
  - **Step-3:** The OTV Update is optimally replicated in the transport and delivered to all remote edge devices which decapsulate it and hand it to the OTV control process.
  - **Step-4:** The MAC reachability information is imported in the MAC Address Tables (CAMs) of the edge devices.
  - **Step-5:** The only difference with a traditional CAM entry is that instead of having associated a physical interface, these entries refer the IP address of the Join interface of the originating



OTV – Control Plane Functionality

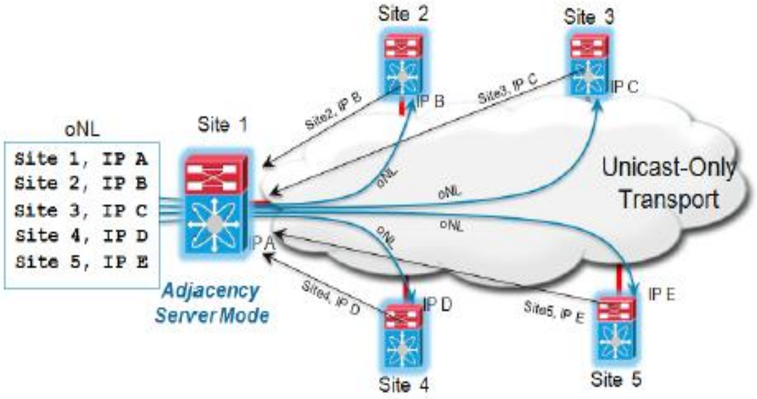
Concept - Unicast-only Transport

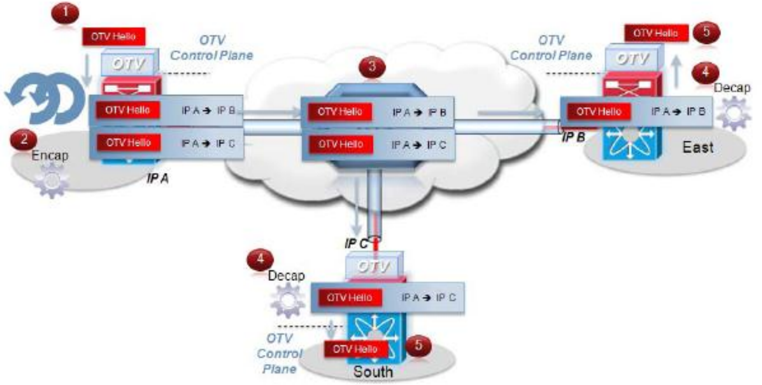
- Neighbor Discovery

  - **Step-1:** The OTV control protocol running on the left OTV edge device generates Hello packets that need to be sent to all other OTV edge devices. This is required to communicate its existence and to trigger the establishment of control plane adjacencies

  - **Step-2 (a):** The left OTV device must perform head-end replication, creating one copy of the Hello message for each remote OTV device part of the unicast-replication-list previously received from the Adjacency Server.

  - **Step-2(b):** Each of these frames must then be OTV-encapsulated, adding an external IP header.
    - ✓ The source IP address in the external header is set to the IP address of the Join interface of the local edge device
    - ✓ The destination is the Join interface address of a remote OTV edge device.
    - ✓ The resulting unicast frames are then sent out the Join interface toward the Layer 3 network domain





OTV – Control Plane Functionality

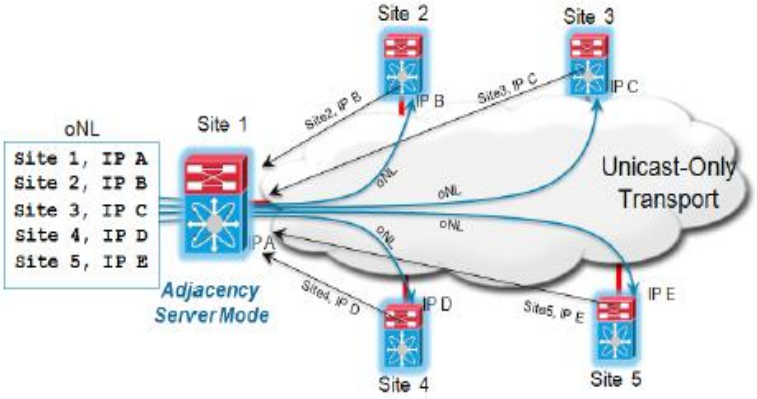
Concept - Unicast-only Transport

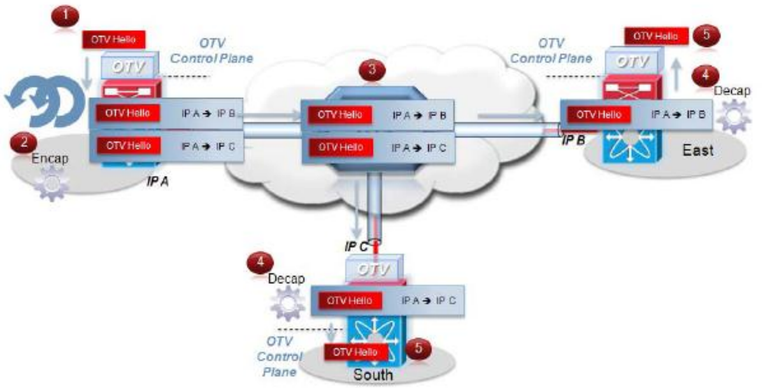
- Neighbor Discovery

  - **Step-3:** The unicast frames are routed across the unicast-only transport infrastructure and delivered to their specific destination sites.

  - **Step-4:** The receiving OTV edge devices decapsulate the packets

  - **Step 5:** The Hellos are passed to the control protocol process





OTV – Control Plane Functionality

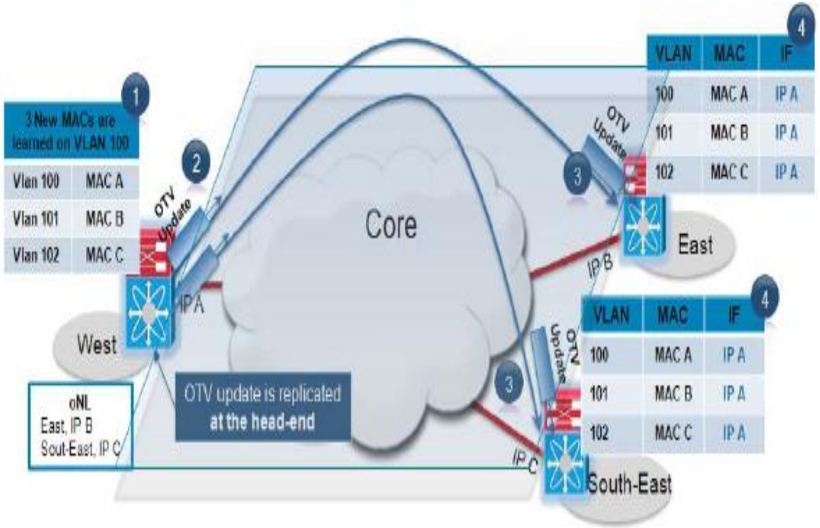
Concept - Unicast-only Transport

- **MAC Learning**
  - **Step-1:** The OTV edge device in the West data center site learns new MAC addresses (MAC A, B and C on VLAN 100, 101 and 102) on its internal interface. This is done via traditional data plan learning.

  - **Step-2:** An OTV Update message containing information for MAC A, MAC B and MAC C is created for each remote OTV edge device (head-end replication). The IP destination address of the packet in the outer header is the Join interface address of each specific remote OTV device..

  - **Step-3:** The OTV Updates are routed in the unicast-only transport and delivered to all remote edge devices which decapsulate them and hand them to the OTV control process.

  - **Step-4:** The MAC reachability information is imported in the MAC Address Tables (CAMs) of the edge devices. The only difference with a traditional CAM entry is that instead of having associated a physical interface, these entries refer the IP address (IP A) of the Join interface of the originating edge device.



OTV – Data Plane Functionality

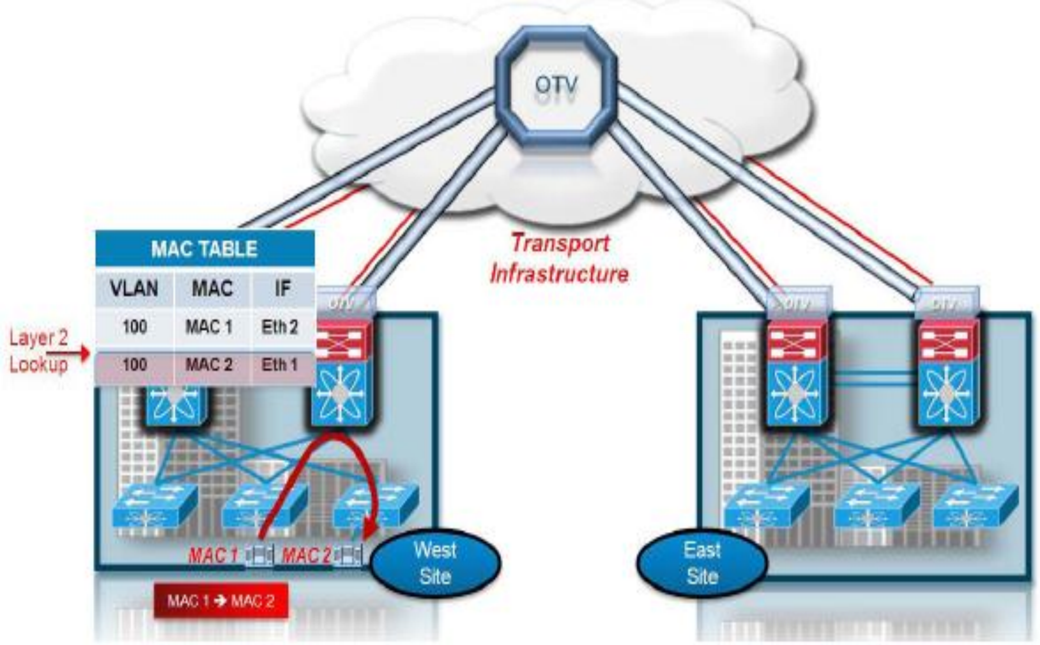
Concept - Intra Site Traffic Forwarding

- **Intra-site forwarding**

  - **Step-1:** MAC 1 (Server 1) needs to communicate with MAC 2 (Server 2), both belonging to the same VLAN.

  - **Step-2:** When the frame is received at the aggregation layer device (which in this case is also deployed as the OTV edge device), the usual Layer 2 lookup is performed to determine how to reach the MAC 2 destination.

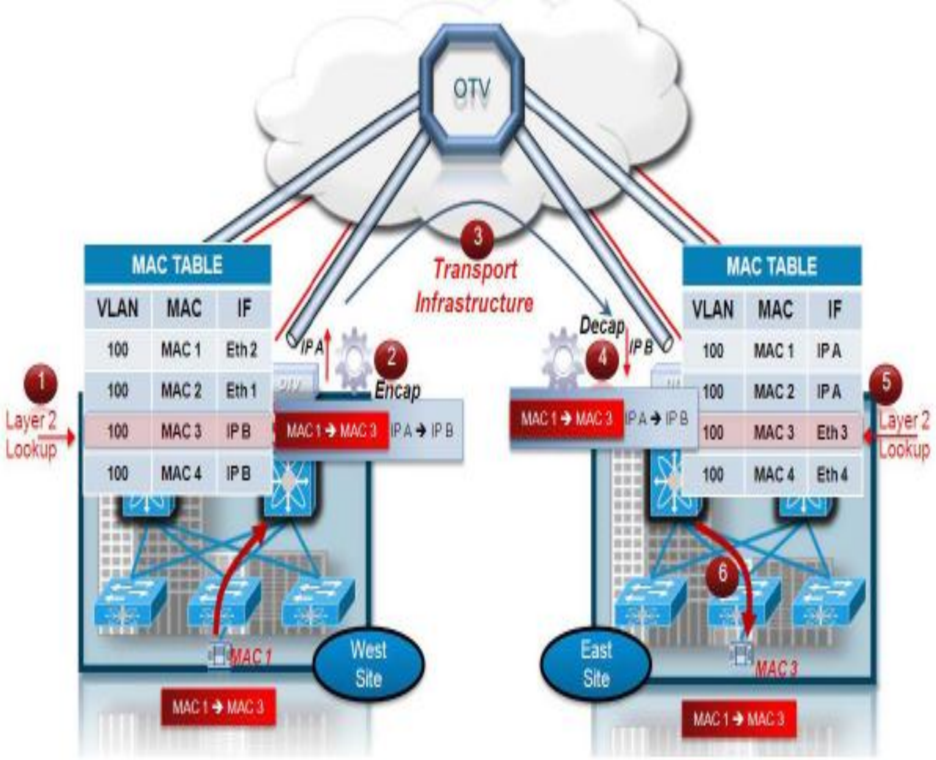
  - **Step-3:** Information in the MAC table points out a local interface (Eth 1), so the frame is delivered by performing classical Ethernet local switching



OTV – Data Plane Functionality

Concept - Inter-Site Traffic Forwarding

- Inter-site forwarding
  - **Step-1:** The Layer 2 frame is received at the OTV edge device. A traditional Layer 2 lookup is performed, but this time the MAC 3 information in the MAC table does not point to a local Ethernet interface but to the IP address of the remote OTV edge device that advertised the MAC reachability information.
  - **Step-2:** The OTV edge device encapsulates the original Layer 2 frame: the source IP of the outer header is the IP address of its Join interface, whereas the destination IP is the IP address of the Join interface of the remote edge device
  - **Step-3:** The OTV encapsulated frame (a regular unicast IP packet) is carried across the transport infrastructure and delivered to the remote OTV edge device.
  - **Step-4:** The remote OTV edge device decapsulates the frame exposing the original Layer 2 packet



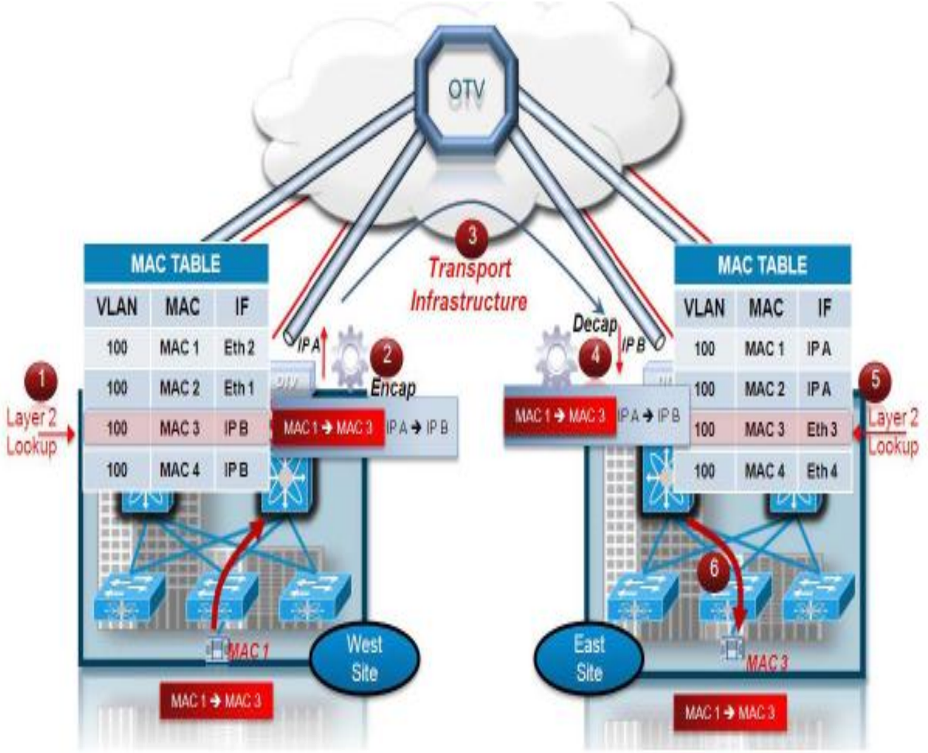
OTV – Data Plane Functionality

Concept - Inter-Site Traffic Forwarding

- Inter-site forwarding

  - **Step-5:** The edge device performs another Layer 2 lookup on the original Ethernet frame and discovers that it is reachable through a physical interface, which means it is a MAC address local to the site.

  - **Step-6:** The frame is delivered to the MAC 3 destination.



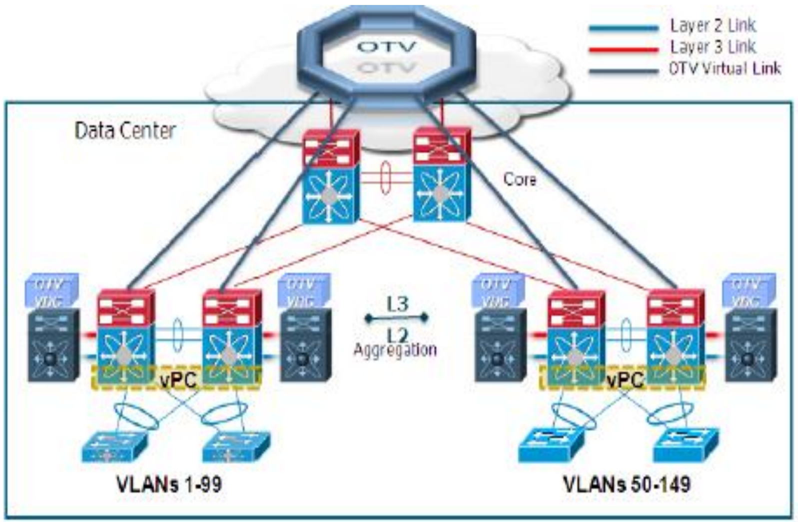
OTV – Deployment Case Study

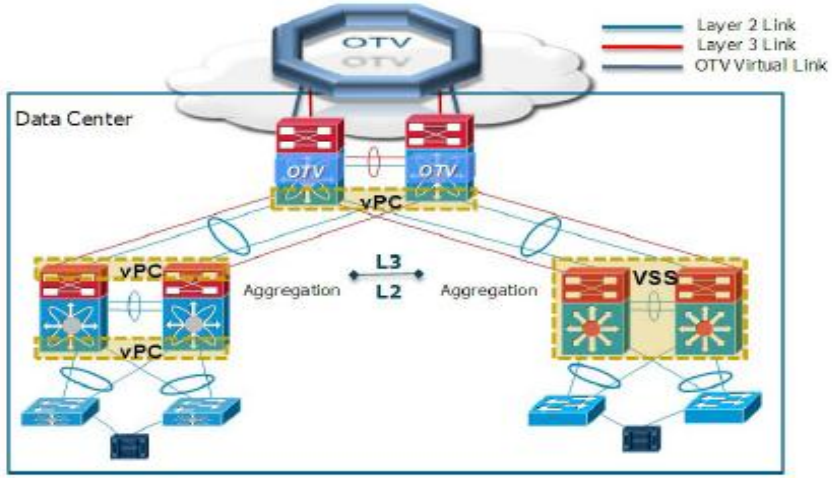
- **Case-1: OTV @ Aggregation Layer**

  ✓ Each aggregation block represents a separate STP domain.
  ✓ Routed links interconnecting each aggregation layer to the core and having native OTV STP isolation functionality.
  ✓ inter and Intra Aggregation layer traffic will be forwarded via core routers
  ✓ Aggregation layer instability will be collocated within itself.

- **Case-2: OTV @ Core Layer (Large Data Center)**

  ✓ DC Core devices will perform Layer 3 and OTV function
  ✓ Each aggregation layer will be connected to transport layer via layer 3 link which brings resiliency and stability to the overall design
  ✓ For core devices to start functioning as OTV edge devices, traffic for all the VLANs that need to be extended to remote sites must now be carried to the DC core





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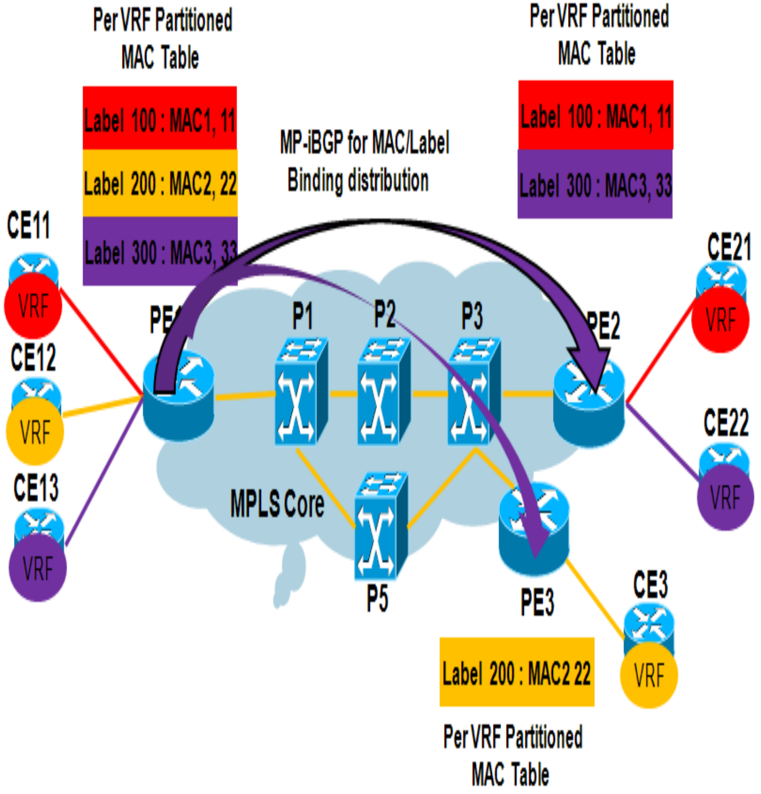
IETF MAC VPN – Technology Overview

Building blocks

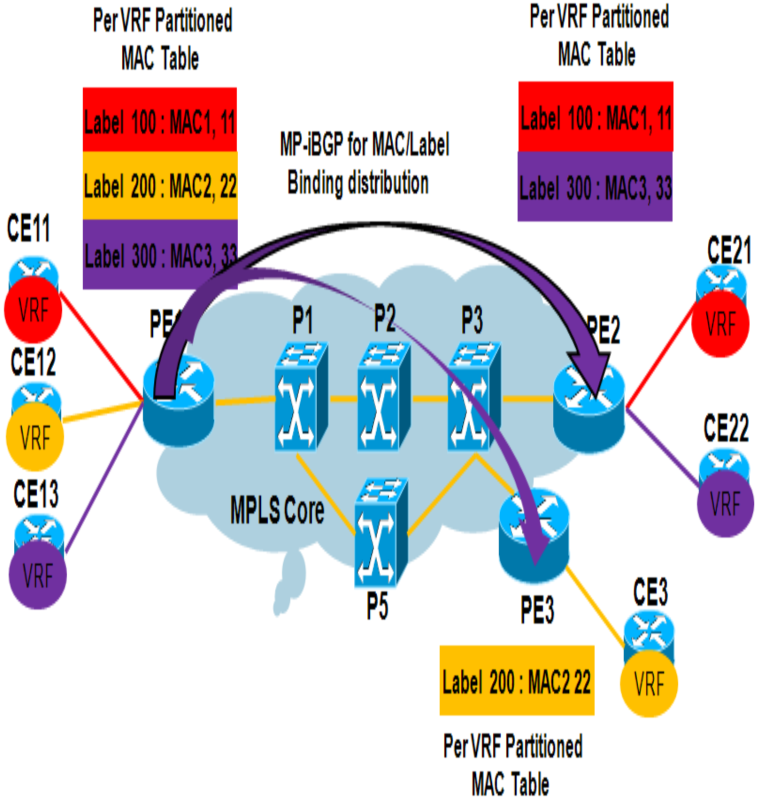
- **Customer Edge routers (CEs)**
  - ➢ Can be a host , a router or a switch
- **MPLS Edge Switches (MEs)**
  - ➢ Provides layer 2 virtual bridge connectivity between CEs
  - ➢ Partitioned MAC table over VRF boundaries MVI – Security for multi-tenant application /overlapping MACs can be used
  - ➢ Distributes MAC table across PE routers via MP-iBGP
  - ➢ Provides MPLS transport
  - ➢ Encapsulates L2 Packets into MPLS header
- **Virtual Routing and Forwarding Instance**
  - ➢ Route Distinguishers are used to uniquely identify overlap MAC addresses
  - ➢ Way to virtually partition MAC table
  - ➢ Import and Export Filters are the key to install routes into VRF partition



IETF MAC VPN – Technology Overview

Building blocks

- Multi-Protocol BGP
  - ➢ Extensions are added to distributes MAC addresses across MEs using iBGP sessions
  - ➢ Export Filters carries over in the update must match target VRF import map to be qualified to install the route



Technology Comparison vs Problem Domain

Comparative Analysis of Technologies

Problem Domain	VxLAN	OTV	MAC VPN	VPLS
L2 Extension over Any Transport	Yes	Yes	Partial (Only MPLS)	Yes
Addressing MAC scalability on TOR	Yes	No	No	No
Addressing MAC scalability on Transport	Yes	Yes	Yes	Yes
Addressing VLAN scalability limitation	Yes	No	No	No
Security Isolation for Multi-tenancy	Yes	No	Yes	No
Addressing SPT limitation	Yes	Yes	Yes	Yes

Q&A