Cloud e Datacenter Networking

Università degli Studi di Napoli Federico II
Dipartimento di Ingegneria Elettrica e delle Tecnologie dell'Informazione DIETI
Laurea Magistrale in Ingegneria Informatica

Prof. Roberto Canonico

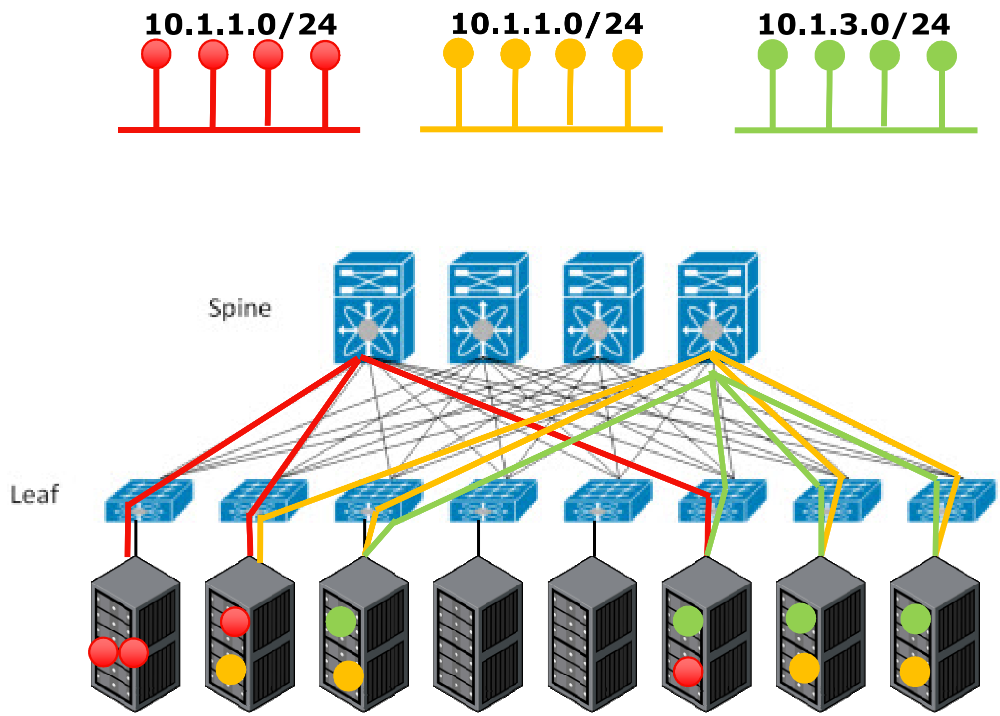
Datacenter networking and multitenancy

Lesson outline

- Multitenancy
- Virtual networking techniques in a datacenter
- Tunneling protocols

Virtual networking in a Cloud datacenter

- In a multi-tenant virtualized datacenter proper solutions are needed to map multiple independent virtual infrastructures (provided as a IaaS service) on top of a shared physical infrastructure
  - Requirements: isolation, fully flexible VM placement and migration, address independance
  - Challenges: address collisions, partitioning, mapping, …

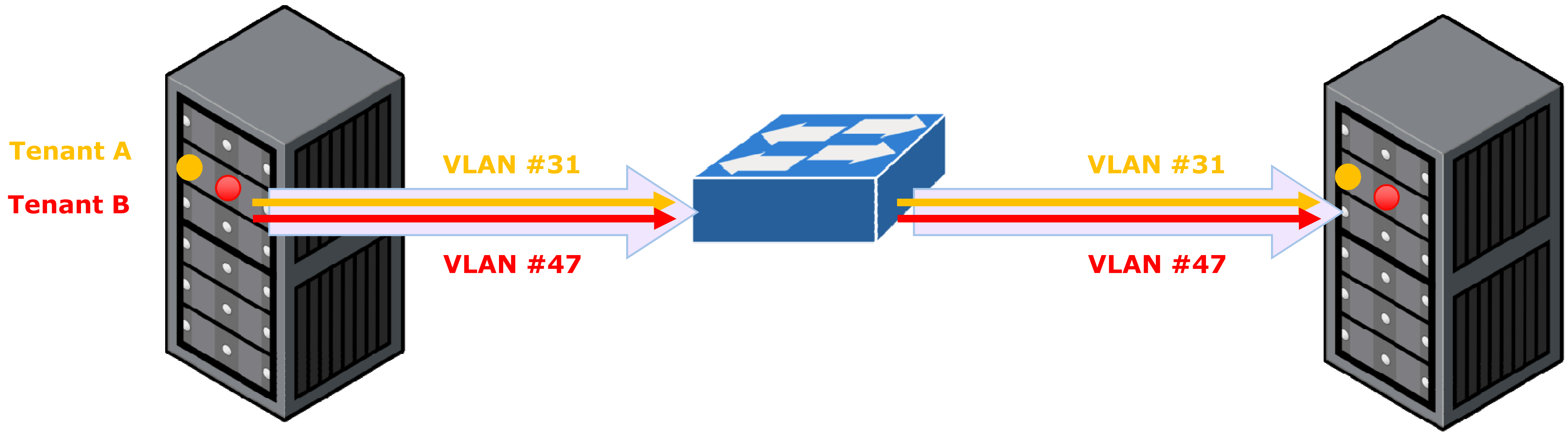


Multi-tenancy: approaches

- Network virtualization techniques allow to map logical tenant networks onto a common shared physical substrate
- Most common network virtualization approaches are based on traffic encapsulation (a.k.a. *tunneling*) and creation of *overlays*
- VLANs is a form of layer 2 encapsulation natively supported by Ethernet switches
- Other forms of encapsulation:
  - Q-in-Q
  - VXLAN: Virtual Extensible LAN
  - NVGRE: Network Virtualization using Generic Routing Encapsulation
  - MPLS

Tenant isolation via VLANs

- Within an L2 island, VLANs can be used to isolate tenants' traffic
- Limitations:
  - Only 4096 VLAN IDs available in IEEE 802.1q
  - Tenants are not allowed to choose VLAN IDs to preserve uniqueness



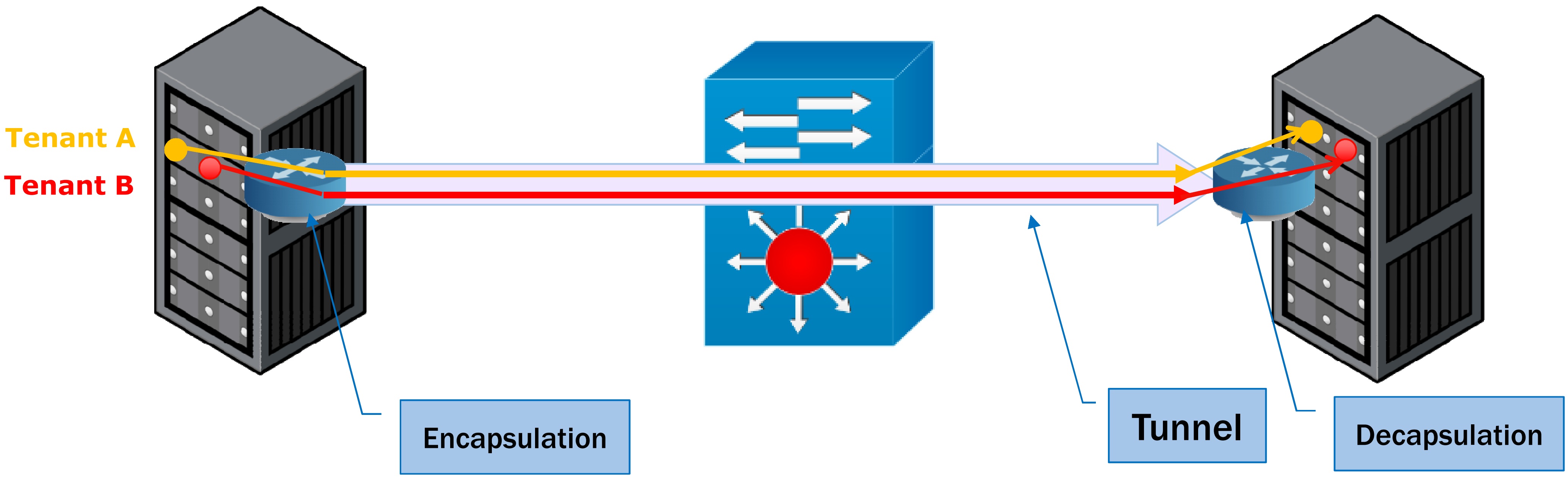
IEEE 802.1ad: Q-in-Q

- IEEE 802.1ad allows to wrap an 802.1q VLAN-tagged packet with an outer VLAN tag (*Q-in-Q*)
- This technique is used to carry proprietary VLAN-tagged traffic on a shared service provider network where the outer 12-bit VLAN ID is used to identify the customer traffic in the provider network
  - Mainly adopted in Metro Ethernet services
- The 3-bit VLAN priority field may be used to provide different classes of service in the provider network
- The inner VLAN ID is left untouched and can be used by the customer for their own purposes
- The 12-bit limit of the VLAN ID severely limits the usability of this technique in large scale provider networks and datacenters

DMAC	SMAC	Outer VLAN	Inner VLAN	Type	IP	TCP/UDP	Data

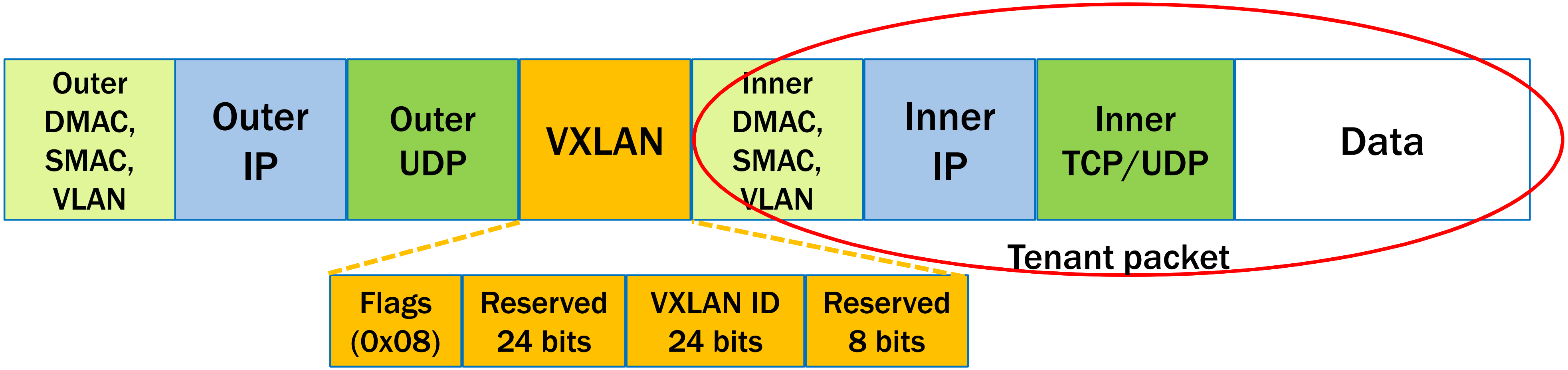
Network Virtualization using encapsulation

- VXLAN and NVGRE are two different network virtualization methods that use encapsulation and tunneling to create large numbers of virtual LANs for subnets that can extend across layer 2 and 3
- Encapsulation/decapsulation is performed by entities that could reside either in End Devices or in ToR edge switches (or in both)
- VXLAN is supported by Cisco and Vmware
- NVGRE was proposed by Microsoft, Intel, HP and Dell



VXLAN (RFC 7348)

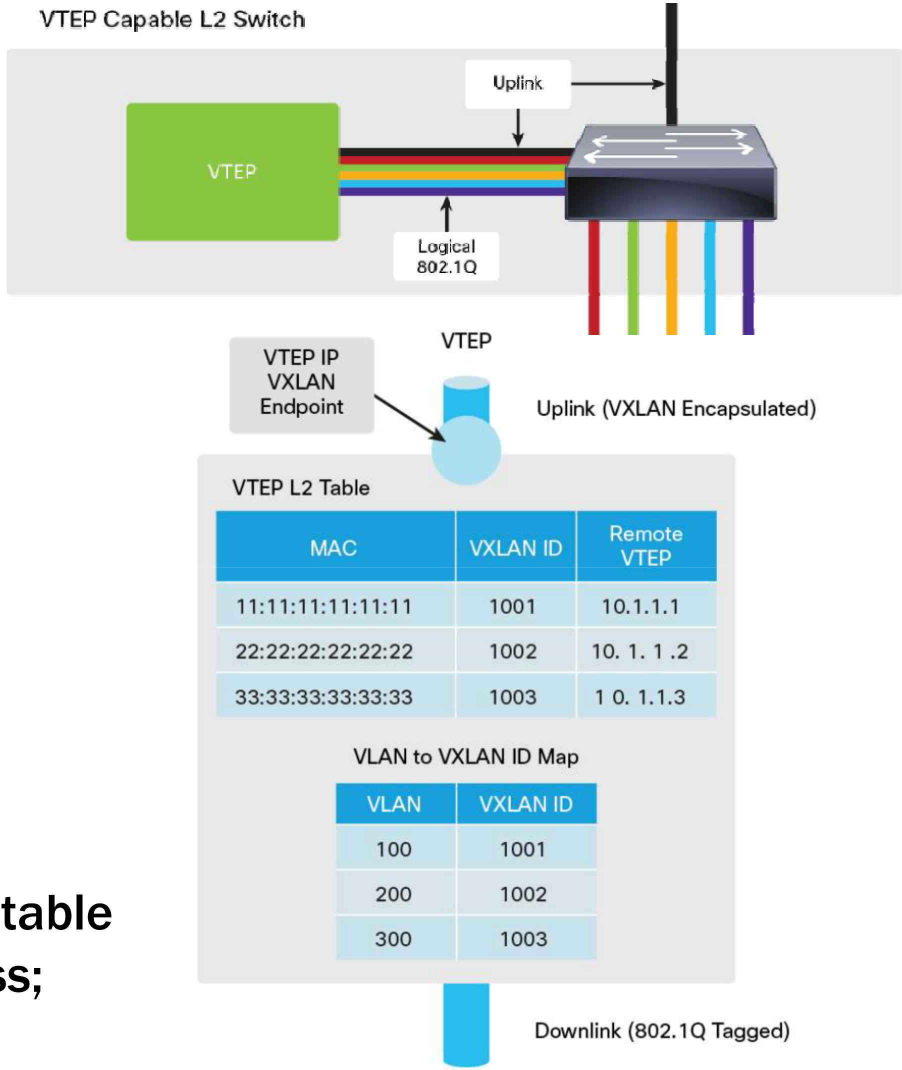
- Virtual eXtensible LAN (VXLAN) was originally proposed by Cisco and VMware to tunnel virtual layer 2 networks on a substrate layer 3 physical network



- VXLAN encapsulate packets in UDP tunnels with destination port number 4789
- In the shared L3 infrastructure, packets are identified by outer MAC addresses imposed by the infrastructure provider
- Tenants free to choose their own MAC addresses and VLAN IDs with no conflicts
- To avoid packet fragmentation in the shared infrastructure, it must support larger MTU values
- Encapsulation/decapsulation is performed at *VXLAN Tunnel End Points* (VTEPs)
- VXLAN ID allows to identify up to 2^{24} distinct virtual networks

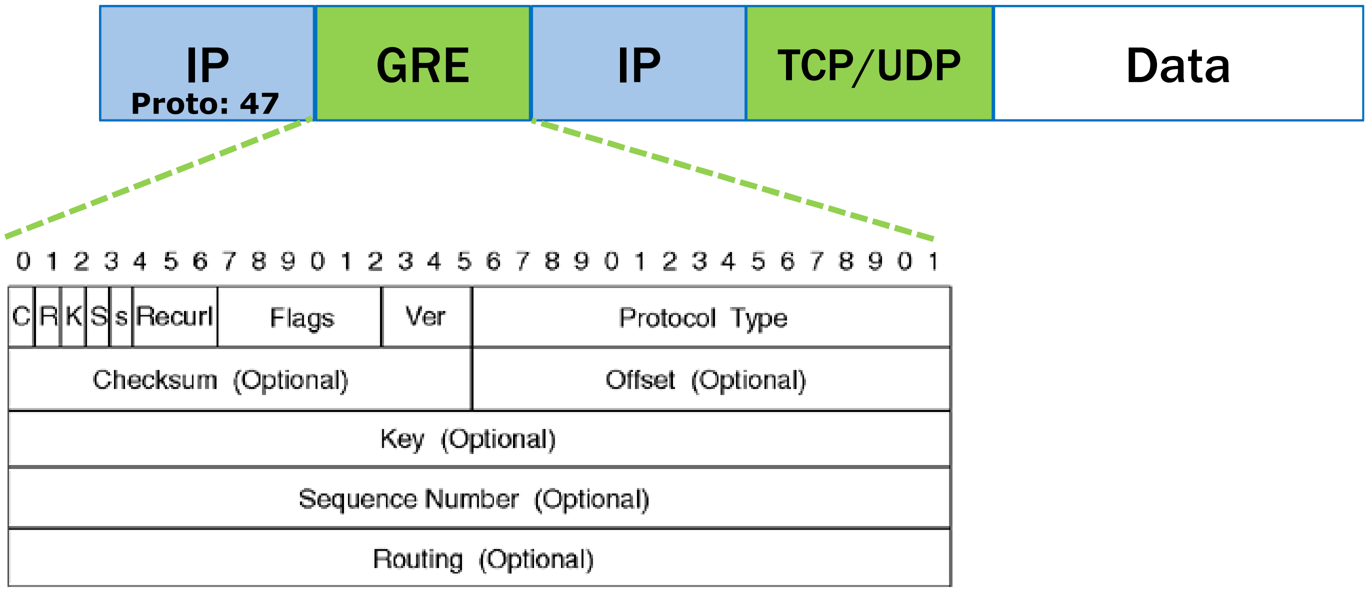
VXLAN: VTEP encapsulation & decapsulation

- A VTEP has two logical interfaces: an uplink and a downlink
  - Uplink to encapsulate
  - Downlink to decapsulate
- The VTEP can be located either on a physical switch (e.g. a ToR) or within the hypervisor’s virtual switch
- The *outer IP destination* address is that assigned to the destination VTEP
- The *outer IP source* address is that assigned to the VTEP sending the frame
- Packets received from a tenant’s VM on the downlink are mapped to a VXLAN ID
  - A lookup is then performed in the VTEP Layer 2 table using the VXLAN ID and destination MAC address; this lookup provides the IP address of the destination VTEP
- Packets received from a VTEP on the uplink are mapped from the VXLAN ID to an IEEE 802.1Q VLAN ID and sent as Ethernet frames on the downlink to the VM



GRE: Generic Routing Encapsulation (RFC 2784)

- **Generic Routing Encapsulation (GRE) is a protocol that encapsulates packets in order to route other protocols over IP networks**
- **GRE was developed as a tunneling tool meant to carry any OSI Layer 3 protocol over an IP network**
- **GRE works by encapsulating an *inner packet* (*payload*) that needs to be delivered to a destination network inside an *outer IP packet***

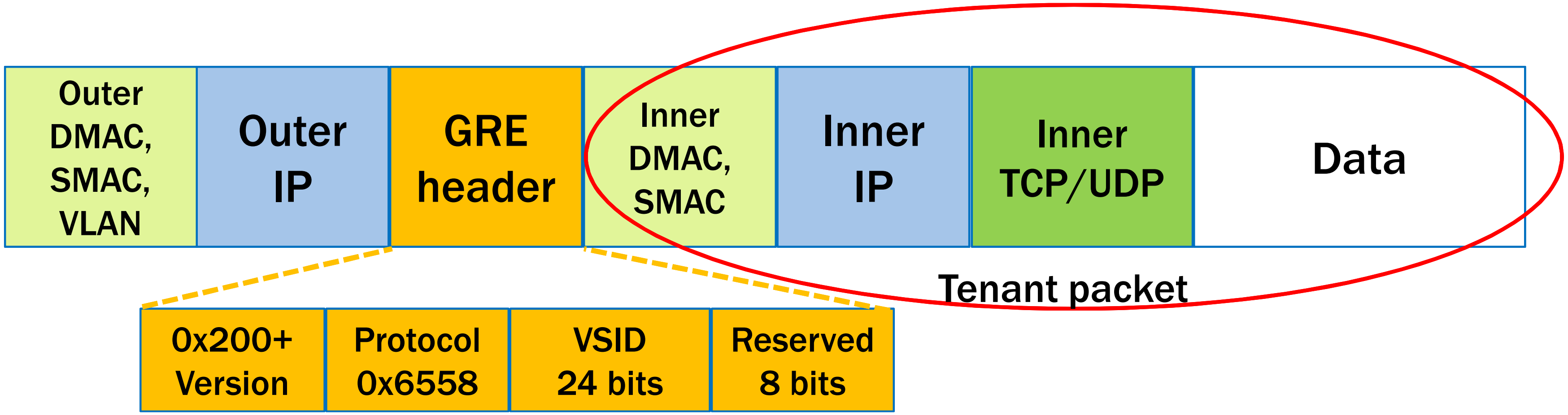


How GRE works

- GRE creates point-to-point connections as those used to create Virtual Private Networks (VPNs)
- IP routers along the way do not parse the payload
- Upon reaching the tunnel endpoint, GRE header is removed and the payload is forwarded along to its ultimate destination
- GRE tunneling can transport multicast and IPv6 traffic as payload but it does not use encryption like the IPsec Encapsulating Security Payload (ESP) as defined in RFC 2406

Network Virtualization using Generic Routing Encapsulation

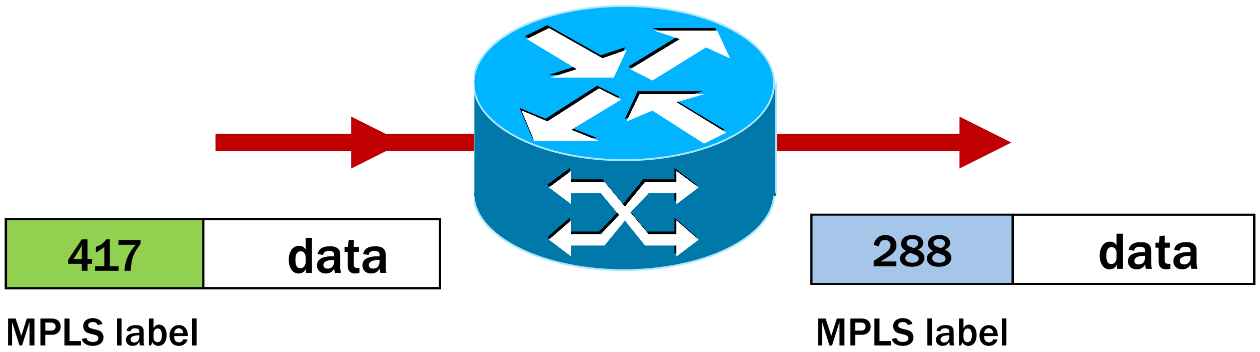
- NVGRE (*Network Virtualization using Generic Routing Encapsulation*) is a network virtualization method that uses encapsulation and tunneling to create large numbers of virtual LANs for subnets that can extend across layer 2 and 3

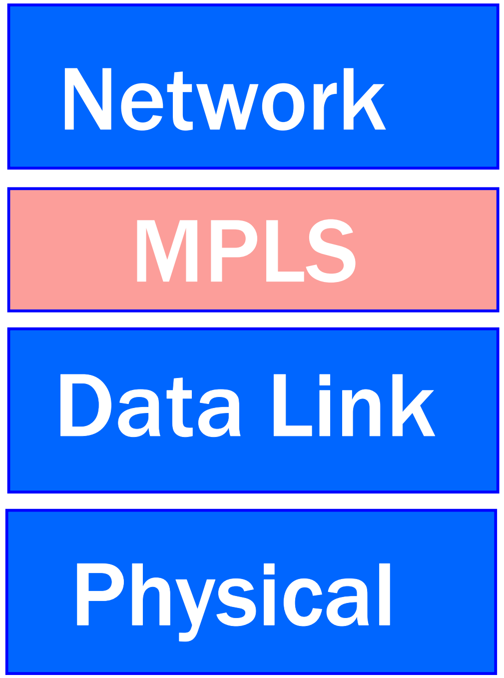


- VSID is a 24 bits Virtual Segment Identifier
- The inner packet does not contain a VLAN ID as in VXLAN
  - If a tenant needs multiple VLANs, it must be assigned different VSIDs
- Encapsulation/decapsulation is performed by *Network Virtual Endpoints* (NVEs)
- Which NVE is associated to a given DMAC is through mechanisms not in NVGRE specs

MPLS

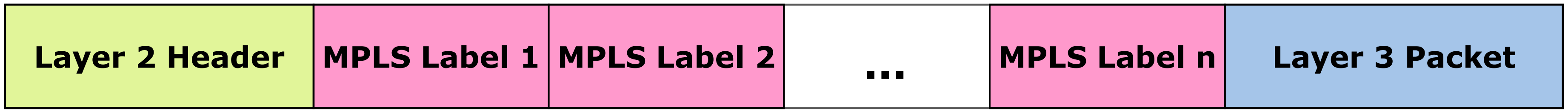
- A “Layer 2.5” tunneling protocol based on ATM-like notion of “label swapping”
  - A simple way of labeling each network layer packet
  - Independent of Link Layer
  - Independent of Network Layer
- Used to set up “Label-switched paths” (LSP), similar to ATM PVCs, to carry L3 packets (e.g. IP datagrams) on virtual circuits
- RFC 3031: Multiprotocol Label Switching Architecture
- An MPLS switch forwards packets according to labels





MPLS encapsulation

- RFC 3032. MPLS Label Stack Encoding

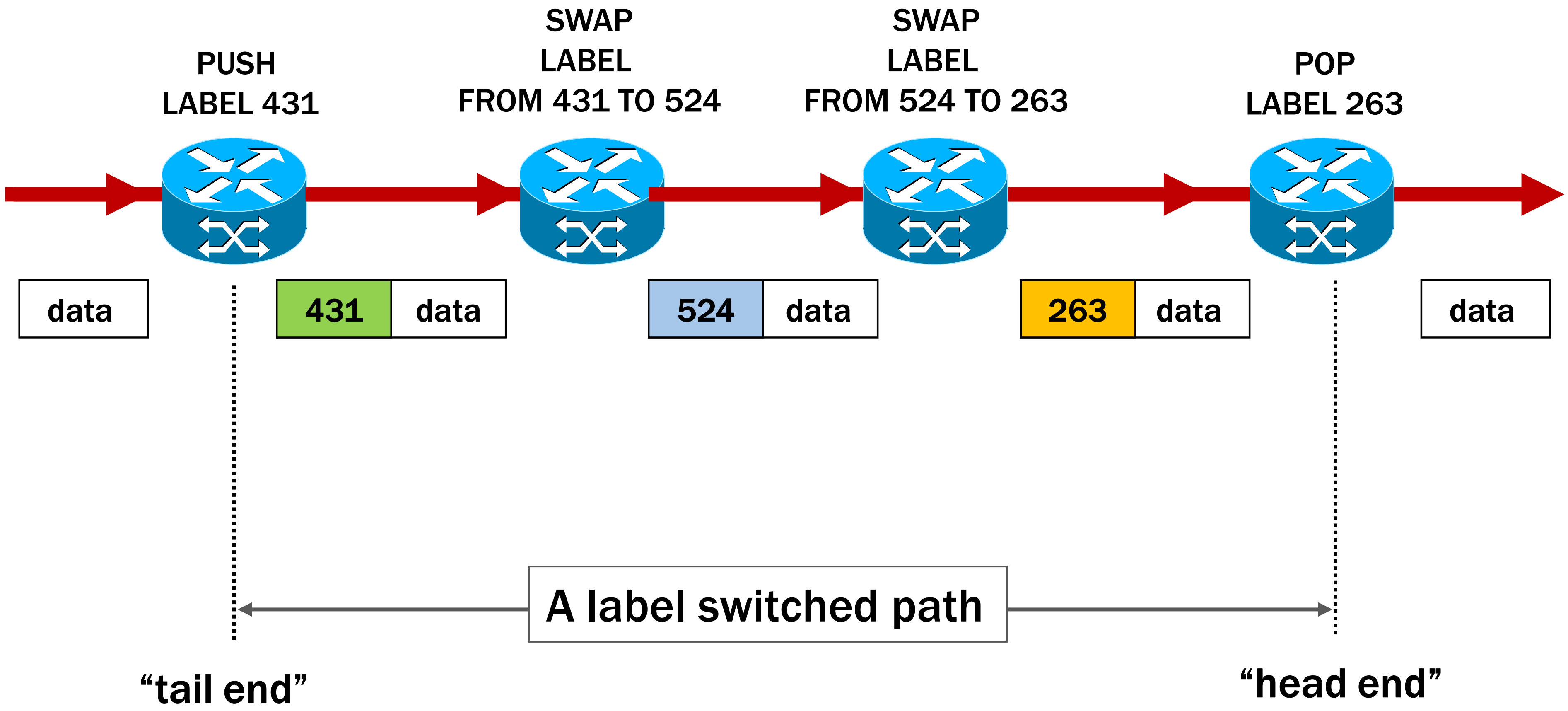



```
 0                   1                   2                   3
 0 1 2 3 4 5 6 7 8 9 0 1 2 3 4 5 6 7 8 9 0 1 2 3 4 5 6 7 8 9 0 1
+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
|                Label                  | Exp |S|       TTL     |
+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
```

- Label: Label Value, 20 bits
- Exp: Experimental, 3 bits
- S: Bottom of Stack, 1 bit
- TTL: Time to Live, 8 bits

LSP: Label Switched Path

- Also called an MPLS tunnel: payloads (*data*) are not inspected inside an LSP
- MPLS can carry any traffic, not only IP



MPLS label distribution

- Label distribution protocols are needed to
  1. create labels associated to an LSP
  2. distribute bindings to neighbors
  3. maintain consistent label swapping tables
- Two different approaches
  - "Piggyback" label information on top of existing IP routing protocol
    - Allows only traditional destination-based, hop-by-hop forwarding paths
  - Create new label distribution protocol(s)
    - Not limited to destination-based, hop-by-hop forwarding paths
    - E.g. LDP (IETF) and TDP (Cisco proprietary)
- Combine resource reservation with label distribution; two approaches:
  - Add label distribution and explicit routes to a resource reservation protocol
    - RSVP-TE
  - Add explicit routes and resource reservation to a label distribution protocol
    - CR-LDP