Cloud Networking (VITMMA02)
Network Virtualization: Overlay Networks
OpenStack Neutron Networking

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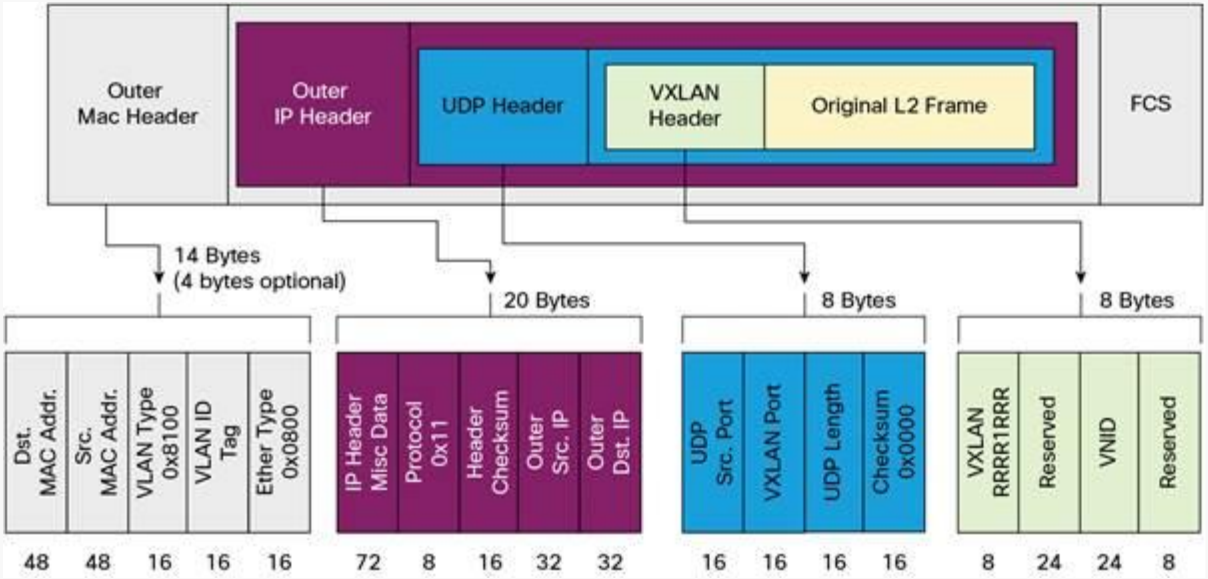
OVERLAY NETWORKS

Network Virtualization

- Support for tenant separation
  - Virtual Extensible LAN (VXLAN) – RFC 7348
    - Cisco, VMware
    - transport of virtual L2 traffic over physical L3 network
  - Network Virtualization using Generic Routing Encapsulation (NVGRE)
    - Microsoft, Intel, HP, Dell
  - Generic Network Virtualization Encapsulation (GENEVE)
    - superset of VXLAN and NVGRE
  - Stateless Transport Tunneling (STT)
    - Nicira ⇨ VMware

VXLAN

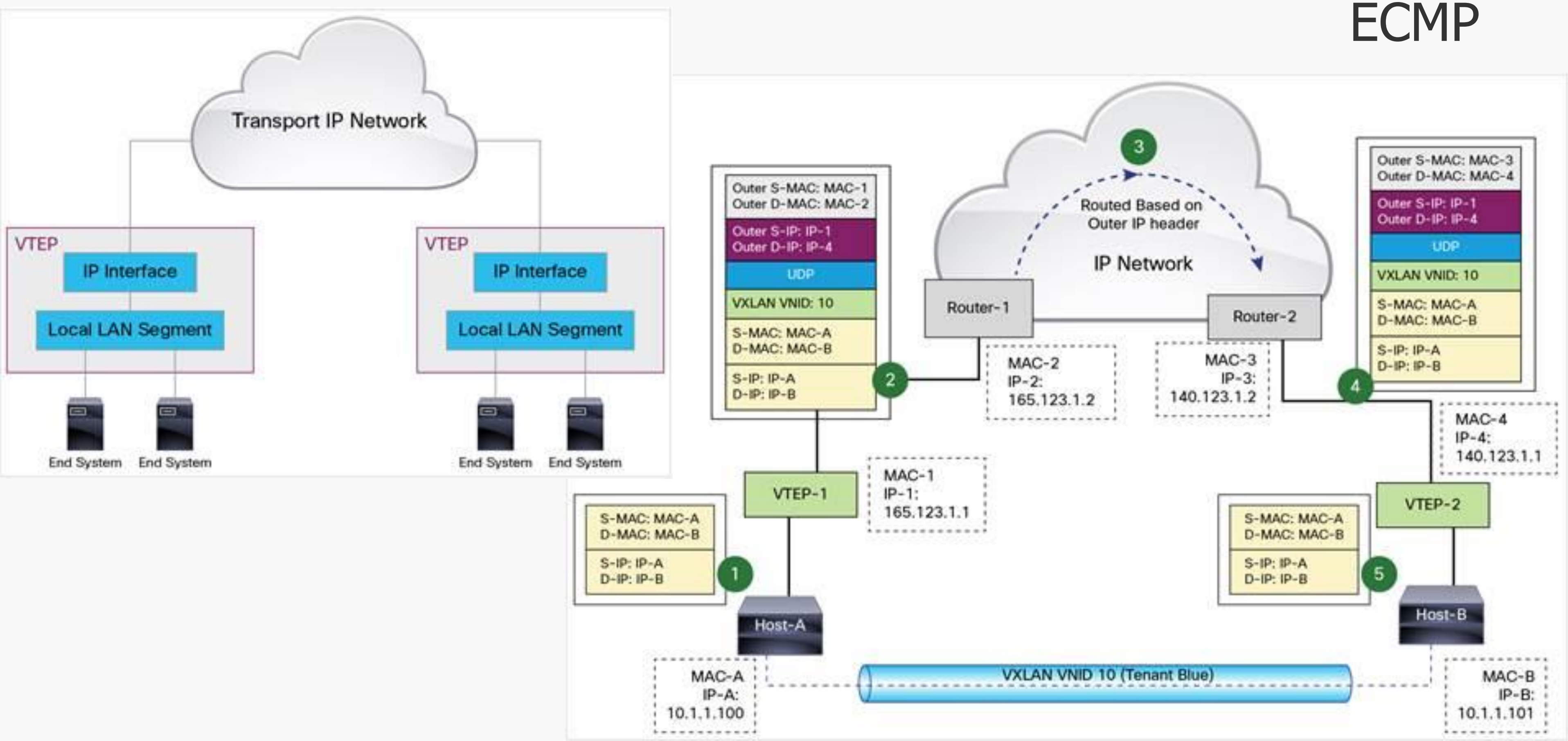
- Original L2 frame of tenant
  - original MAC address and VLAN tag
- MAC-in-UDP
- VXLAN and UDP header
  - VXLAN network ID (VNID) – identifying the tenant
    - 24 bit ⇨ 16 million tenant
- physical network: IP routing (Layer3)



VXLAN

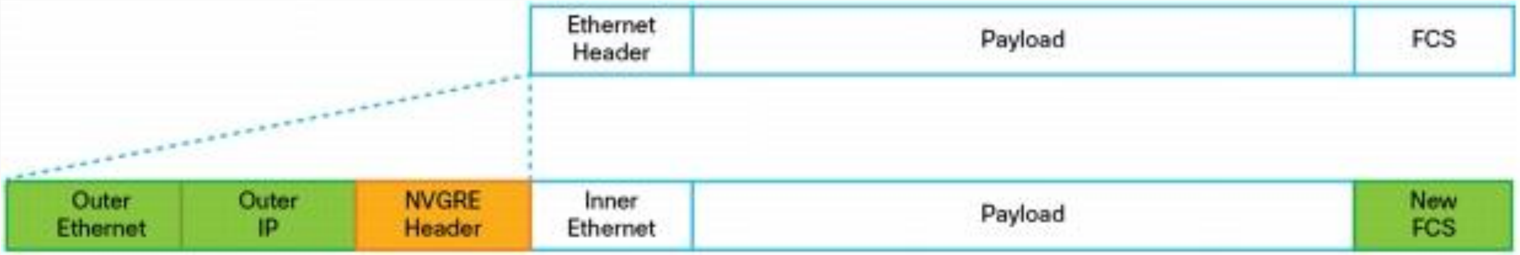
- VXLAN Tunnel End Point (VTEP)
- MAC-to-VTEP tables by learning (IP multicast)
  - all VTEP of a VNI in a multicast group

ECMP



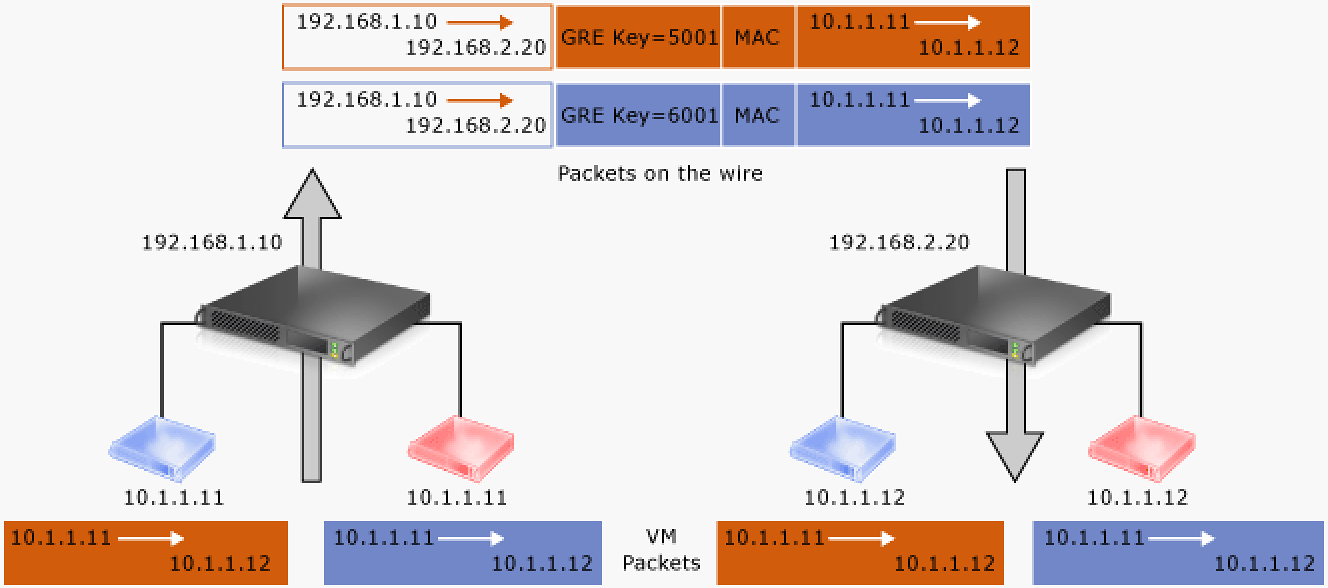
NVGRE

- is very similar to VXLAN
- basis: Generic Routing Encapsulation (GRE)
  - generic header
  - can encapsulate a wide variety of network layer protocols
  - point-to-point links over an Internet Protocol network
- NVGRE
  - GRE header
  -
    ```
    +-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
    |0| |1|0|   Reserved0      | Ver |   Protocol Type 0x6558        |
    +-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
    |               Virtual Subnet ID (VSID)        |    FlowID     |
    +-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
    ```
    - Virtual Subnet Identifer (VSID) 24 bit ⇨ 16 million tenant
    - FlowID: optional, unique flow identifier
      - for ECMP hashing
  - no inner VLAN tag (or it is removed)
    - encoded into VSID or multiple VSIDs for the same tenant



NVGRE

- Network Virtual Endpoint (NVE)
  - forwarding to the destination based on VSID and DMAC
- not specified in the Internet draft
  - dissemination of addressing information
  - restoring VLAN information



Generic Network Virtualization Encapsulation

- MAC-in-UDP over IPv4/IPv6
- universal, extensible
- specifies only the encapsulation format
- optional fields
  - variable field lengths, flexibility
- Geneve header:

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

Location of Tunnel Endpoint

- Inside hypervisor/vSwitch
  - most common
  - closest to the VMs
  - consumes CPU resources
  - TCP segmentation offload (TSO), checksum offload support for non-encapsulated packets
- NIC
  - offload support for tunneling
- ToR switch
  - VMs are unknown
  - has to identify VM based on inner MAC to assign VNI/VSID

Stateless Transport Tunneling (STT)

- primary goal: communication between vSwitches
- more complex than the others
- max. 64 kbyte Ethernet frames
  - maximum transmission unit (MTU)
  - using TCP segmentation offload on NIC
- STT header
  - 64 bit Context ID field
- TCP-like/IP/Eth header before the segments
  - reassembling the original data based on this

```
 0                   1                   2                   3
 0 1 2 3 4 5 6 7 8 9 0 1 2 3 4 5 6 7 8 9 0 1 2 3 4 5 6 7 8 9 0 1
+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
|  Version      | Flags         |  L4 Offset    |  Reserved     |
+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
|    Max. Segment Size          | PCP |V|     VLAN ID           |
+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
|                                                               |
+                     Context ID (64 bits)                      +
|                                                               |
+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
|     Padding                   |    data                       |
+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+                               +
|                                                               |
```

```
                   +------------+    +-----------+     +-----------+
                   | IP Header  |    |IP Header  |     |IP header  |
+------------+     +------------+    +-----------+     +-----------+
|STT Frame   |     |TCP-like    |    |TCP-like   |     |TCP-like   |
| Header     |     | header     |    | header    |     | header    |
+------------+     +------------+    +-----------+     +-----------+
|            | --->| STT Frame  |    |Next part  | ... |Last part  |
|Payload     |     |  Header    |    |of Payload |     |of Payload |
.            .     +------------+    |           |     |           |
.            .     |            |    |           |     |           |
.            .     |  Start of  |    |           |     |           |
+------------+     |  Payload   |    |           |     +-----------+
                   +------------+    +-----------+

Original data            STT frame segments
```

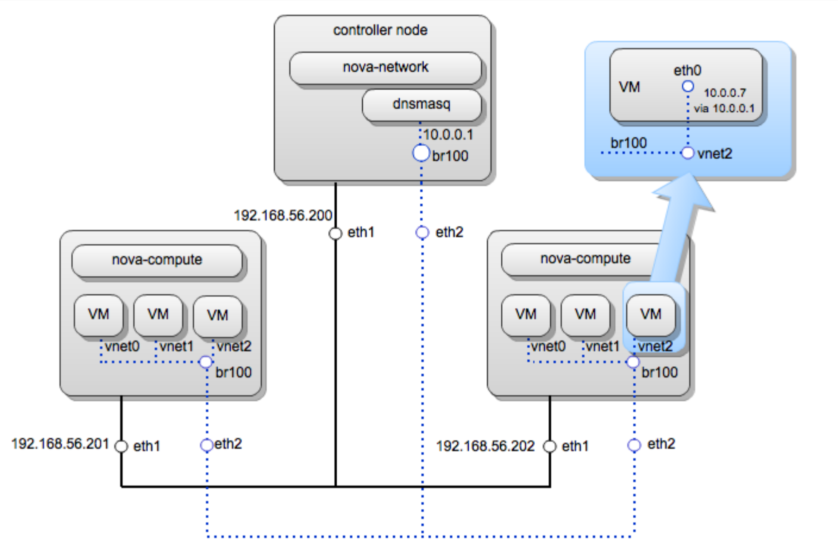
Comparison

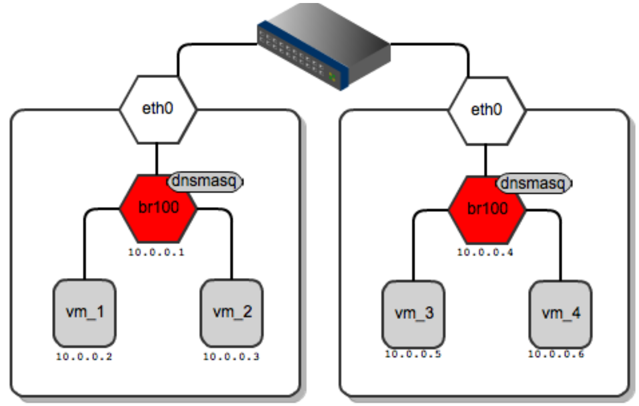
	VXLAN	NVGRE	STT
Extra bytes	50 (VLAN: +4)	42 (VLAN: +4)	First segment: 76 Others: 58 (VLAN: +4)
Protocol	UDP	GRE	TCP
Tenant separation	24 bit VNID	24 bit VSID	64 bit Context ID
ECMP flow differentiation (inner ⇨ outer flow)	Source UPD port	VSID + FlowID (8bit)	Source TCP port

OPENSTACK NEUTRON

OpenStack network architecture

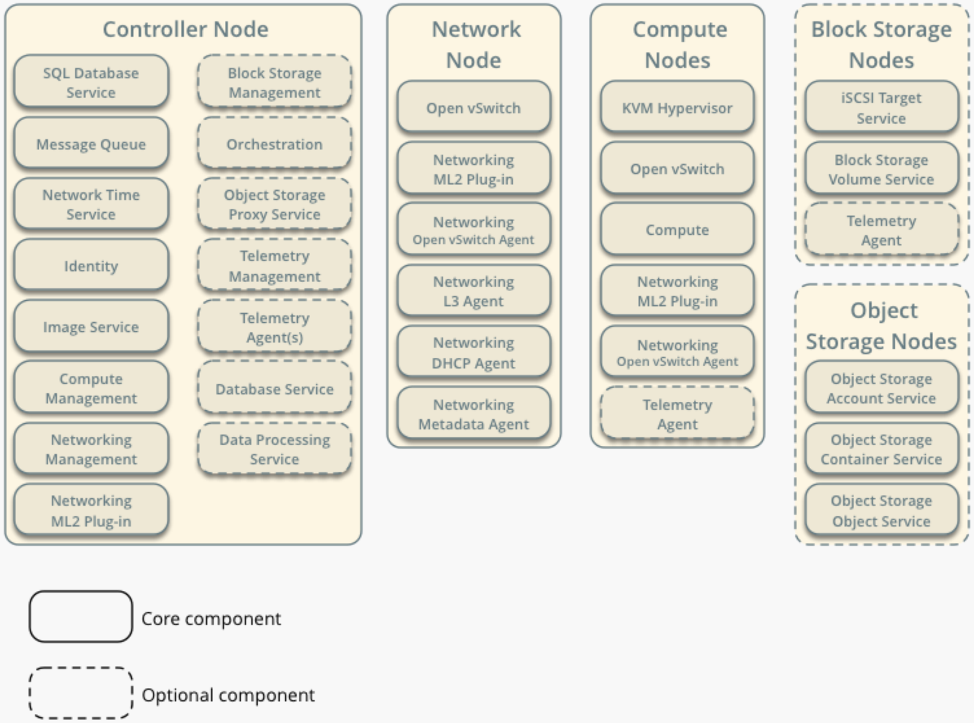
- „Networking in OpenStack is a complex, multifaceted challenge.” /OpenStack Operations Guide/
- Network as a Service
- functions
  - IP addressing
    - static, DHCP
    - floating IP
  - virtual networks
    - flat, VLAN
  - self-service
- alternatives
  - Nova networking / Neutron
  - single-host / multi-host
- Neutron
  - plug-in architecture
  - SDN/OpenFlow





Neutron network

Minimal Architecture Example - Service Layout
OpenStack Networking (neutron)



Controller Node
- SQL Database Service
- Message Queue
- Network Time Service
- Identity
- Image Service
- Compute Management
- Networking Management
- Networking ML2 Plug-in
- Block Storage Management
- Orchestration
- Object Storage Proxy Service
- Telemetry Management
- Telemetry Agent(s)
- Database Service
- Data Processing Service

Network Node
- Open vSwitch
- Networking ML2 Plug-in
- Networking Open vSwitch Agent
- Networking L3 Agent
- Networking DHCP Agent
- Networking Metadata Agent

Compute Nodes
- KVM Hypervisor
- Open vSwitch
- Compute
- Networking ML2 Plug-in
- Networking Open vSwitch Agent
- Telemetry Agent

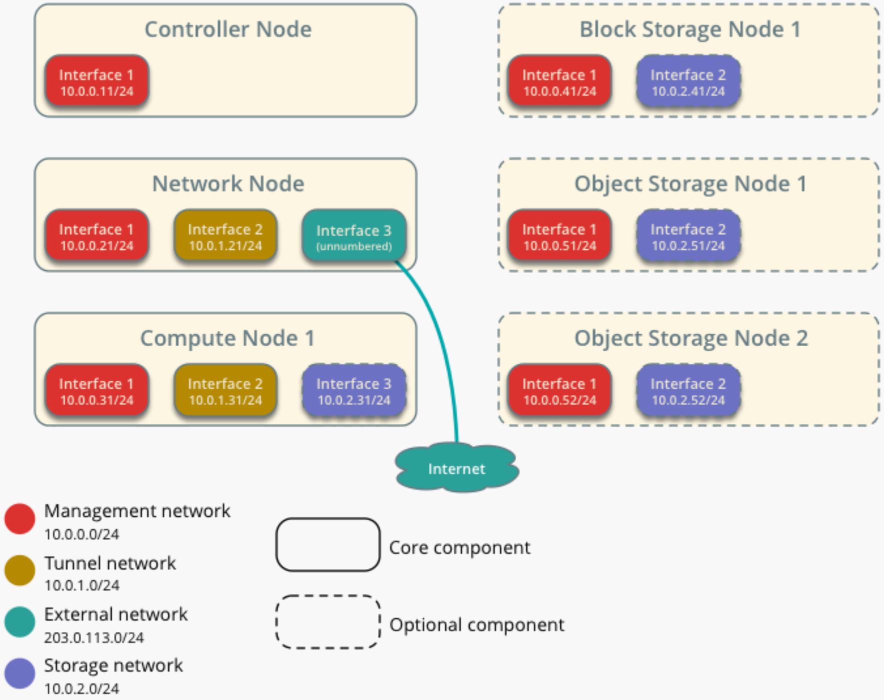
Block Storage Nodes
- iSCSI Target Service
- Block Storage Volume Service
- Telemetry Agent

Object Storage Nodes
- Object Storage Account Service
- Object Storage Container Service
- Object Storage Object Service

Core component

Optional component

Minimal Architecture Example - Network Layout
OpenStack Networking (neutron)



Controller Node
- Interface 1 10.0.0.11/24

Network Node
- Interface 1 10.0.0.21/24
- Interface 2 10.0.1.21/24
- Interface 3 (unnumbered)

Compute Node 1
- Interface 1 10.0.0.31/24
- Interface 2 10.0.1.31/24
- Interface 3 10.0.2.31/24

Block Storage Node 1
- Interface 1 10.0.0.41/24
- Interface 2 10.0.2.41/24

Object Storage Node 1
- Interface 1 10.0.0.51/24
- Interface 2 10.0.2.51/24

Object Storage Node 2
- Interface 1 10.0.0.52/24
- Interface 2 10.0.2.52/24

Internet

● Management network 10.0.0.0/24
● Tunnel network 10.0.1.0/24
● External network 203.0.113.0/24
● Storage network 10.0.2.0/24

Core component

Optional component

Nova and Neutron Network

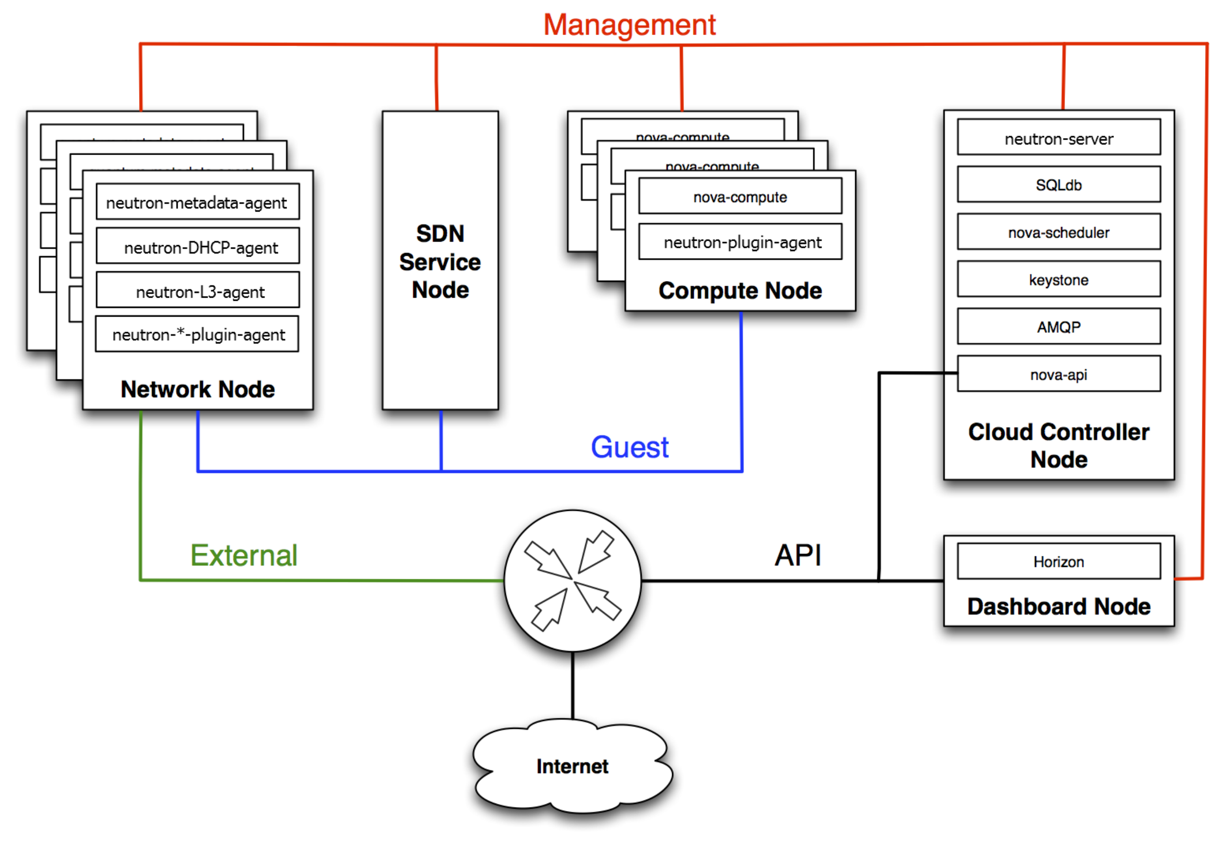
- Nova
  - basic networking functions
    - network address translation (NAT), DHCP, DNS
  - only support L2 bridge networking
    - allows virtual interfaces to connect to the outside network through the physical interface
  - limited scalability
    - VLAN, DNS&DHCP (dnsmasq)
- Neutron
  - network abstraction
  - L2/L3 network, self-service
    - e.g. more LAN segments for a web service
  - Load Balancing, Virtual IP, VPN, firewall
  - overlay VLAN tunneling
  - Distributed Virtual Router (from Juno)

Neutron network abstraction

- External /physical/ network, e.g. Internet
- Internal networks to connect VMs
  - virtual: network, subnetwork, router
  - floating IP from external network address space for reaching a VM from outside
- Security groups
  - firewall rules
  - assigned to the VM
- Open vSwitch
  - core plugin
  - br-int (integration bridge)
    - connected to VMs
  - br-ex
    - connected to external network

Neutron components

- server + plugin + agent architecture
  - neutron-server
    - on controller node
    - handling API requests
    - network modell and port IP address setup
  - plugin – extensions: neutron-*-plugin
    - on network node
  - plugin-agent: neutron-*-agent
    - on compute node
    - managing the local vswitch
  - general agents
    - DHCP: neutron-dhcp-agent
    - L3 agent: neutron-l3-agent
      - L3/NAT functionality towards the external network
      - implementation: Linux IP stack and iptables



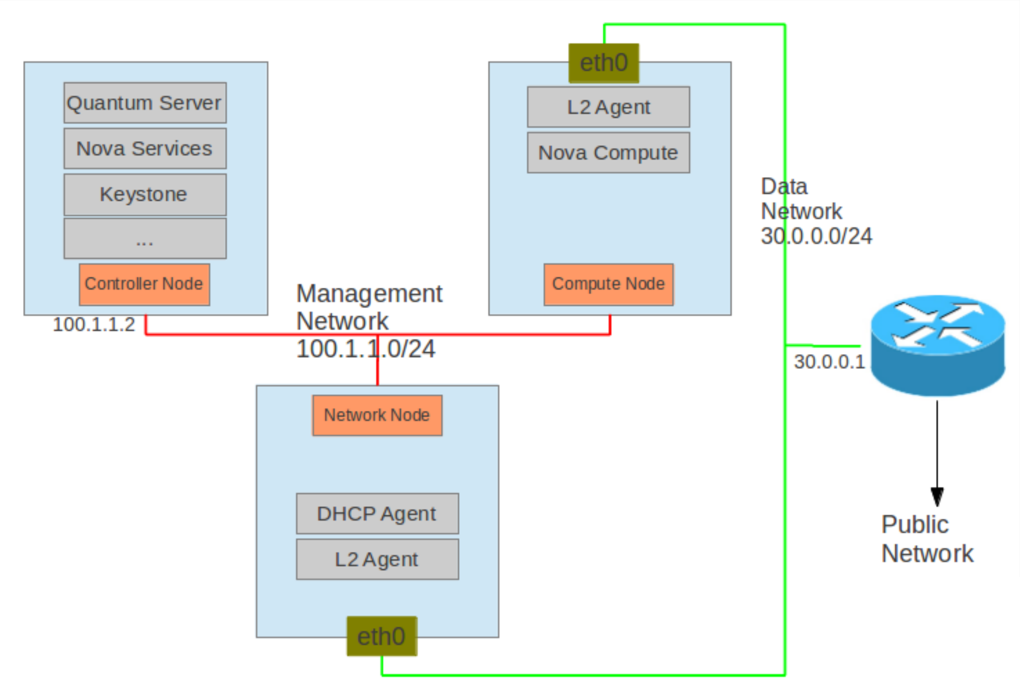
Modular Layer 2 (ML2) plugin

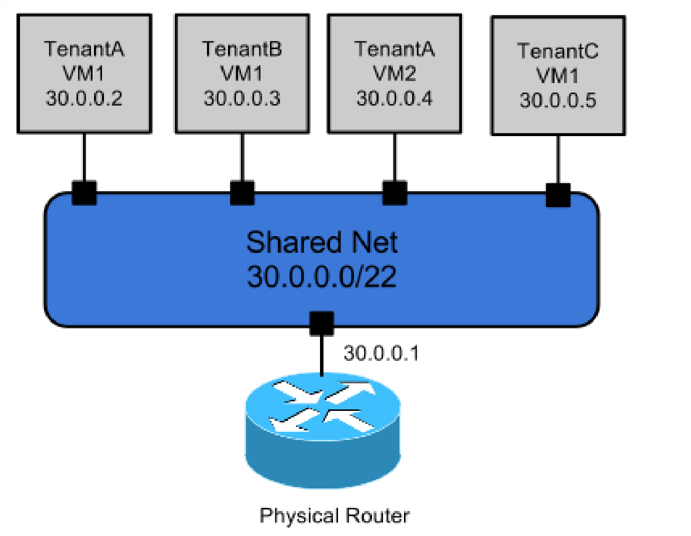
- Managing different L2 network technologies in uniform way
- Operates with openvswitch, linuxbridge and Hyper-V L2 agents
- Type drivers for different network types
  - Flat
  - Local (DevStack single box)
  - VLAN
  - GRE
  - VXLAN

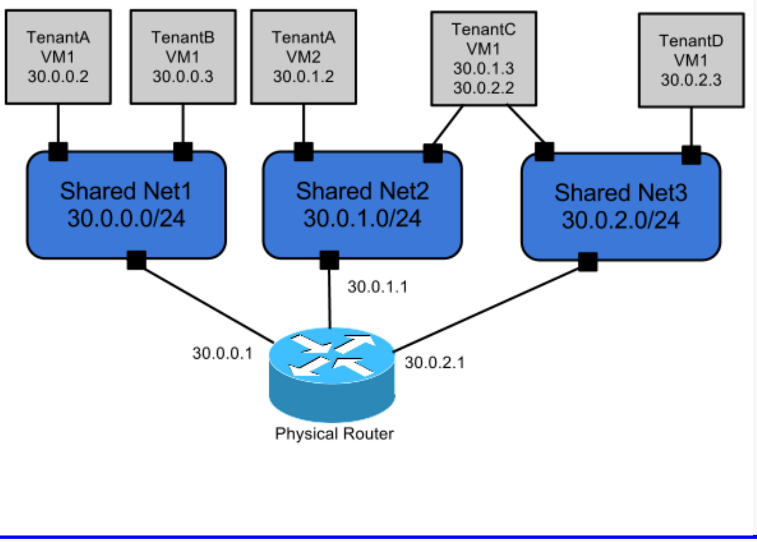
Network namespaces

- kernel level namespaces, not only for networking
  - file system, process, user, etc.
- isolated Layer2 networks with overlapping IP addresses
- separating virtual interfaces, routers
- e.g. dhcp-agent and l3-agent runs in different namespaces
- In practice
  - `ip netns`
    - lists available network namespaces
  - `ip netns exec <namespace> <command>`
    - e.g. `ip netns exec qdhcp-e521f9d0-a1bd-4ff4-bc81-78a60dd88fe5 ip a`

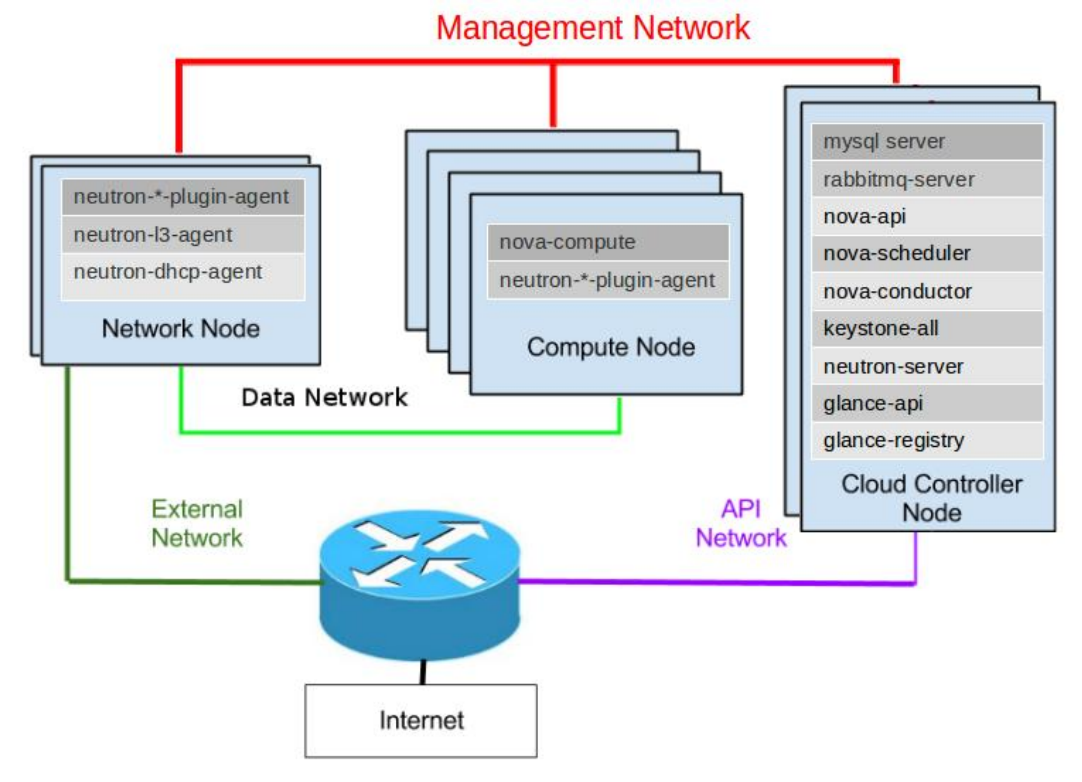
Neutron: single/multiple flat network

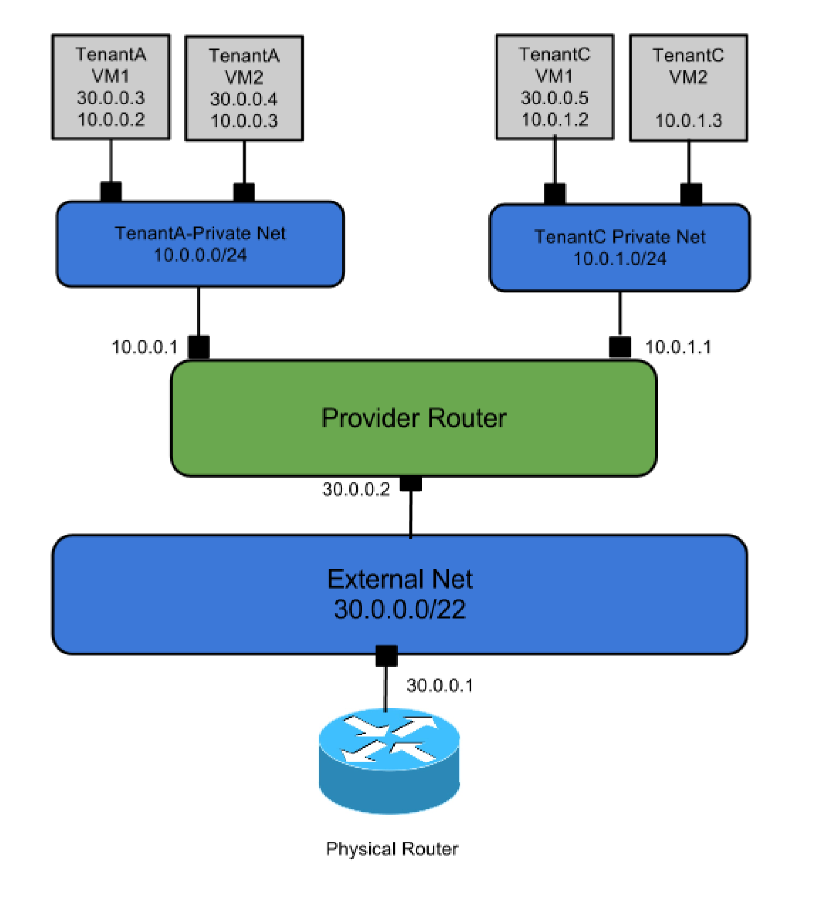




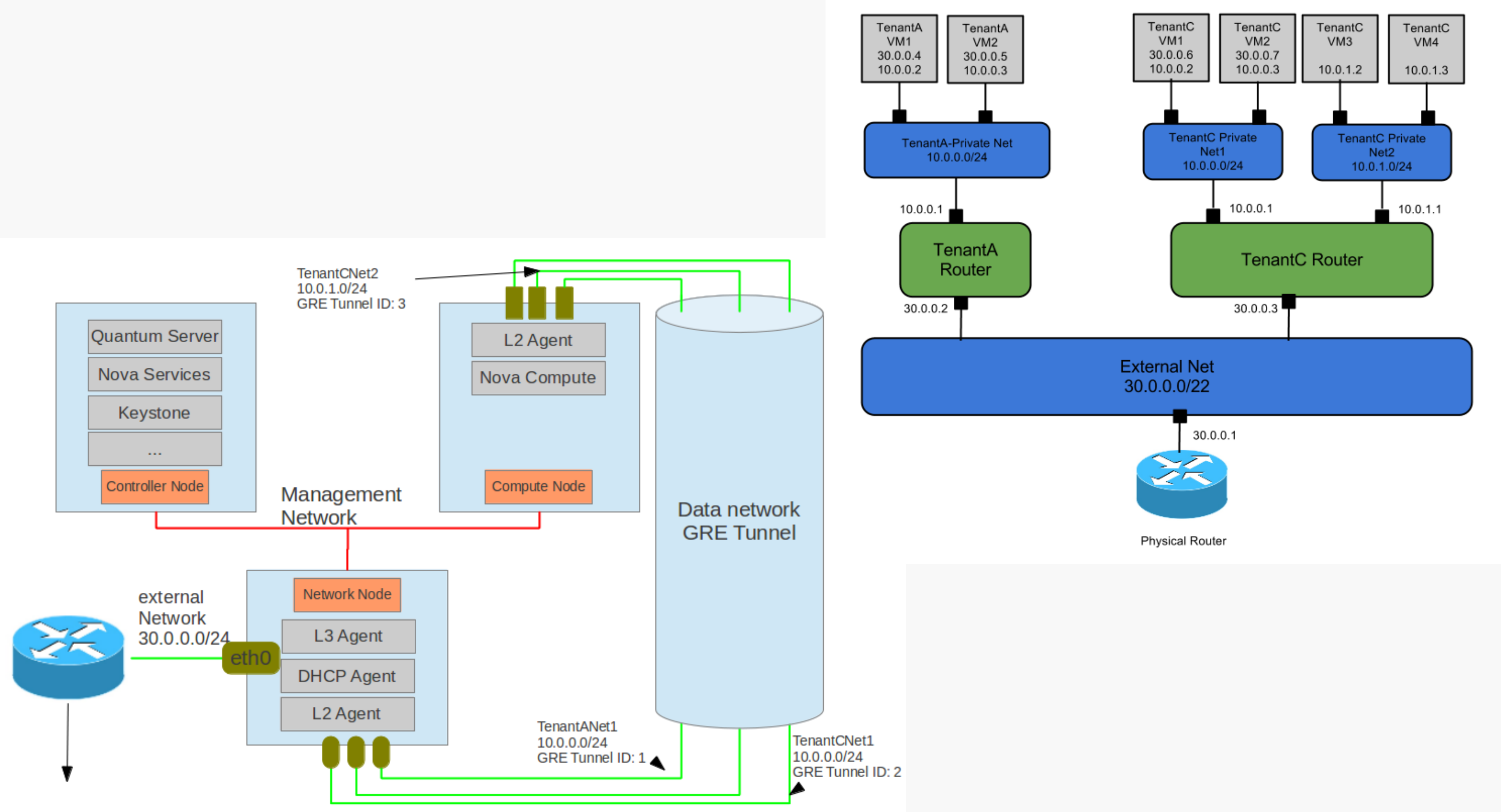


Neutron: provider router



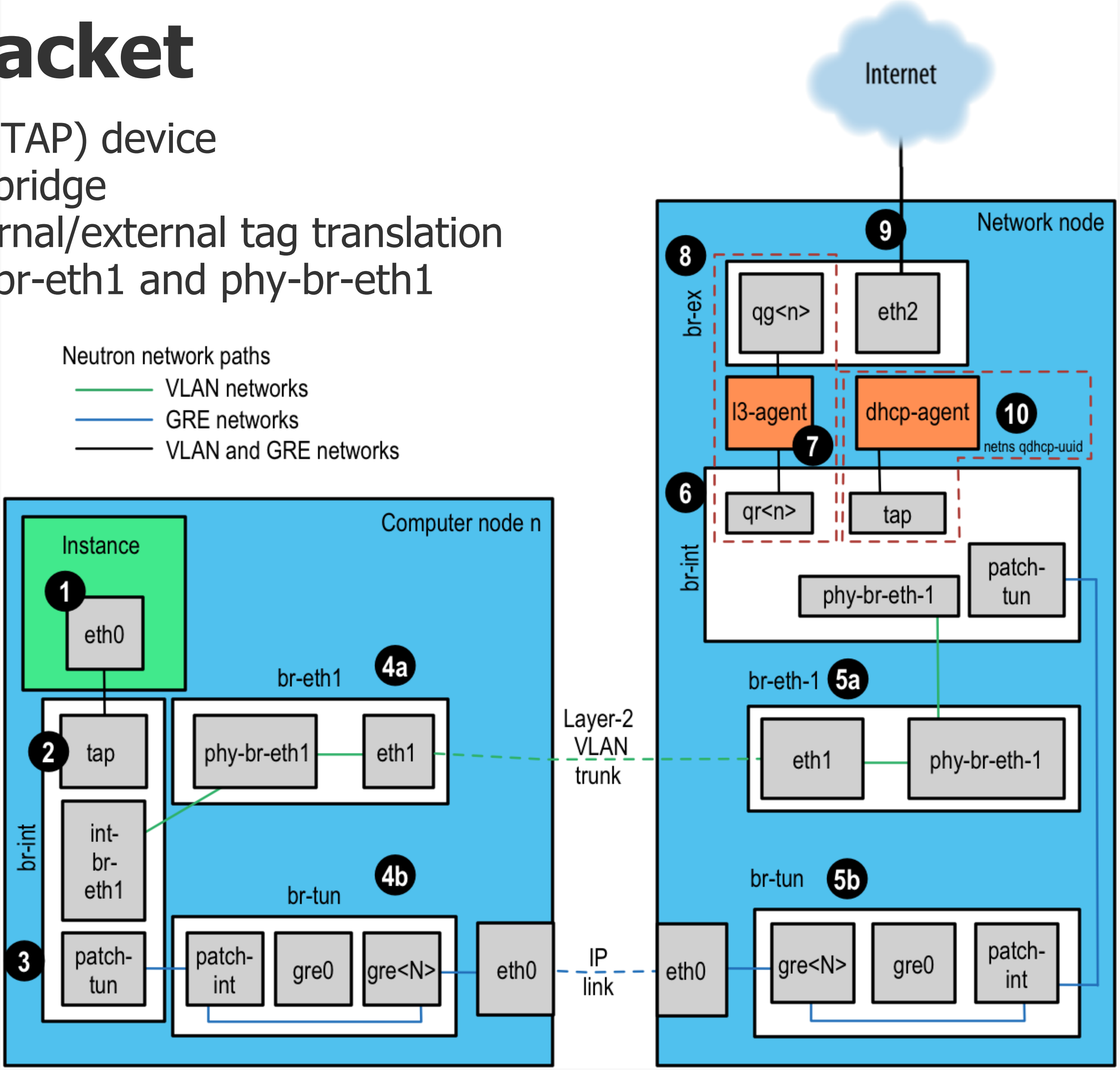

TenantA VM1 30.0.0.3 10.0.0.2
TenantA VM2 30.0.0.4 10.0.0.3
TenantC VM1 30.0.0.5 10.0.1.2
TenantC VM2 10.0.1.3
TenantA-Private Net 10.0.0.0/24
TenantC Private Net 10.0.1.0/24
10.0.0.1
10.0.1.1
Provider Router
30.0.0.2
External Net 30.0.0.0/22
30.0.0.1
Physical Router

Neutron: tenant routers



Path of a packet

- » Test Access Point (TAP) device
- » int-br: integration bridge
- » br-eth1: VLAN internal/external tag translation
- » veth: between int-br-eth1 and phy-br-eth1



Floating IP

- Neutron router
  - gateway for VMs
  - iptables/NAT rules in the namespace of router
    - nova network: in hypervisor
  - floating IP addresses allocated form the public network address range

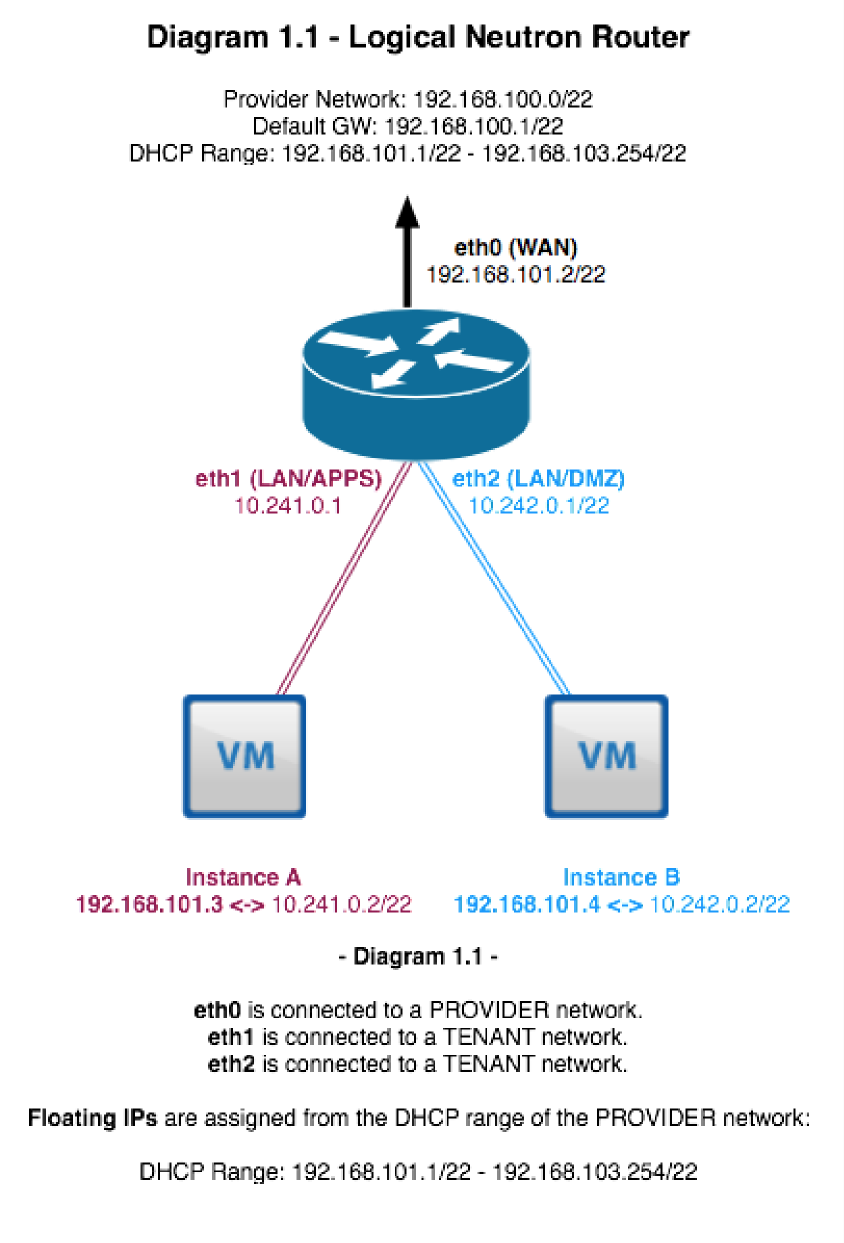


Diagram 1.1 - Logical Neutron Router

Provider Network: 192.168.100.0/22
Default GW: 192.168.100.1/22
DHCP Range: 192.168.101.1/22 - 192.168.103.254/22

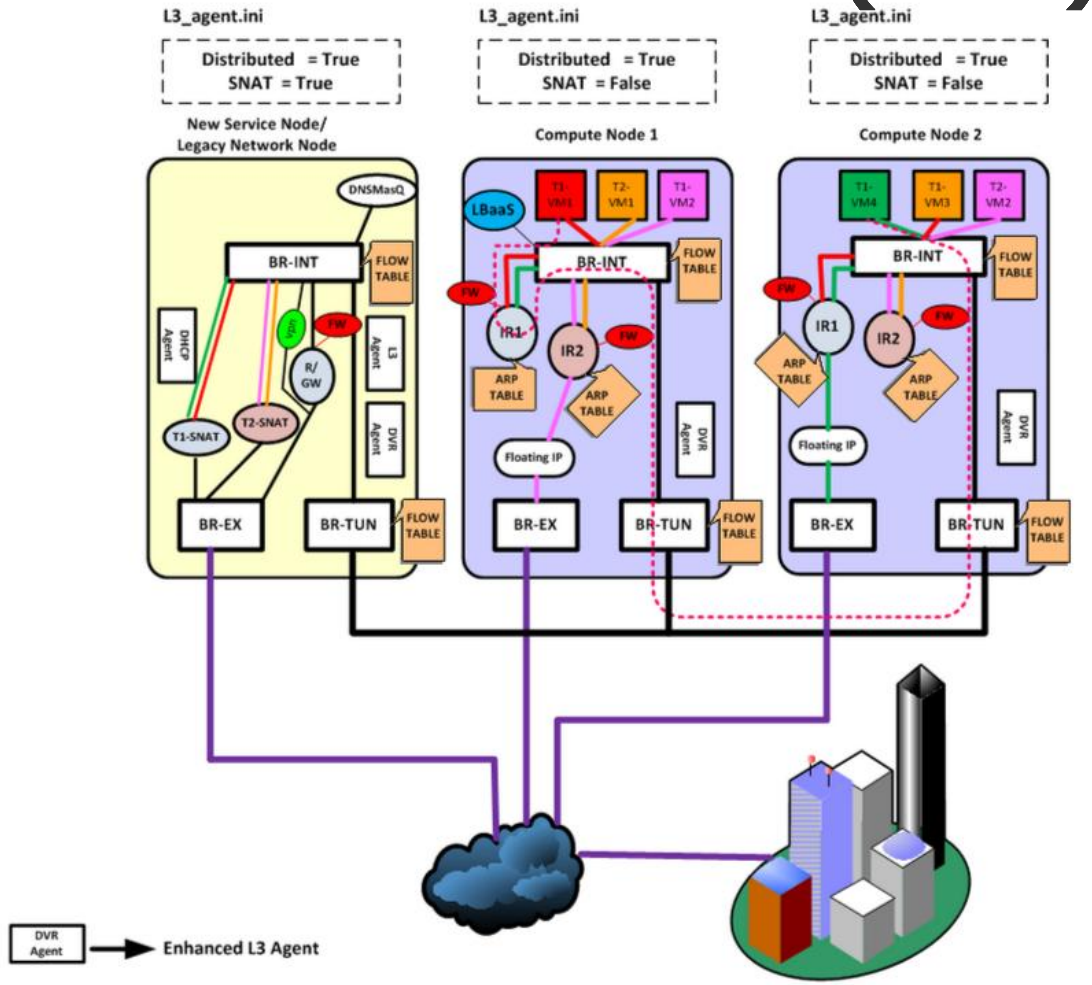
- Diagram 1.1 -

eth0 is connected to a PROVIDER network.
eth1 is connected to a TENANT network.
eth2 is connected to a TENANT network.

Floating IPs are assigned from the DHCP range of the PROVIDER network:

DHCP Range: 192.168.101.1/22 - 192.168.103.254/22

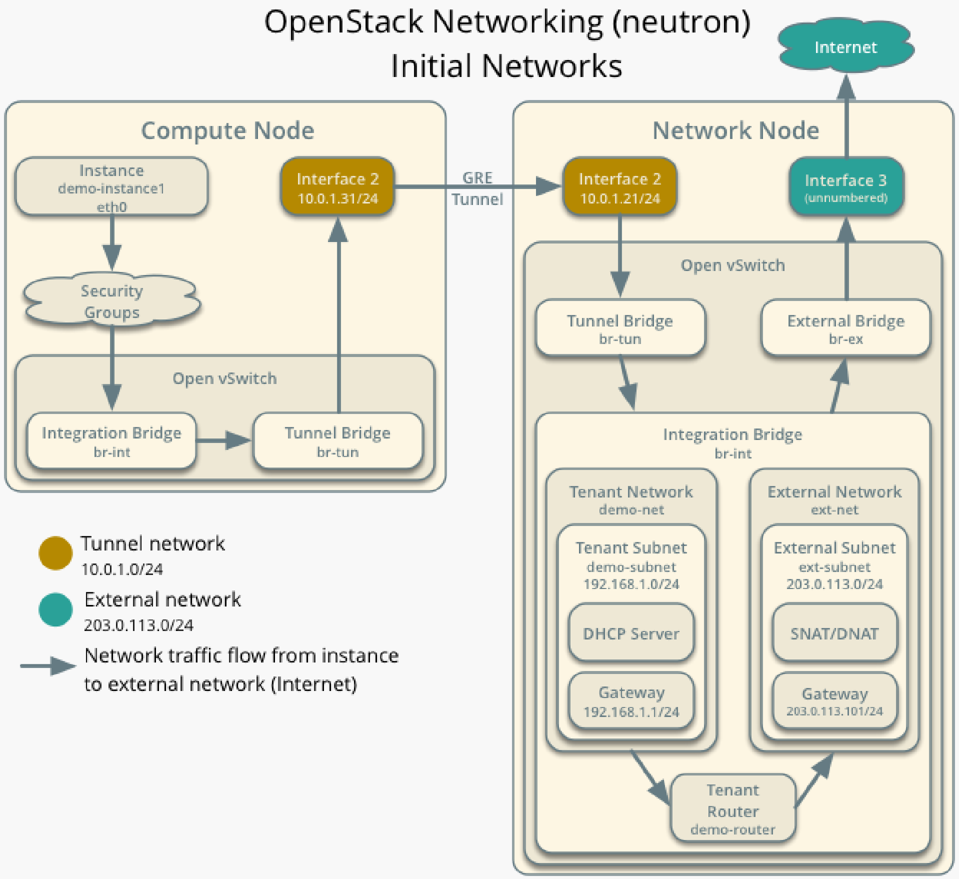
Distributed Virtual Router (DVR)



🟥🟩 TENANT A – With Distributed Routers and the Green VM in Compute Node 2 configured with Floating IP. The Default SNAT is provided by the Service Node

🟧🟪 TENANT B – With Distributed Routers and the Pink VM in Compute Node 1 configured with Floating IP. The Default SNAT is provided by the Service Node

Virtual network configuration



- » Open vSwitch
  - » setup by ovs-dpctl / OpenFlow
    - » e.g. mapping VM MAC address and hypervisor transport IP address

References

- Overlay Virtual Networking Explained, Ivan Pepelnjak, NIL Data Communications, 2011.
- http://docs.openstack.org
- https://developer.rackspace.com/blog/neutron-networking-l3-agent/
- https://www.rdoproject.org/Networking_in_too_much_detail