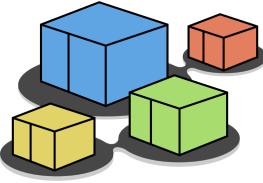




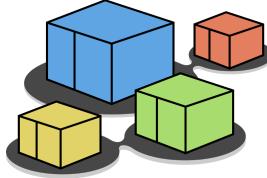
data centers and VXLAN

Version	3.1
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Web	http://www.kathara.org/
Description	Data Centers' Routing: BGP and VXLAN



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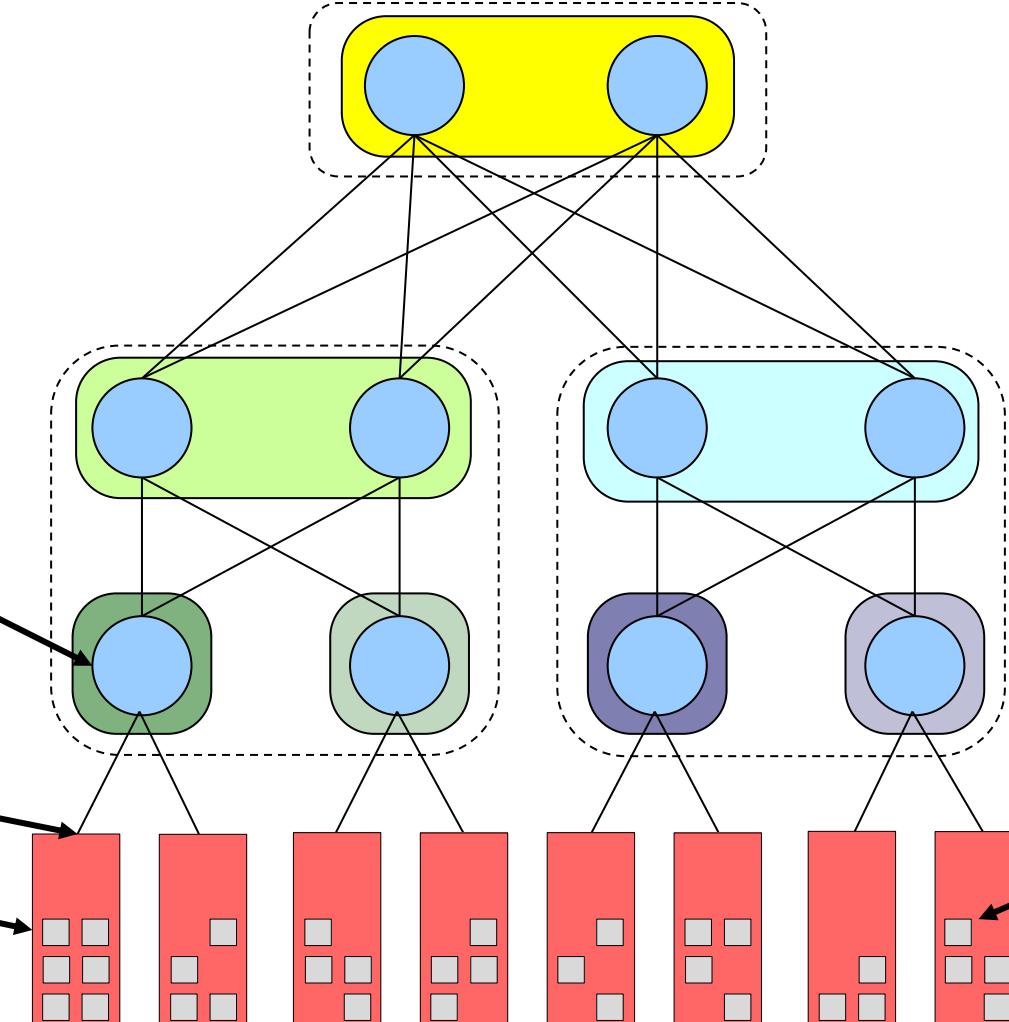
a Fat-Tree with BGP routing

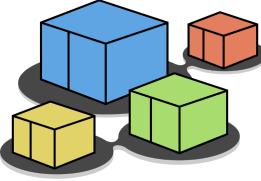
each Leaf
announces its
server's prefix

Prefixes are
assigned directly to
the servers

Servers

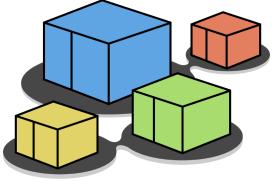
Containers or VMs





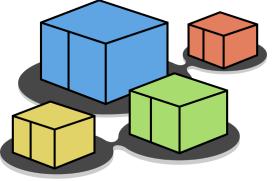
drawbacks of using just BGP

- containers/VMs share the same IP prefix of the server
 - no possibility to move containers between servers without IP remapping
- tenants must follow the IP plan of the data center
 - cannot expose containers with custom IPs
- there is no isolation between
 - the data center traffic and the tenant's traffic
 - different tenants



how to handle multiple tenants?

again, why (EVPN) BGP?



overview – multiple tenants

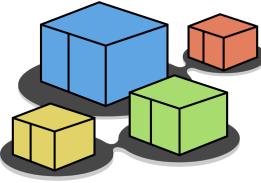
- requirements

- servers' architecture requirements
- orchestration requirements
- tenant requirements

- tunneling protocols

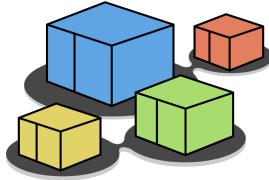
- VXLAN

- EVPN-BGP



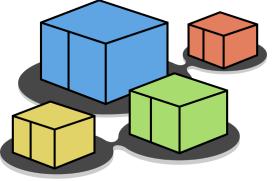
servers' architecture requirements

- having services directly on bare metal is not used
 - too many physical servers needed
 - no way to scale if more resources are requested
 - no isolation between different services on the same server
- support a virtual layer of containers or VMs
 - high-availability guaranteed via orchestration
 - useful for resource-slicing
 - complete isolation between different containers or VMs on the same server
 - possibility to assign containers or VMs to different tenants



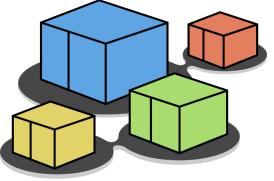
orchestration requirements

- an orchestrator is a software that manages the lifecycle of containers/VMs
 - creates, moves, and destroys containers/VMs
- needed for
 - optimal resource allocation, handling failures, management
- when moving a container/VM
 - possibility to keep network configurations (MAC/IP)
 - minimal downtime



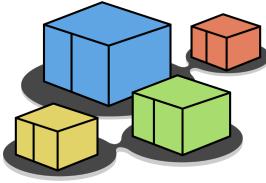
tenant requirements

- each tenant wants to independently manage its own private IP address space
 - containers/VMs traffic must be segregated between tenants and between the data center traffic



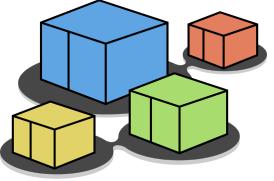
consequence of requirements

- server, orchestration, and tenant requirements have a consequence
 - usage of tunnels



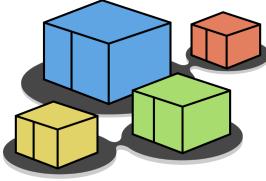
tunneling protocol requirements

- minimal configuration
- encapsulate the traffic of each tenant
 - an identifier of the tenant is needed
- encapsulation in Layer-4
 - to fully exploit IP Multi-Path
 - to traverse routers
 - data center fabric is Layer-3
 - to traverse Internet
 - different data centers must interconnect via Internet transparently (to create the so called *regions*)



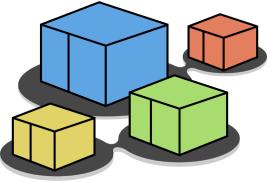
possible choices for tunneling

- VLAN
 - can be used only in L2, the data center is L3
- MPLS
 - each router must be configured for each new tenant
 - traversing Internet requires ISP to configure intermediate routers
- VXLAN
 - created ad-hoc ☺



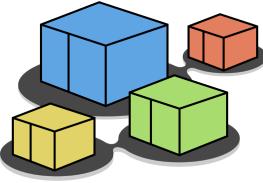
VXLAN

- Virtual eXtensible Local Area Network (RFC-7348)
- designed to address the need for overlay networks within virtualized data centers accommodating multiple tenants
- encapsulates Layer-2 frames into UDP packets



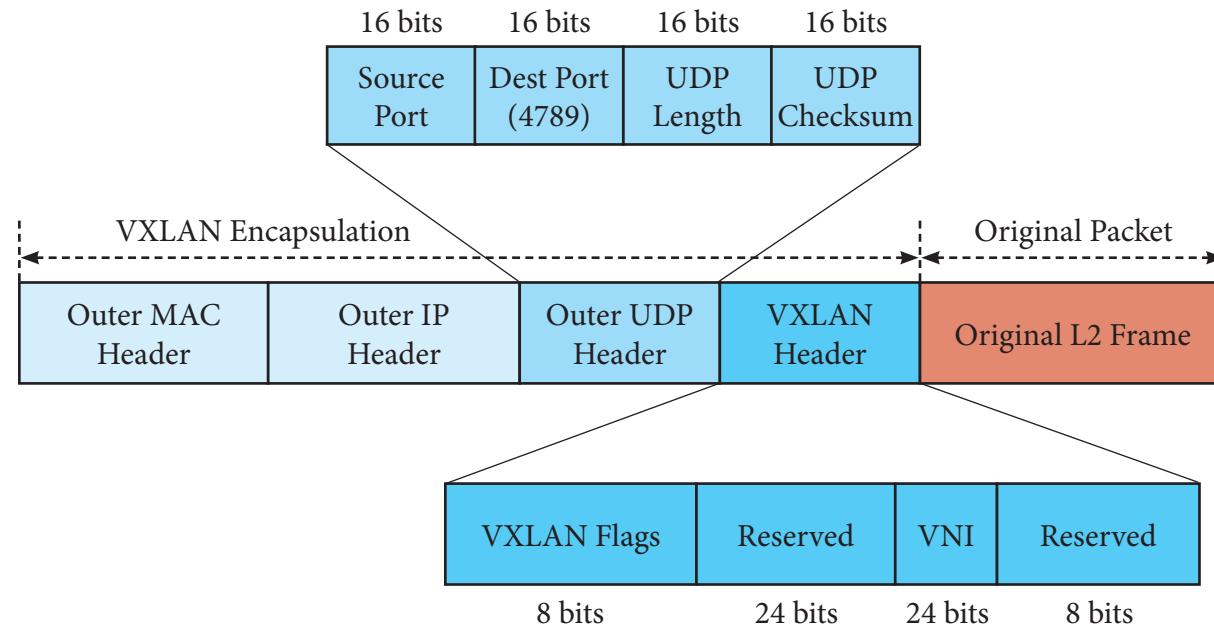
VXLAN terminology

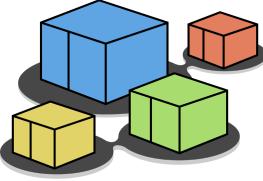
- **VNI: VXLAN Network Identifier**
 - identifier of a specific VXLAN tunnel
 - similar to the VLAN ID
 - 24 bit address space, more than 16M possible VNIs
- **VTEP: VXLAN Tunnel End Point**
 - device (physical or virtual) that encapsulates and decapsulates VXLAN packets



VXLAN encapsulation

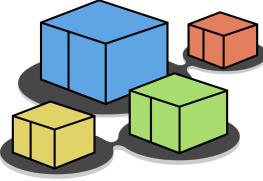
- overhead of 50 bytes
- random Source Port to fully exploit Multi-Path





MAC-to-VTEP Table

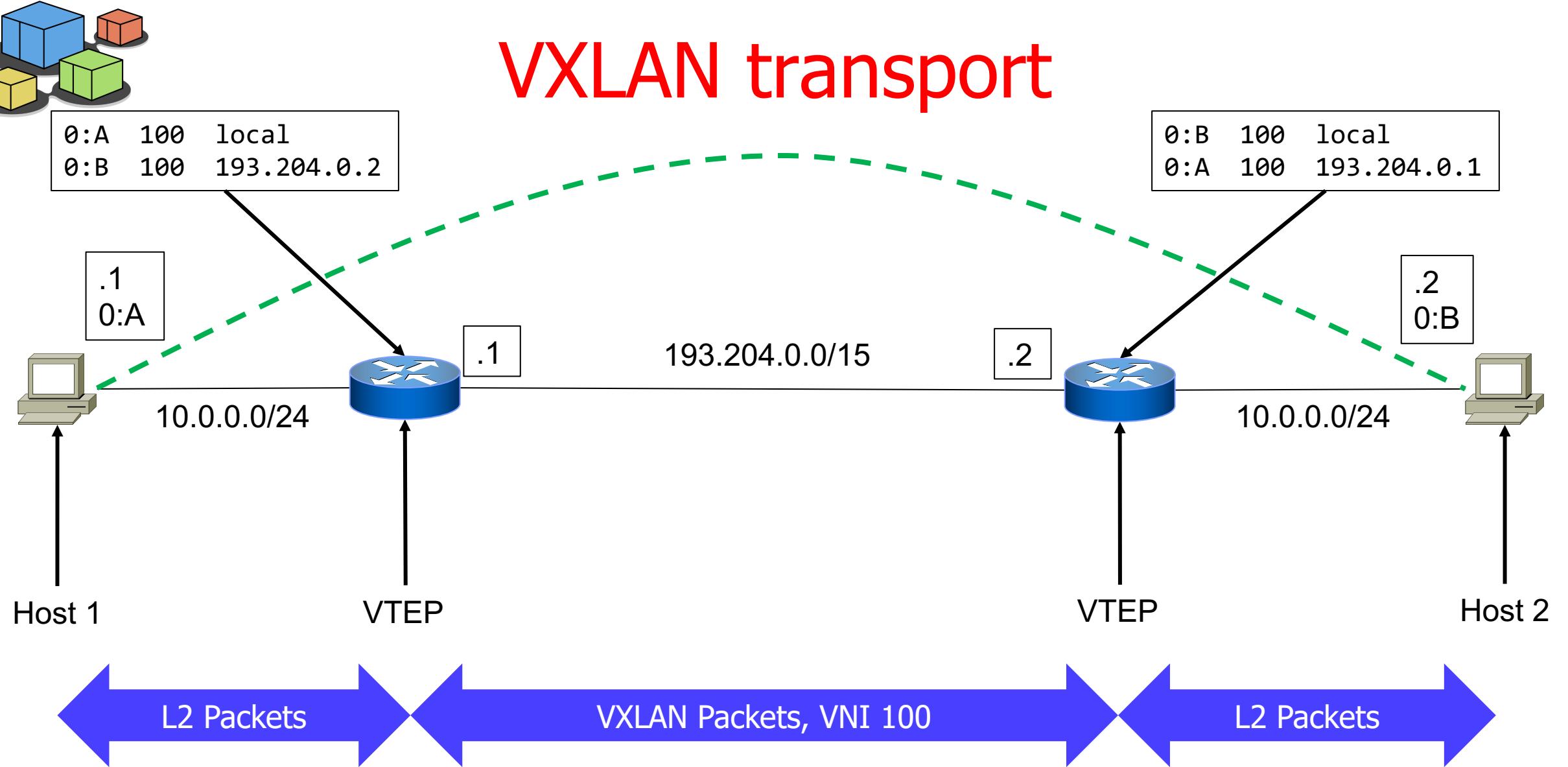
- hosted in each VTEP
- similar to the switch forwarding table
- for each VNI the VTEP keeps a table of pairs $\langle mac, ip \rangle$, that associates MAC Addresses and destination VTEP IPs
- each physical (or VLAN) L2 interface of a VTEP is assigned to a VNI
 - the MAC addresses learned on such interfaces are *local*, and the IPs of their pairs is replaced by the word *local*

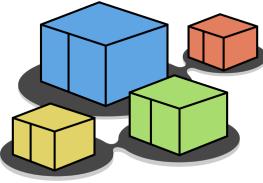


MAC-to-VTEP Table

- when a VTEP receives a frame destined to a MAC Address m from a local interface belonging to a certain VNI, it checks for the existence (in the VNI) of a pair $\langle m, i \rangle$ containing m
 - if the pair exists, the VTEP encapsulates the frame, and sends the resulting packet to the destination VTEP IP i
 - if not, the frame is sent to all the other VTEPs (encapsulated) and to all the local ports of that VNI

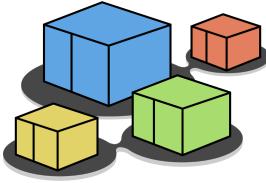
VXLAN transport





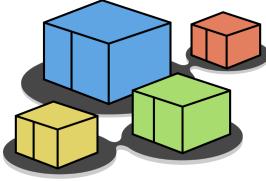
how to handle broadcast traffic

- two types of broadcast must be handled
 - traffic directed to the MAC broadcast address
 - e.g., ARP traffic
 - traffic directed to a MAC address that has not been learned
- IP multicast groups are used by default
 - each VNI is assigned to an IP multicast group of the underlay network and each VTEP subscribes itself to each group of its VNIs
 - the multicast group of a VNI is used only to send the broadcast traffic



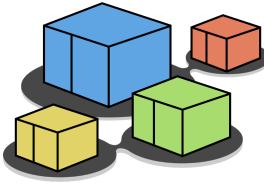
disadvantages of multicast

- multicast must be enabled in the underlay network
 - it may require to deploy several protocols
 - e.g., IGMP, IGMP Snooping, PIM,
 - complex configuration
- if multicast is not enabled, broadcast frames are duplicated and sent unicast to all the VTEPs of the VNI
- proxy ARP techniques can be used to mitigate broadcast traffic

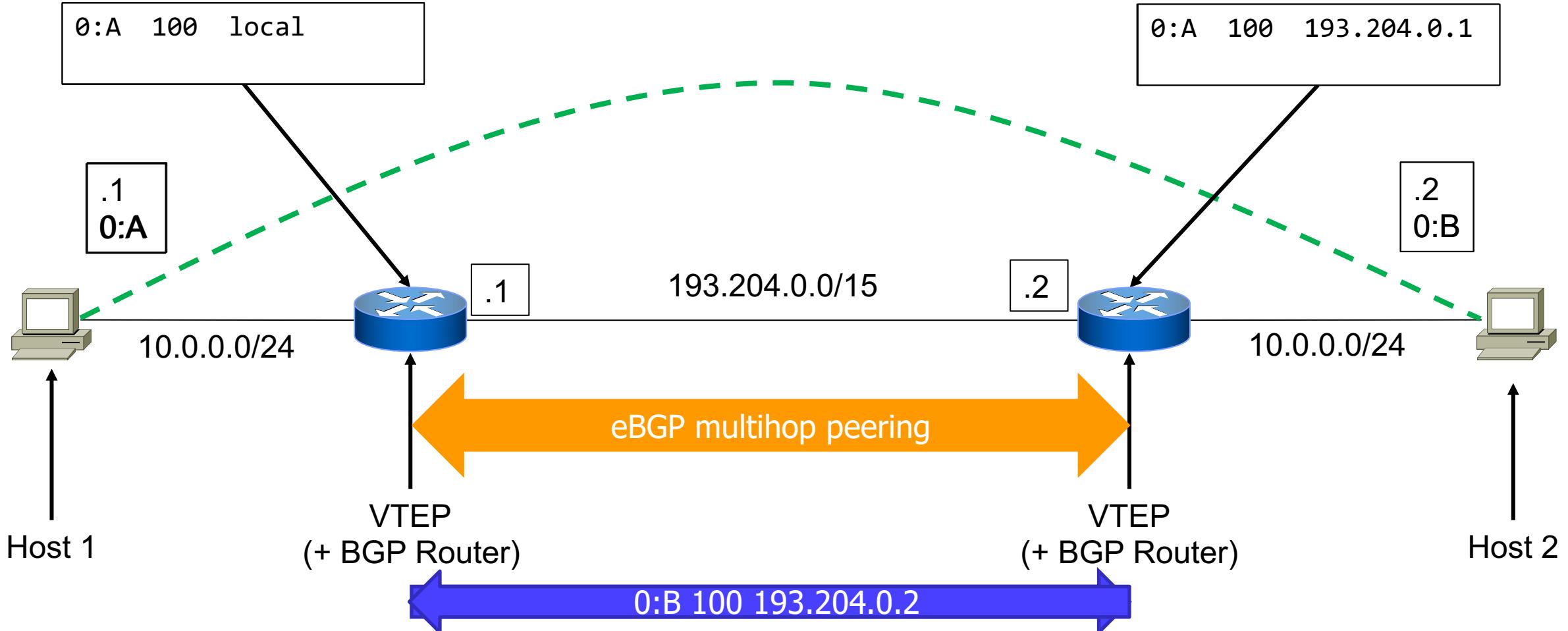


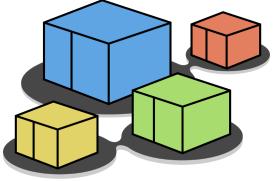
EVPN-BGP

- Ethernet VPN (RFC-7432 and RFC-8365)
- uses MP-BGP with specific AFI/SAFI
 - Address Family Identifier/Subsequent AFI
 - AFI=25 (L2VPN) – SAFI=70 (EVPN)
- advertises MAC Addresses of VNIs using BGP updates
- a VTEP automatically learns local MAC Addresses and advertises them to all other VTEPs (of the same VNI)
- VTEP proxies ARP requests to limit broadcast traffic



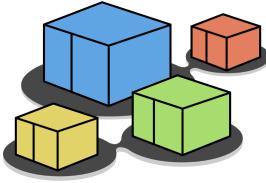
VXLAN and EVPN-BGP transport



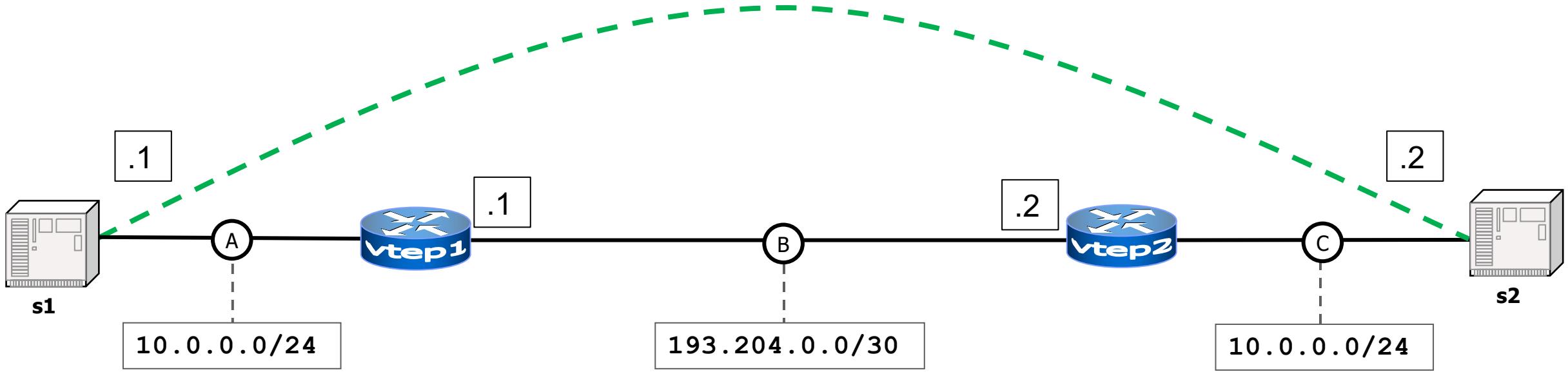


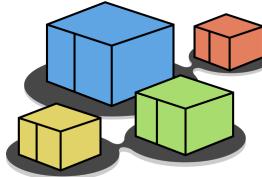
VXLAN and EVPN-BGP Lab

time to use Kathará



topology





lab base config – topology, s1, and s2

lab.conf

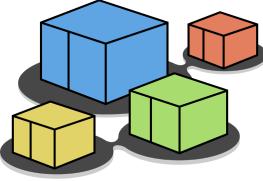
```
s1[0]=A  
  
vtep1[0]=A  
vtep1[1]=B  
  
vtep2[0]=C  
vtep2[1]=B  
  
s2[0]=C
```

s1.startup

```
ip address add 10.0.0.1/24 dev eth0  
ip link set dev eth0 mtu 1450  
systemctl start apache2
```

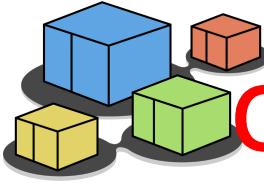
s2.startup

```
ip address add 10.0.0.2/24 dev eth0  
ip link set dev eth0 mtu 1450  
systemctl start apache2
```



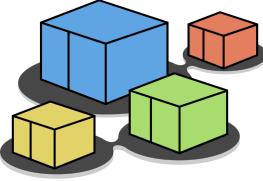
MTU

- need to set manual MTU of each device's interface associated to a VNI
- when a frame is encapsulated by a VTEP, if its size is greater than 1450 (LAN MTU – VXLAN overhead)
 - the frame is dropped
 - an ICMP "packet too big" message is sent back



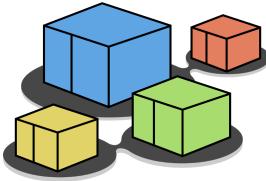
configuring a bridge/router with VTEPs

- we need to configure a Kathara device that is able to:
 - act as a bridge on L2 ports
 - able to perform L2 learning
 - act as a router on the ports on the underlay networks
 - able to establish BGP peerings
 - able to encapsulate/decapsulate VXLAN traffic

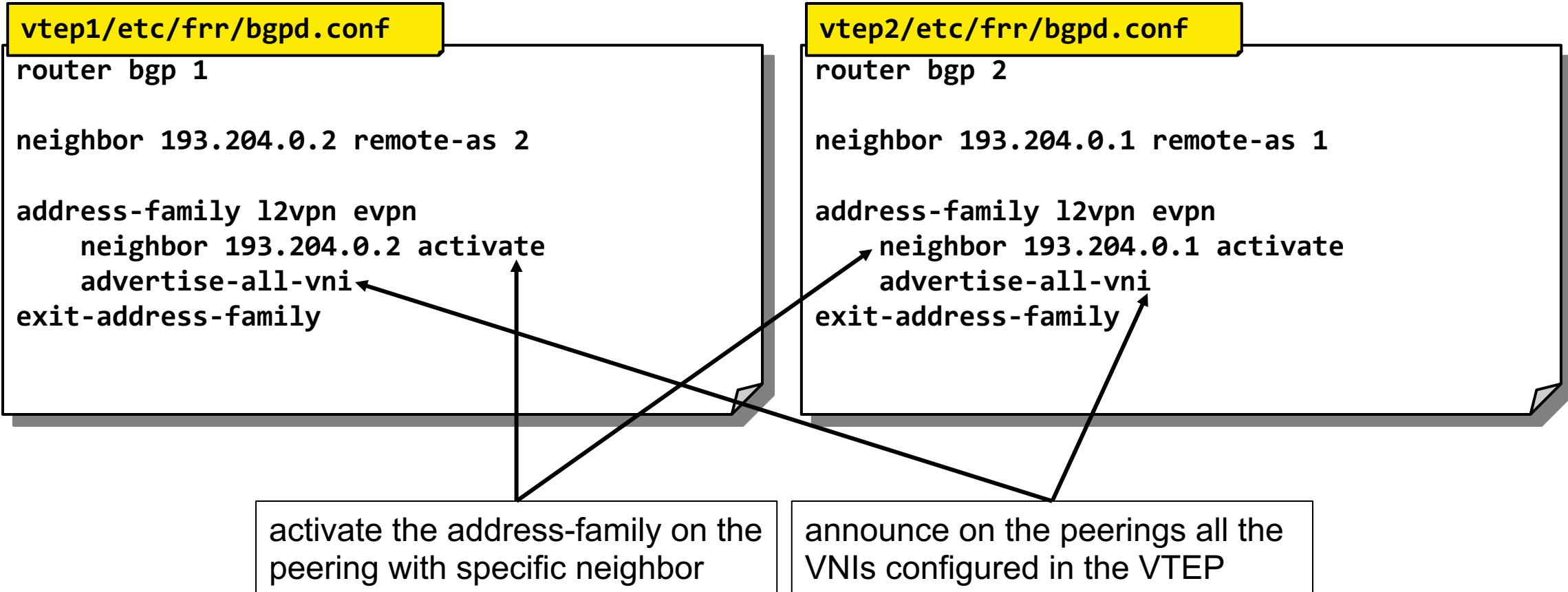


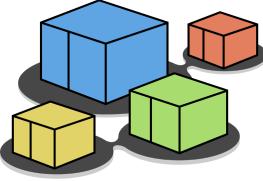
VTEP configuration

- create bridge facilities (aka companion bridges)
 - one virtual bridge with ports assigned to VLANs corresponding to VNIs
- attach the collision domains associated to a VNI to the companion bridge of that VNI
- configure the base BGP peerings
 - enable the AFI/SAFI of EVPN
- configure VXLAN



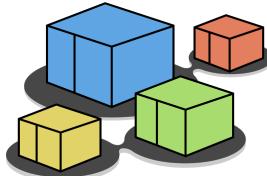
vtep e-BGP configuration





companion bridge

- the bridge connected to VTEP interfaces
- used by the VTEP to perform source address learning of local interfaces
- when in combination with EVPN-BGP
 - its forwarding table is also populated via updates received from BGP
 - the FRR control plane watch to updates of the bridge forwarding table to send updates via BGP



vtep1 bridge configuration

vtep1.startup

```
ip address add 193.204.0.1/30 dev eth1
```

Setting up VXLAN interfaces

```
ip link add vtep100 type vxlan id 100 dev eth1 dstport 4789 local 193.204.0.1 nolearning  
ip link set up dev vtep100
```

Creating the companion bridge

```
ip link add br100 type bridge  
# Attach interfaces to the bridge
```

```
ip link set dev vtep100 master br100 noforward none
```

```
ip link set vtep100 type bridge name of the interface ss on learning off
```

```
ip link set dev eth0 master br100
```

Enable bridge vlans

```
ip link set dev br100 create the interface tering 1  
bridge vlan add vid 100 dev vtep100 pvid untagged  
bridge vlan add vid 100 dev eth0 pvid untagged  
ip link set up dev br100
```

Enabling FRR

```
systemctl start frr
```

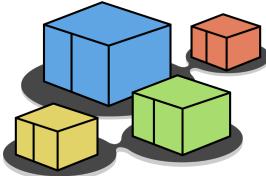
VNI

VXLAN dst port

VXLAN src IP

attach eth0 (the server s1 collision domain) to the bridge

disable the mcast learning



vtep1 bridge configuration

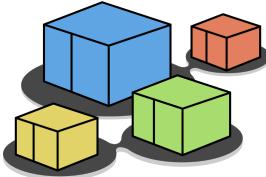
vtep1.startup

```
ip address add 193.204.0.1/30 dev eth1

# Setting up VXLAN interfaces
ip link add vtep100 type vxlan id 100 dev eth1 dstport 4789 local 193.204.0.1 nolearning
ip link set up dev vtep100

# Creating the companion bridge
ip link add br100 type bridge
# Attach interfaces to the bridge
ip link set dev vtep100 master br100 addrgenmode none
ip link set vtep100 type bridge_slave learning off
ip link set dev eth0 master br100
# Enable bridge vlans
ip link set dev br100 type bridge_vlan_filtering 1
bridge vlan add vid 100 dev vtep100 pvid untagged
bridge vlan add vid 100 dev eth0 pvid untagged
ip link set up dev br100

# Enabling FRR
systemctl start frr
```



vtep1 bridge configuration

vtep1.startup

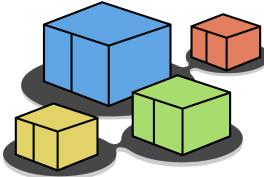
```
ip address add 193.204.0.1/30 dev eth1

# Setting up VXLAN interfaces
ip link add vtep100 type vxlan id 100 dev eth1 dstport 4789 local 193.204.0.1 nolearning
ip link set up dev vtep100

# Creating the companion bridge
ip link add br100 type bridge←
# Attach interfaces to the bridge
ip link set dev vtep100 master br100 addrgenmode none
ip link set vtep100 type bridge_slave neigh_suppress on learning off
ip link set dev eth0 master br100
# Enable bridge vlans
ip link set dev br100 type bridge_vlan_filtering 1
bridge vlan add vid 100 dev vtep100 pvid untagged
bridge vlan add vid 100 dev eth0 pvid untagged
ip link set up dev br100

# Enabling FRR
systemctl start frr
```

create the companion bridge and name it



vtep1 bridge configuration

vtep1.startup

```
ip address add 193.204.0.1/30 dev eth1

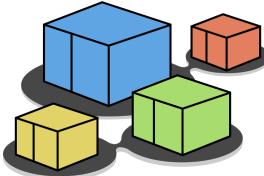
# Setting up VXLAN interfaces
ip link add vtep100 type vxlan id 100 dev eth1 dstport 4789 local 193.204.0.1 nolearning
ip link set up dev vtep100

# Creating the companion bridge
ip link add br100 type bridge
# Attach interfaces to the bridge
ip link set dev vtep100 master br100 addrgenmode none
ip link set vtep100 type bridge_slave neigh_suppress on learning off
ip link set dev eth0 master br100
# Enable bridge vlans
ip link set dev br100 type bridge vlan_filtering 1
bridge vlan add vid 100 dev vtep100 pvid untagged
bridge vlan add vid 100 dev eth0 pvid untagged
ip link set up dev br100

# Enabling FRR
systemctl start frr
```

attach the VXLAN interface to the bridge

do not generate IPv6 link-local addresses



vtep1 bridge configuration

vtep1.startup

```
ip address add 193.204.0.1/30 dev eth1

# Setting up VXLAN interfaces
ip link add vtep100 type vxlan id 100 dev eth1 dstport 4789 local 193.204.0.1 nolearning
ip link set up dev vtep100

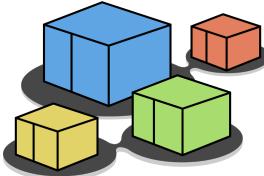
# Creating the companion bridge
ip link add br100 type bridge
# Attach interfaces to the bridge
ip link set dev vtep100 master br100 addrgenmode none
ip link set vtep100 type bridge_slave neigh_suppress on learning off
ip link set dev eth0 master br100
# Enable bridge vlans
ip link set dev br100 type bridge vlan_filtering 1
bridge vlan add vid 100 dev vtep100 pvid untagged
bridge vlan add vid 100 dev eth0 pvid untagged
ip link set up dev br100

# Enabling FRR
systemctl start frr
```

suppress neighbor
discovery (ARP and
ND)

do not learn MAC
addresses

set the type of
vtep100 to
bridge_slave



vtep1 bridge configuration

vtep1.startup

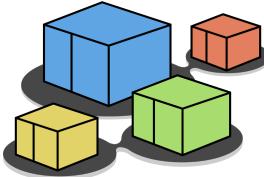
```
ip address add 193.204.0.1/30 dev eth1

# Setting up VXLAN interfaces
ip link add vtep100 type vxlan id 100 dev eth1 dstport 4789 local 193.204.0.1 nolearning
ip link set up dev vtep100

# Creating the companion bridge
ip link add br100 type bridge
# Attach interfaces to the bridge
ip link set dev vtep100 master br100 addrgenmode none
ip link set vtep100 type bridge_slave neigh_suppress on learning off
ip link set dev eth0 master br100
# Enable bridge vlans
ip link set dev br100 type bridge vlan_filtering 1
bridge vlan add vid 100 dev vtep100 pvid untagged
bridge vlan add vid 100 dev eth0 pvid untagged
ip link set up dev br100

# Enabling FRR
systemctl start frr
```

attach eth0 (the server s1 collision domain) to the bridge



vtep1 bridge configuration

vtep1.startup

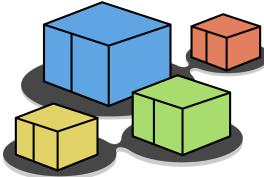
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# Creating the companion bridge
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# Attach interfaces to the bridge
ip link set dev vtep100 master br100 addrgenmode none
ip link set vtep100 type bridge_slave neigh_suppress on learning off
ip link set dev eth0 master br100
# Enable bridge vlans
ip link set dev br100 type bridge vlan_filtering 1
bridge vlan add vid 100 dev vtep100 pvid untagged
bridge vlan add vid 100 dev eth0 pvid untagged
ip link set up dev br100

# Enabling FRR
systemctl start frr
```

enable VLANs on the bridge



vtep1 bridge configuration

vtep1.startup

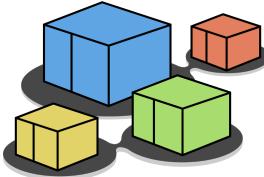
```
ip address add 193.204.0.1/30 dev eth1

# Setting up VXLAN interfaces
ip link add vtep100 type vxlan id 100 dev eth1 dstport 4789 local 193.204.0.1 nolearning
ip link set up dev vtep100

# Creating the companion bridge
ip link add br100 type bridge
# Attach interfaces to the bridge
ip link set dev vtep100 master br100 addrgenmode none
ip link set vtep100 type bridge_slave neigh_suppress on learning off
ip link set dev eth0 master br100
# Enable bridge vlans
ip link set dev br100 type bridge vlan_filtering 1
bridge vlan add vid 100 dev vtep100 pvid untagged
bridge vlan add vid 100 dev eth0 pvid untagged
ip link set up dev br100

# Enabling FRR
systemctl start frr
```

configure VLANs on
bridge ports



vtep1 bridge configuration

vtep1.startup

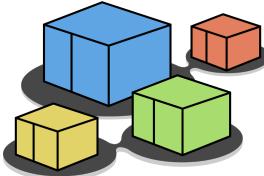
```
ip address add 193.204.0.1/30 dev eth1

# Setting up VXLAN interfaces
ip link add vtep100 type vxlan id 100 dev eth1 dstport 4789 local 193.204.0.1 nolearning
ip link set up dev vtep100

# Creating the companion bridge
ip link add br100 type bridge
# Attach interfaces to the bridge
ip link set dev vtep100 master br100 addrgenmode none
ip link set vtep100 type bridge_slave neigh_suppress on learning off
ip link set dev eth0 master br100
# Enable bridge vlans
ip link set dev br100 type bridge vlan_filtering 1
bridge vlan add vid 100 dev vtep100 pvid untagged
bridge vlan add vid 100 dev eth0 pvid untagged
ip link set up dev br100

# Enabling FRR
systemctl start frr
```

enable the bridge



vtep2 bridge configuration

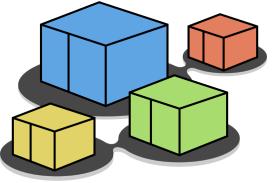
vtep2.startup

```
ip address add 193.204.0.2/30 dev eth1

# Setting up VXLAN interfaces
ip link add vtep100 type vxlan id 100 dev eth1 dstport 4789 local 193.204.0.2 nolearning
ip link set up dev vtep100

# Creating the companion bridge
ip link add br100 type bridge
# Attach interfaces to the bridge
ip link set dev vtep100 master br100 addrgenmode none
ip link set vtep100 type bridge_slave neigh_suppress on learning off
ip link set dev eth0 master br100
# Enable bridge vlans
ip link set dev br100 type bridge vlan_filtering 1
bridge vlan add vid 100 dev vtep100 pvid untagged
bridge vlan add vid 100 dev eth0 pvid untagged
ip link set up dev br100

# Enabling FRR
systemctl start frr
```

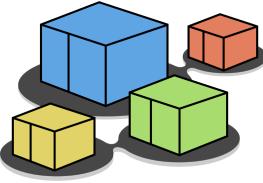


the EVPN-BGP control-plane

```
vtep1# show evpn mac vni all

VNI 100 #MACs (local and remote) 2

Flags: N=sync-neighs, I=local-inactive, P=peer-active, X=peer-proxy
MAC          Type   Flags Intf/Remote ES/VTEP      VLAN Seq #'s
a2:6d:c7:06:6f remote    193.204.0.2
c2:93:31:36:31:b6 local     eth0               0/0
                                         0/0
```



a BGP update

```
> Frame 3: 170 bytes on wire (1360 bits), 170 bytes captured (1360 bits)
> Ethernet II, Src: ee:8d:53:3a:12:b5 (ee:8d:53:3a:12:b5), Dst: ea:4f:03:8c:4b:95 (ea:4f:03:8c:4b:95)
> Internet Protocol Version 4, Src: 193.204.0.2, Dst: 193.204.0.1
> Transmission Control Protocol, Src Port: 41530, Dst Port: 179, Seq: 1, Ack: 1, Len: 104
> Border Gateway Protocol - UPDATE Message
  Marker: fffffffffffffffffffff
  Length: 104
  Type: UPDATE Message (2)
  Withdrawn Routes Length: 0
  Total Path Attribute Length: 81
  < Path attributes
    < Path Attribute - MP_REACH_NLRI
      > Flags: 0x90, Optional, Extended-Length, Non-transitive, Complete
      Type Code: MP_REACH_NLRI (14)
      Length: 44
      Address family identifier (AFI): Layer-2 VPN (25)
      Subsequent address family identifier (SAFI): EVPN (70)
      > Next hop: 193.204.0.2
      Number of Subnetwork points of attachment (SNPA): 0
    < Network Layer Reachability Information (NLRI)
      < EVPN NLRI: MAC Advertisement Route
        Route Type: MAC Advertisement Route (2)
        Length: 33
        Route Distinguisher: 0001c1cc00020002 (193.204.0.2:2)
        > ESI: 00:00:00:00:00:00:00:00
        Ethernet Tag ID: 0
        MAC Address Length: 48
        MAC Address: a2:6d:75:c7:06:6f (a2:6d:75:c7:06:6f)
        IP Address Length: 0
        > IP Address: NOT INCLUDED
        VNI: 100
      > Path Attribute - ORIGIN: IGP
      > Path Attribute - AS_PATH: 2
      > Path Attribute - EXTENDED_COMMUNITIES
```

from vtep2 to vtep1

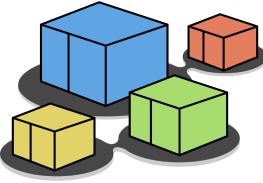
announcement

AFI/SAFI of l2vpn/EVPN

VTEP destination

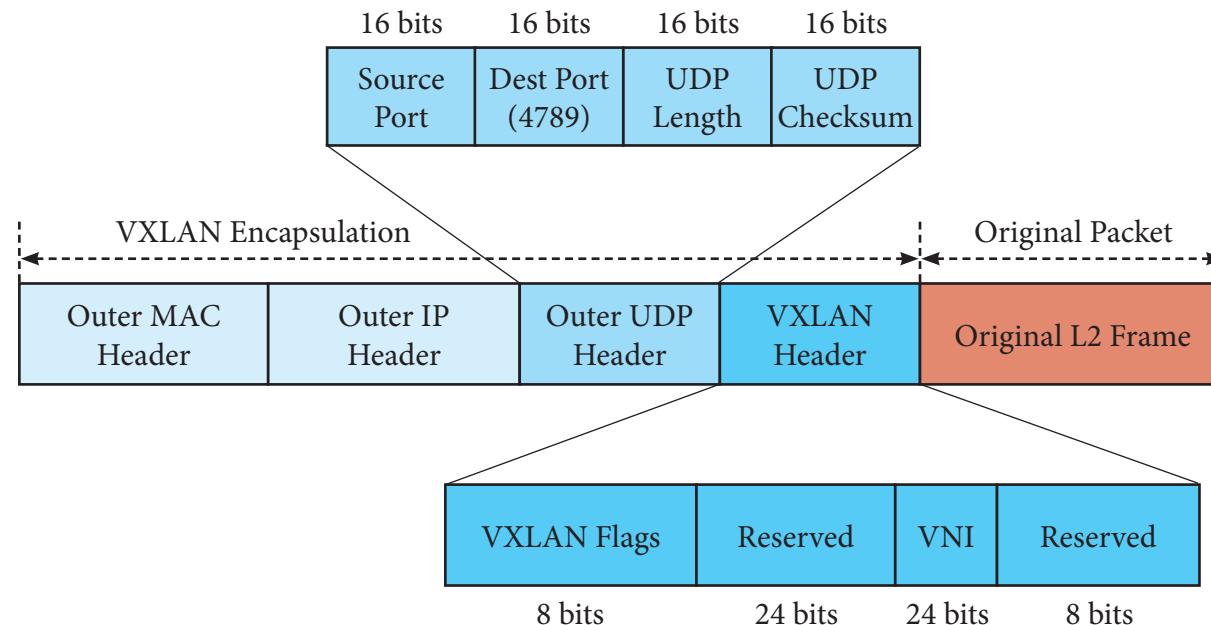
MAC address of s1

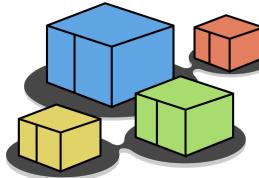
VNI of s1



VXLAN encapsulation

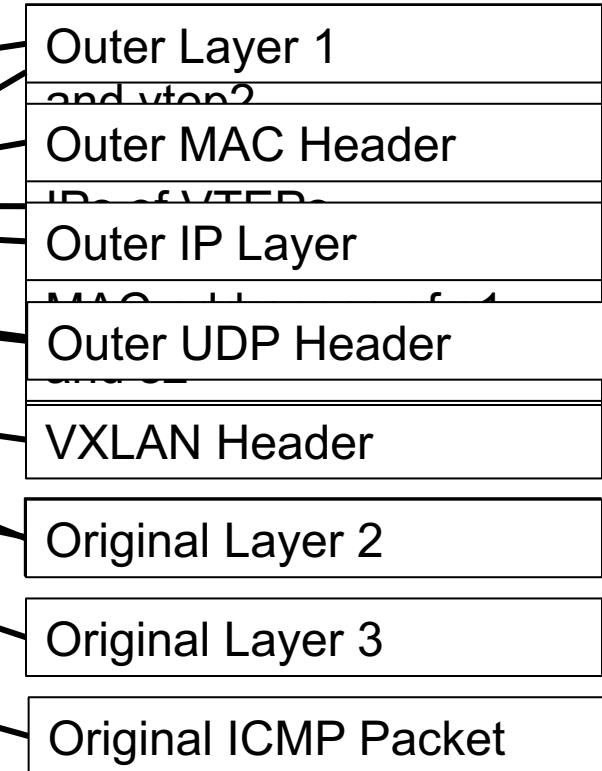
- overhead of 50 bytes
- random Source Port to fully exploit Multi-Path

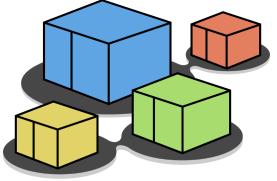




a PING packet encapsulated in VXLAN

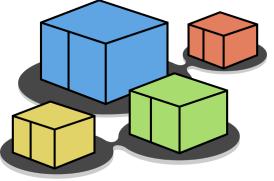
```
> Frame 11: 148 bytes on wire (1184 bits), 148 bytes captured (1184 bits)
> Ethernet II, Src: ea:4f:03:8c:4b:95 (ea:4f:03:8c:4b:95), Dst: ee:8d:53:3a:12:b5 (ee:8d:53:3a:12:b5)
> Internet Protocol Version 4, Src: 193.204.0.1, Dst: 193.204.0.2
> User Datagram Protocol, Src Port: 38648, Dst Port: 4789
> Virtual eXtensible Local Area Network
> Ethernet II, Src: c2:93:31:36:31:b6 (c2:93:31:36:31:b6), Dst: a2:6d:75:c7:06:6f (a2:6d:75:c7:06:6f)
> Internet Protocol Version 4, Src: 10.0.0.1, Dst: 10.0.0.2
< Internet Control Message Protocol
  Type: 8 (Echo (ping) request)
  Code: 0
  Checksum: 0x0945 [correct]
  [Checksum Status: Good]
  Identifier (BE): 11 (0x000b)
  Identifier (LE): 2816 (0xb00)
  Sequence Number (BE): 2 (0x0002)
  Sequence Number (LE): 512 (0x0200)
  [Response frame: 12]
  Timestamp from icmp data: Dec 6, 2022 15:59:10.000000000 CET
  [Timestamp from icmp data (relative): 0.401357000 seconds]
> Data (48 bytes)
```





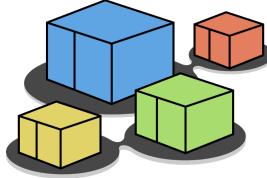
putting together

(EVPN-)BGP ☺

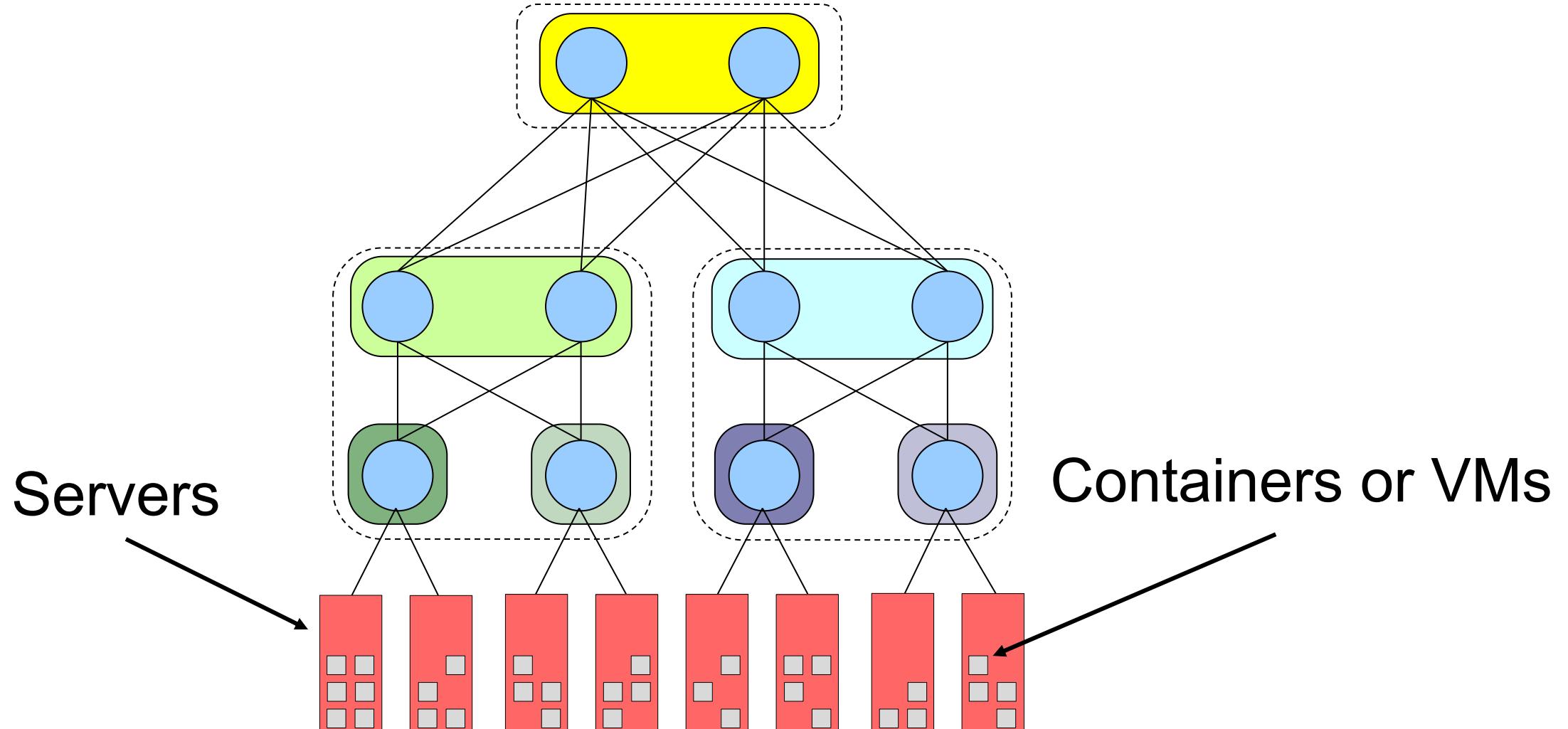


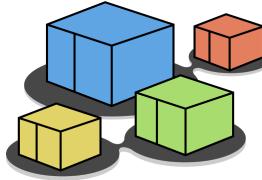
overview

- containers or VMs of different tenants
- where is the VTEP?
- the Leaf-server links
- inside the servers
- dual attached servers
- a complete lab experience



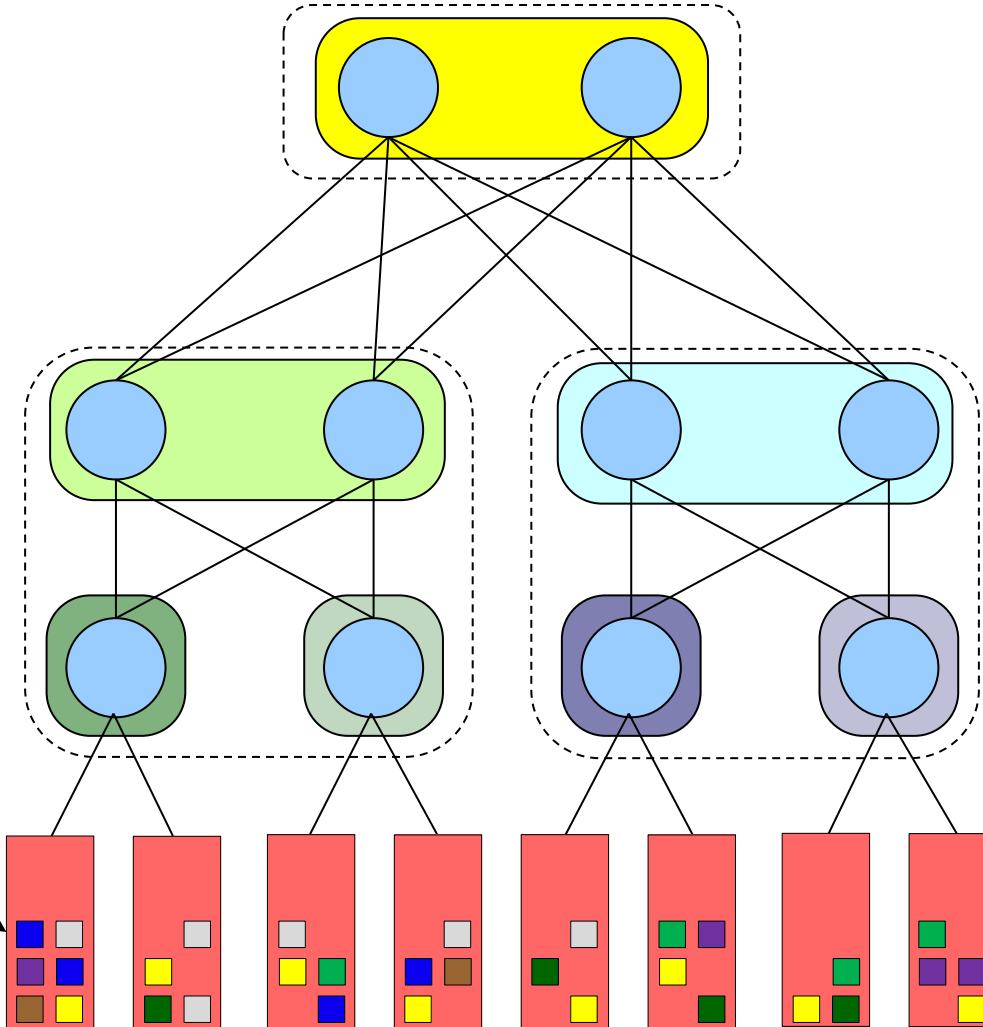
servers in the fabric – recap

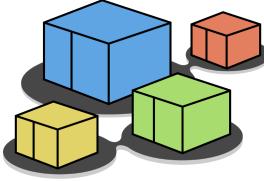




containers or VMs of different tenants

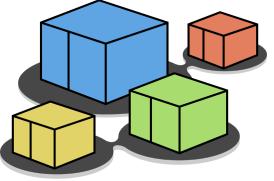
different colours
represent different
tenants





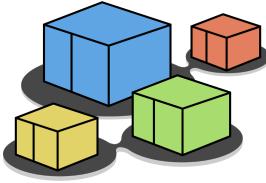
EVPN-BGP – where is the VTEP?

- containers must be unaware of tunneling
- different choices for positioning the VTEP
 - in each server
 - the server should have a BGP peering for enabling EVPN-BGP
 - the server CPU would be used to route packets
 - in each Leaf
 - a Leaf already has a BGP peering
 - a Leaf is a router, so it has dedicated routing hardware
 - usage of VLANs in the link connecting a Leaf and a server to distinguish tenants



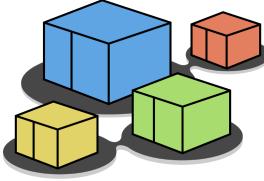
inside the Leaves

- VLANs are used
- mapping between VNIs and VLAN IDs
 - tenants are unaware of the mapping
- Leaves decapsulate VXLAN received packets and encapsulate them into VLAN frames, according to the mapping
 - and vice-versa

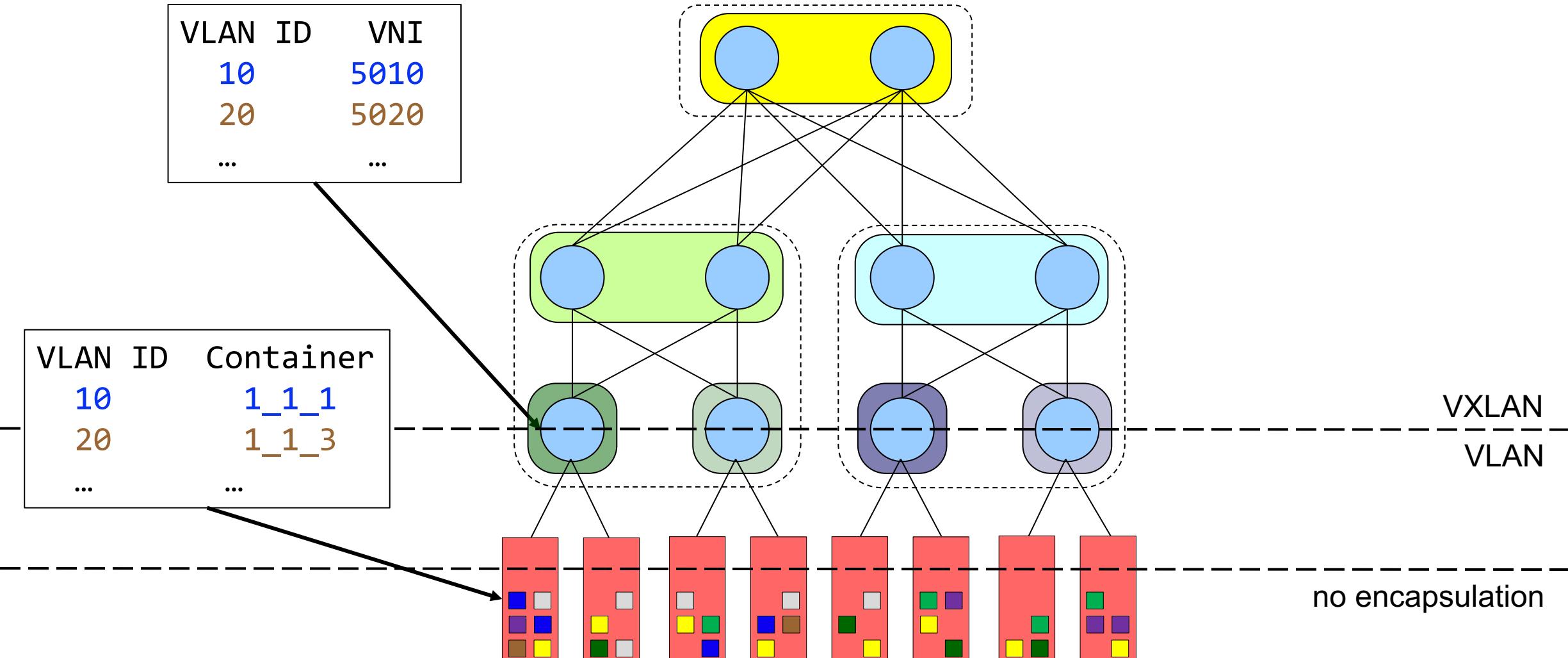


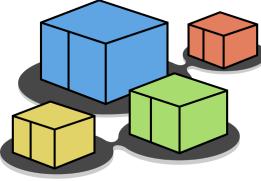
inside the servers

- the server uses the VLAN IDs to forward packets to the correct containers/VMs
- the server untags the packets so that the containers/VMs are unaware of the VLANs
 - containers/VMs of the same tenant share the same virtual Layer-2 network



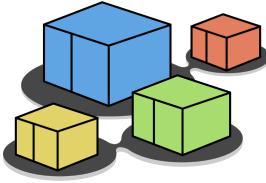
deploying VXLAN





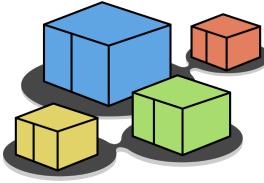
the last problem to overcome

- if a Leaf-server link breaks down, the server is severed off the data center
- if a Leaf breaks, all the servers connected to that Leaf are severed off the data center
- if a maintenance needs to be done on a Leaf, all the servers connected to that Leaf are temporarily severed off the data center

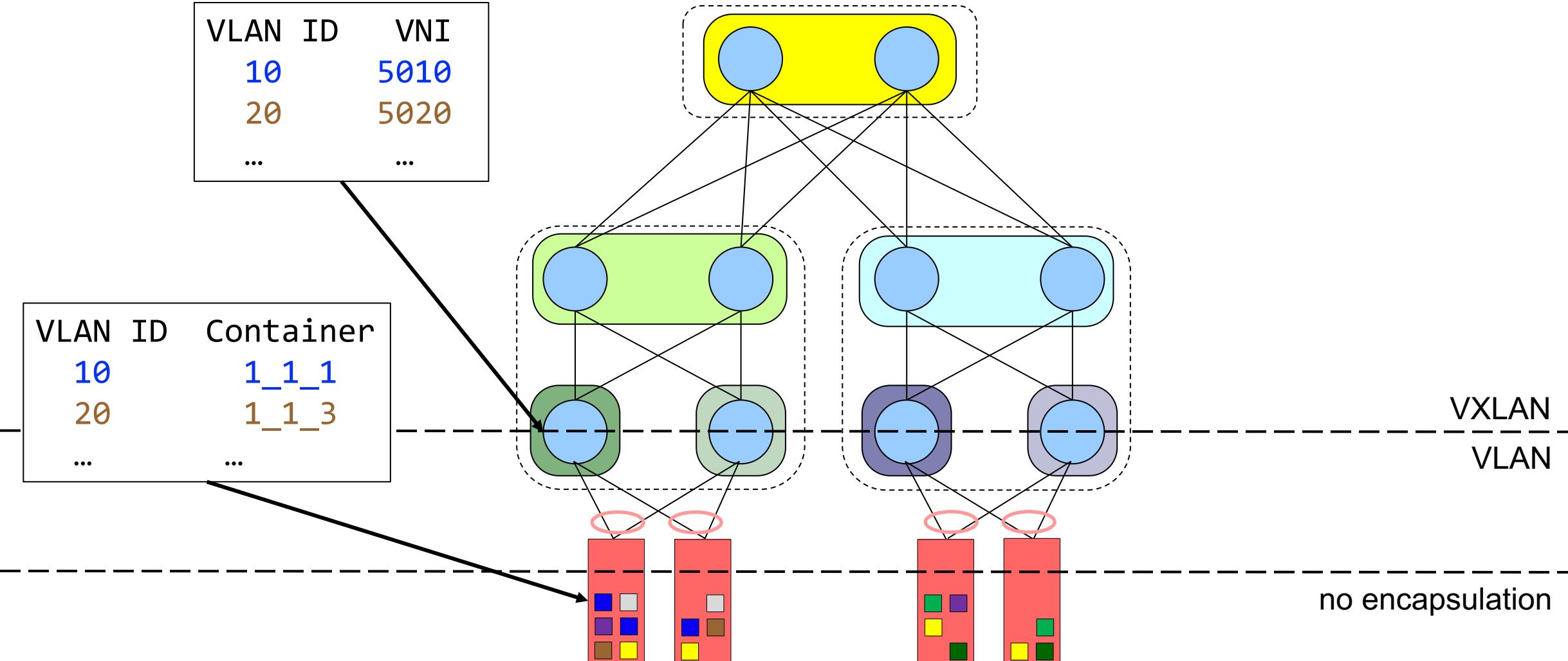


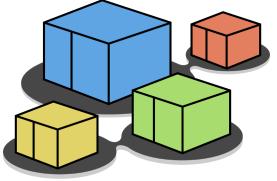
dual attached servers – bonding

- aggregates multiple NICs into a single virtual interface
- Layer-2 technology
- different policies are possible
 - active-backup
 - active-active
 - balance-rr
 - balance-xor
 - 802.3ad
 - and more...



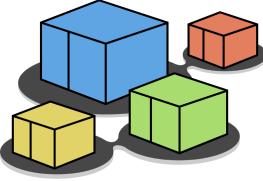
the full picture





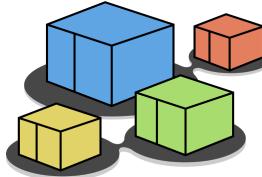
EVPN-BGP Fat-Tree lab

hands on Kathará

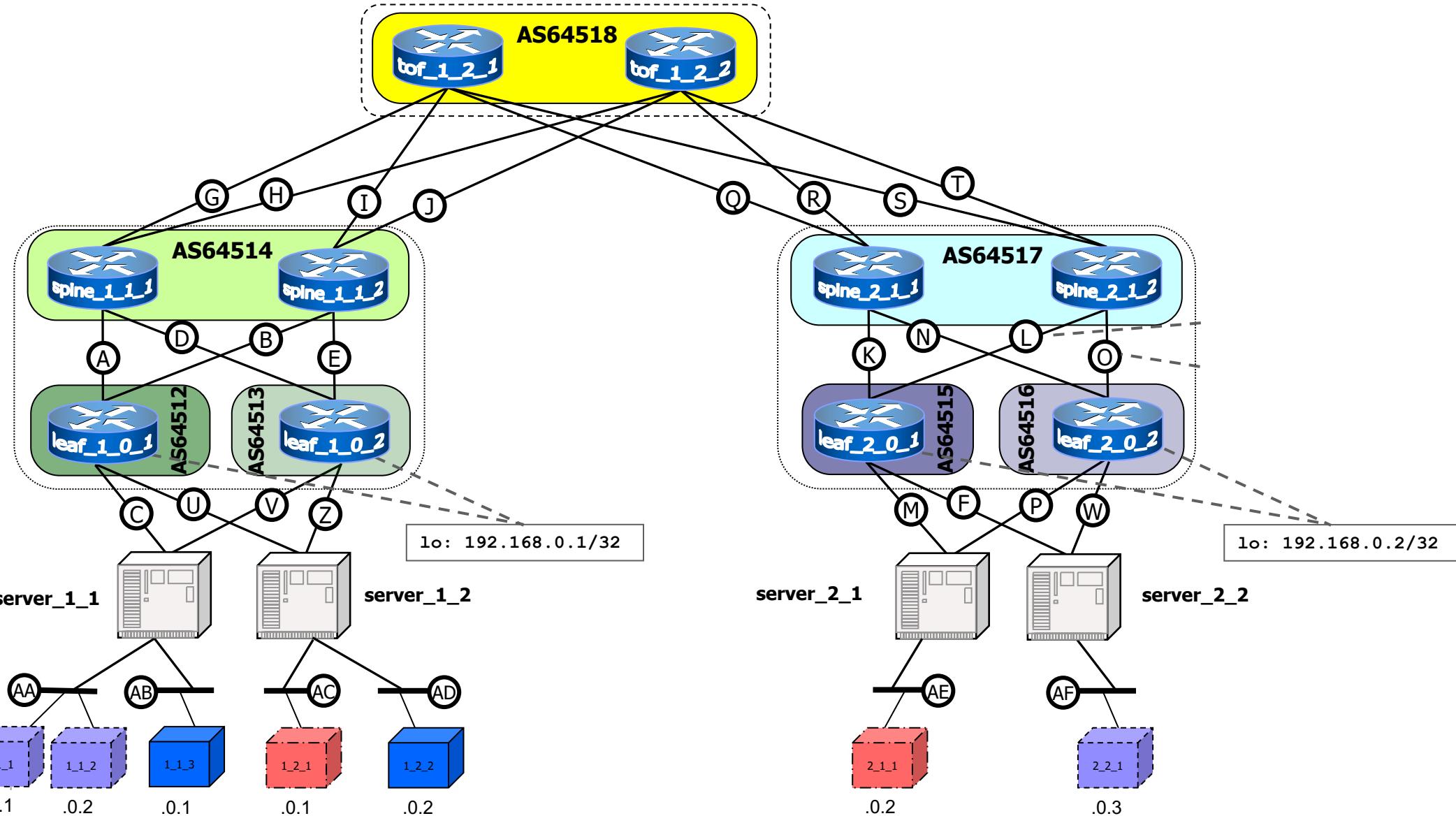


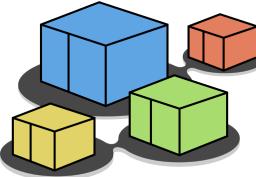
anycast BGP

- technique that allows different devices to share the same IP address
- often used in the Internet with DNS servers and CDN servers
- BGP chooses among the nearest instance of the IP address
- in the data center, multipath is exploit to balance over multiple instances of the same anycast IPs



lab topology





leaf configuration example – part 1

leaf_1_0_1.startup

Create loopback

```
ip addr add 192.168.0.1/32 dev lo
ip route add 192.168.0.1/32 dev lo
```

configure an anycast IP address on the loopback interface

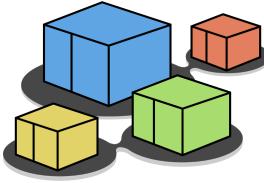
Setting up VXLAN interfaces

```
ip link add vtep5010 type vxlan id 5010 dev lo dstport 4789 local 192.168.0.1 nolearning
ip link set up dev vtep5010
```

```
ip link add vtep5020 type vxlan id 5020 dev lo dstport 4789 local 192.168.0.1 nolearning
ip link set up dev vtep5020
```

```
ip link add vtep5030 type vxlan id 5030 dev lo dstport 4789 local 192.168.0.1 nolearning
ip link set up dev vtep5030
```

set source IP for the VTEPs to be the loopback IP



leaf configuration example – part 2

leaf_1_0_1.startup - part 2

```
ip link add bond2 type bond miimon 100 mode 802.3ad
```

create the bond interface

```
ip link set down dev eth2
```

disable interfaces

```
ip link set dev eth2 master bond2
```

connect physical interfaces to the bond

```
ip link set up dev eth2
```

enable the interfaces

```
ip link set up dev bond2
```

```
ip link add bond3 type bond miimon 100 mode 802.3ad
```

```
ip link set down dev eth3
```

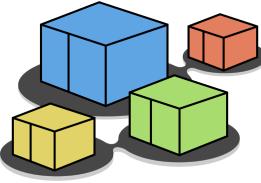
```
ip link set dev eth3 master bond3
```

```
ip link set up dev eth3
```

```
ip link set up dev bond3
```

Creating the companion bridge

```
ip link add br100 type bridge
```



leaf configuration example – part 3

leaf_1_0_1.startup - part 3

```
# Attach interfaces to the bridge
ip link set dev vtep5010 master br100
ip link set dev vtep5020 master br100
ip link set dev vtep5030 master br100
ip link set dev bond2 master br100
ip link set dev bond3 master br100

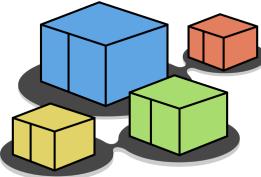
# Enable bridge vlans
ip link set dev br100 type bridge vlan_filtering 1
bridge vlan add vid 10 dev vtep5010 pvid untagged
bridge vlan add vid 20 dev vtep5020 pvid untagged
bridge vlan add vid 30 dev vtep5030 pvid untagged
bridge vlan add vid 10 dev bond2
bridge vlan add vid 20 dev bond2
bridge vlan add vid 20 dev bond3
bridge vlan add vid 30 dev bond3
ip link set up dev br100

systemctl start frr
```

enable VLANs on the bridge

configure the vtep ports to receive/send untagged traffic of specific VLANs

configure the server ports to receive/send VLAN tagged traffic of specific VLANs



leaf BGP configuration example

bgpd.conf - part 1

```
router bgp 64512
  timers bgp 3 9
  bgp router-id 192.168.0.1
  no bgp ebgp-requires-policy
  bgp bestpath as-path multi
```

```
neighbor TOR peer-group
  neighbor TOR remote-as external
  neighbor TOR advertisement-interval 0
  neighbor TOR timers connect 10
  neighbor eth0 interface peer-group TOR
  neighbor eth1 interface peer-group TOR
```

enable the l2vpn evpn
AFI/SAFI A.F.

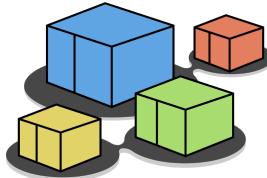
bgpd.conf - part 2

```
address-family ipv4 unicast
  neighbor TOR activate
  redistribute connected route-map LOOPBACKS
  maximum-paths 64
  exit-address-family
```

```
address-family l2vpn evpn
  neighbor TOR activate
  advertise-all-vni
  exit-address-family
```

```
route-map LOOPBACKS permit 10
  match interface lo
```

route-map to announce
the loopback IP



spine BGP configuration example

bgpd.conf - part 1

```
router bgp 64514
  timers bgp 3 9
  bgp router-id 192.168.0.5
  no bgp ebgp-requires-policy
  bgp bestpath as-path multipath-relax

  neighbor TOR peer-group
    neighbor TOR remote-as external
    neighbor TOR advertisement-interval 0
    neighbor TOR timers connect 10
    neighbor eth0 interface peer-group TOR
    neighbor eth1 interface peer-group TOR
```

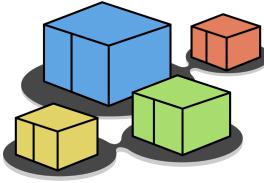
bgpd.conf - part 2

```
neighbor fabric peer-group
  neighbor fabric remote-as external
  neighbor fabric advertisement-interval 0
  neighbor fabric timers connect 10
  neighbor eth2 interface peer-group fabric
  neighbor eth3 interface peer-group fabric
```

```
address-family ipv4 unicast
  neighbor fabric activate
  neighbor TOR activate
  maximum-paths 64
exit-address-family
```

```
address-family l2vpn evpn
  neighbor fabric activate
  neighbor TOR activate
exit-address-family
```

activate the l2vpn evpn
AFI/SAFI A.F.



ToF BGP configuration example

bgpd.conf - part 1

```
router bgp 64518
  timers bgp 3 9
  bgp router-id 192.168.0.13
  no bgp ebgp-requires-policy
  bgp bestpath as-path multipath-relax
```

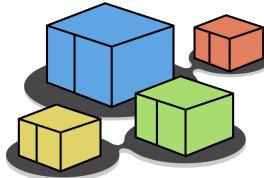
bgpd.conf - part 2

```
neighbor fabric peer-group
  neighbor fabric remote-as external
  neighbor fabric advertisement-interval 0
  neighbor fabric timers connect 10
  neighbor eth0 interface peer-group fabric
  neighbor eth1 interface peer-group fabric
  neighbor eth2 interface peer-group fabric
  neighbor eth3 interface peer-group fabric
```

```
address-family ipv4 unicast
  neighbor fabric activate
  maximum-paths 64
exit-address-family
```

```
address-family l2vpn evpn
  neighbor fabric activate
exit-address-family
```

activate the l2vpn evpn
AFI/SAFI A.F.



server configuration example – part 1

server_1_1.startup

```
ip link add bond1 type bond miimon 100 mode 802.3ad xmit_hash_policy layer3+4 all_slaves_active 1
ip link set dev eth0 down
ip link set dev eth1 down
ip link set dev bond1 down
ip link set eth0 master bond1
ip link set eth1 master bond1
ip link set dev eth0 up
ip link set dev eth1 up
ip link set dev bond1 up

# Creating the bridge
ip link add br100 type bridge

# Attach interfaces to the bridge
ip link set dev bond1 master br100
ip link set dev eth2 master br100
ip link set dev eth3 master br100
```

create the bond interface

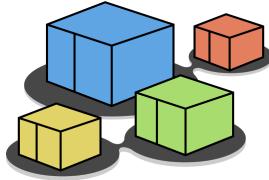
disable interfaces

connect physical interfaces to the bond

enable the interfaces

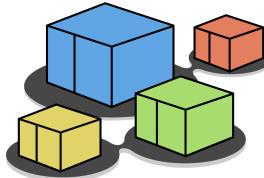
create the bridge

connect the bond and container interfaces to the bridge



why 802.3ad with active-backup?

- usually the right policy is active-active with hash policy
- to support dual attached servers in active-active mode to different switches (leaves), Multi-Chassis Link Aggregation (MLAG) is needed
 - MLAG enables a server or switch with a two-port bond, to connect those ports to different switches and operate as if they are connected to a single, logical switch. This provides greater redundancy and greater system throughput.
- classic Linux kernels do not support MLAG



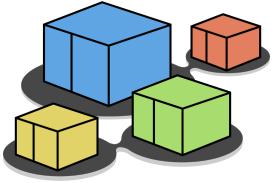
server configuration example – part 2

server_1_1.startup

```
# Enable bridge vlans
ip link set dev br100 type bridge vlan_filtering 1
bridge vlan add vid 10 dev bond1
bridge vlan add vid 20 dev bond1
bridge vlan add vid 10 dev eth2 pvid untagged
bridge vlan add vid 20 dev eth3 pvid untagged
ip link set up dev br100
```

configure the bond port
of the bridge to receive
tagged VLAN packets

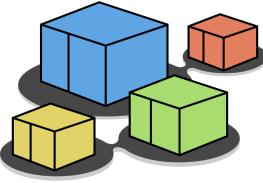
configure the container
ports to send untagged
frames



a leaf data plane

```
root@leaf_1_0_1:/# ip route

10.0.0.0/30 dev eth0 proto kernel scope link src 10.0.0.1
10.0.0.4/30 dev eth1 proto kernel scope link src 10.0.0.5
192.168.0.1 dev lo scope link
192.168.0.7 nhid 10 proto bgp metric 20
    nexthop via 10.0.0.2 dev eth0 weight 1
    nexthop via 10.0.0.6 dev eth1 weight 1
```



a leaf BGP control plane

```
leaf_1_1_1# show ip bgp
```

BGP table version is 2, local router ID is 192.168.0.1, vrf id 0

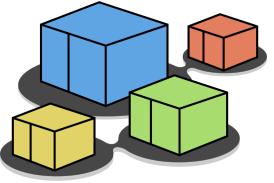
Default local pref 100, local AS 64512

Status codes: s suppressed, d damped, h history, * valid, > best, = multipath,
i internal, r RIB-failure, S Stale, R Removed

Nexthop codes: @NNN nexthop's vrf id, < announce-nh-self

Origin codes: i - IGP, e - EGP, ? - incomplete

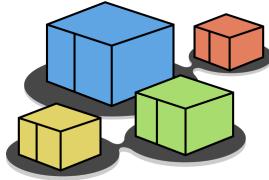
Network	Next Hop	Metric	LocPrf	Weight	Path
*> 192.168.0.1/32	0.0.0.0	0		32768	i
*> 192.168.0.7/32	10.0.0.2			0	64514 64518 64517 64515 i
*=	10.0.0.6			0	64514 64518 64517 64515 i



a leaf EVPN control plane

```
leaf_1_1_1# show evpn mac vni 5010

Number of MACs (local and remote) known for this VNI: 3
Flags: N=sync-neighs, I=local-inactive, P=peer-active, X=peer-proxy
MAC          Type   Flags Intf/Remote ES/VTEP      VLAN Seq #'s
8e:cf:26:1f:44:16 local    eth2                  10    0/0
d2:23:78:4a:e9:02 local    eth2                  10    0/0
76:76:b2:f0:18:6d remote  192.168.0.7          0/0
```



bibliography and further readings

- [Dutt '18] Dutt, "EVPN in the Data Center", O'Reilly, 2018
- [Bernat '17] Bernat, "VXLAN: BGP EVPN with FRR",
<https://vincent.bernat.ch/en/blog/2017-vxlan-bgp-evpn>
- [Bernat '17] Bernat, "VXLAN & Linux",
<https://vincent.bernat.ch/en/blog/2017-vxlan-linux>
- [RFC-7432] Sajassi, Aggarwal, Bitar, Isaac, Uttaro, Drake, Henderickx, "BGP MPLS-Based Ethernet VPN" Internet Engineering Task Force (IETF) Request for Comments: 7432
- [RFC-8365] Sajassi, Drake, Bitar, Shekhar, Uttaro, Henderickx, "A Network Virtualization Overlay Solution Using Ethernet VPN (EVPN)" Internet Engineering Task Force (IETF) Request for Comments: 8365