CS144
An Introduction to Computer Networks

Abstractions and Virtualization

Tags, Tunnels and Translation

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The term “Virtual” is (over) used a lot…

- Virtual LANs (VLAN)
- Virtual Private Network (VPN)
- Network Virtualization (used by cloud providers)
- Network Function Virtualization (NFV)

Learning goals of this class

- To learn how tags, tunnels and translation can be used to provide new abstractions in a network.
- To learn about the match + action abstraction
- To learn about three examples:
  Virtual LANs (VLANs), VPNs, and NATs.
- To learn what network virtualization is.
- To learn how overlay network virtualization works.
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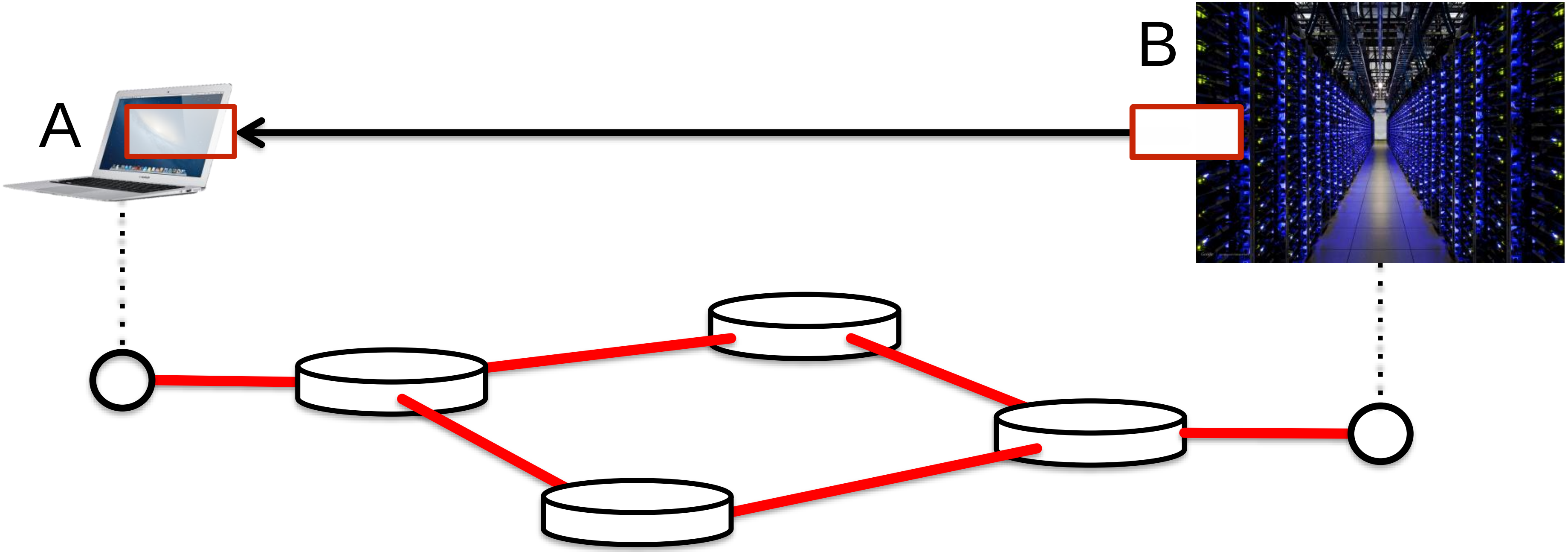
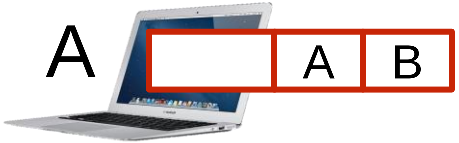
What do we mean by an abstraction?

Example: IP datagram delivery



Example: IP datagram delivery

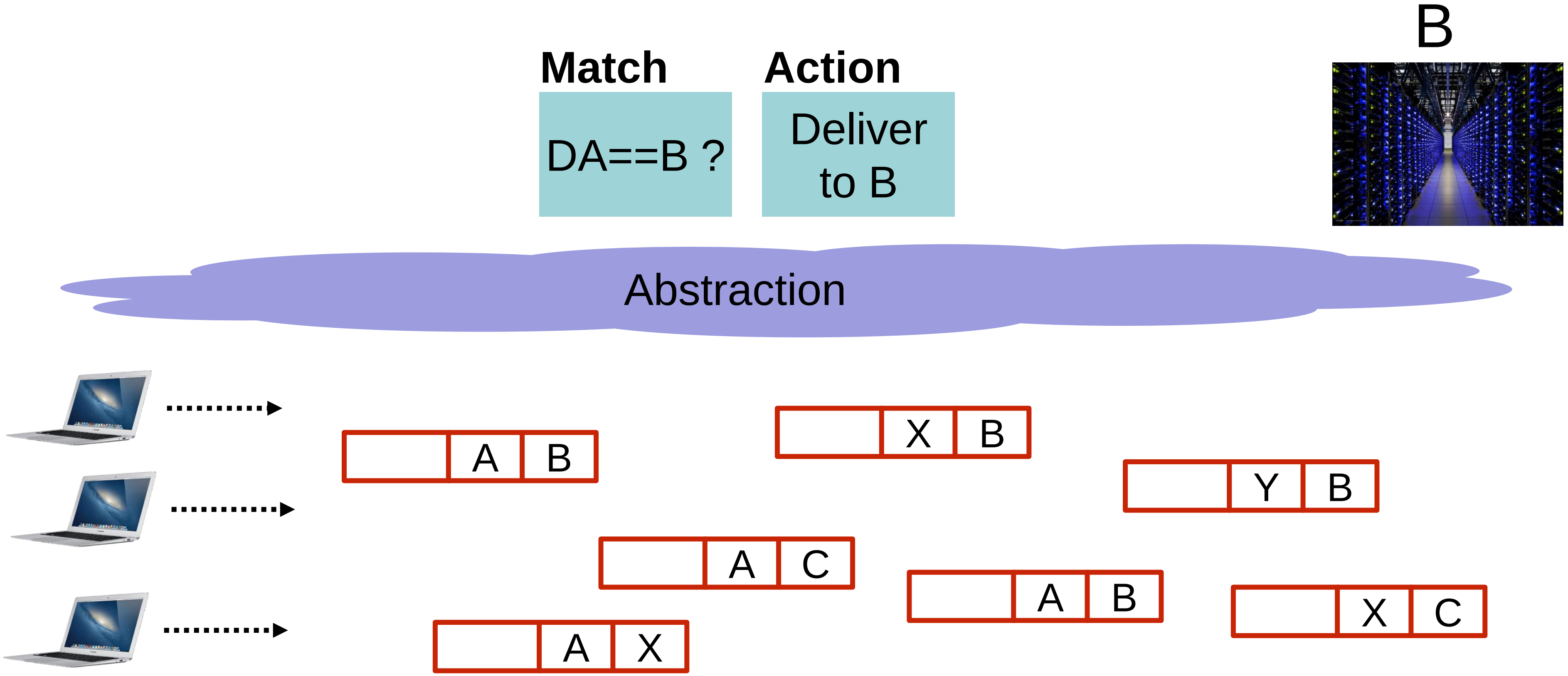


B

Abstraction: Packets with IP DA = B are delivered to B (with best effort)

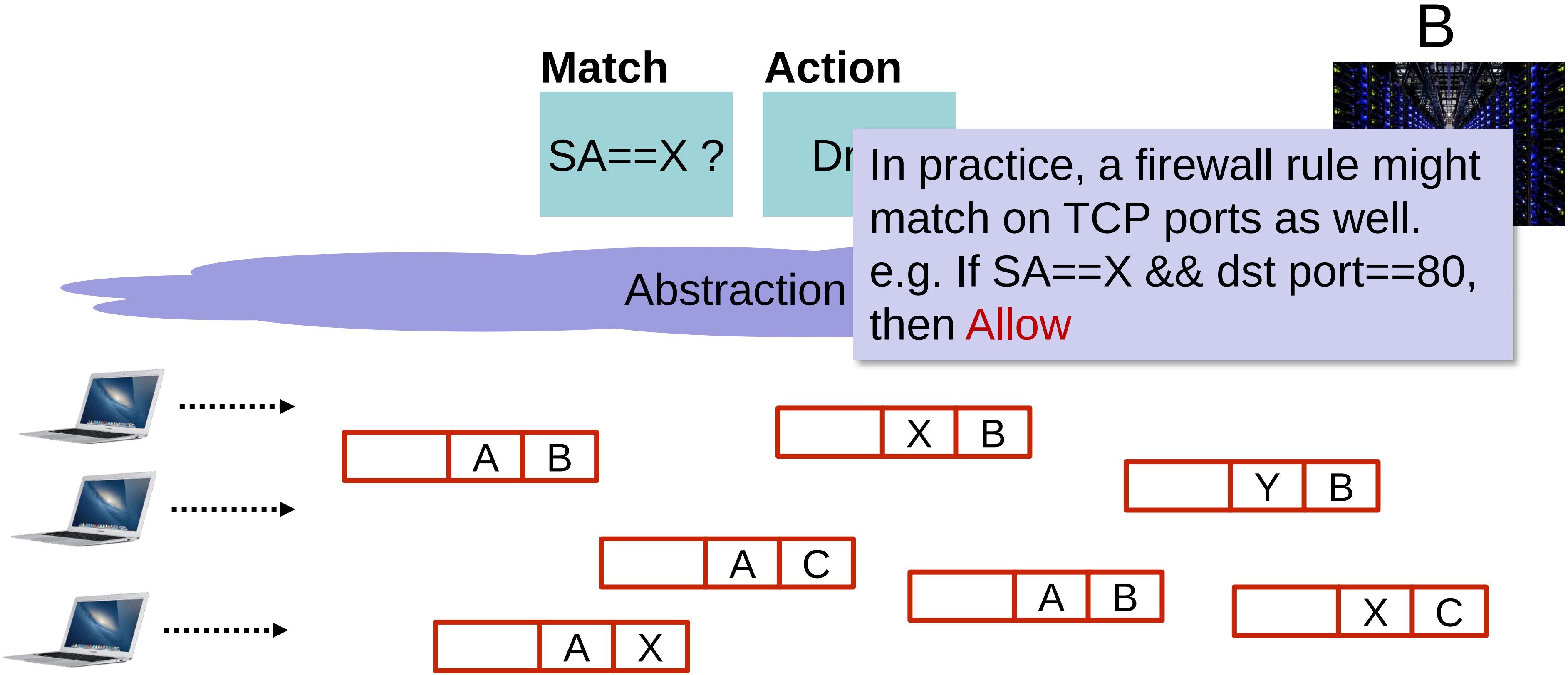
The details of how it is accomplished are hidden from us.

IP Forwarding Abstraction



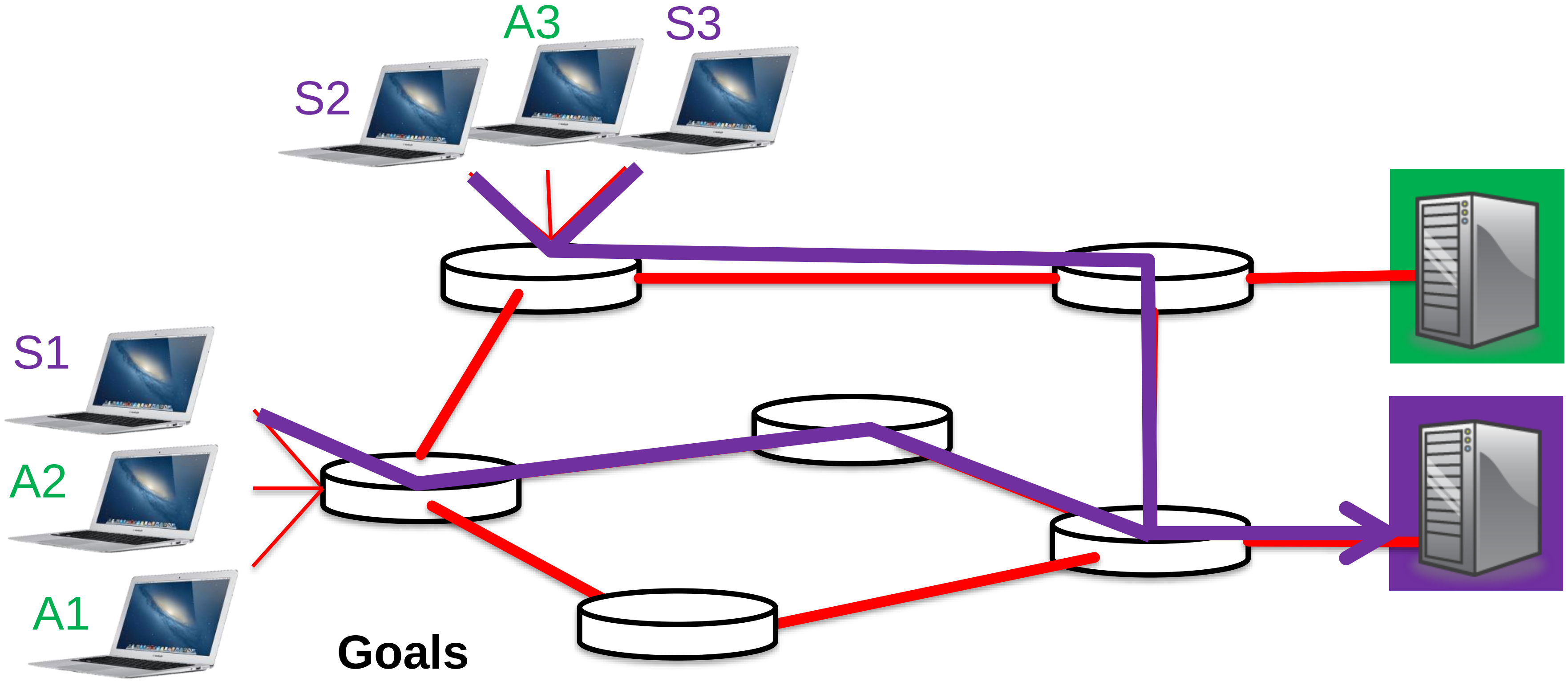
Match	Action
DA==B ?	Deliver to B

Firewall Abstraction



In practice, a firewall rule might match on TCP ports as well.
e.g. If SA==X && dst port==80, then Allow

Virtual LAN Abstraction

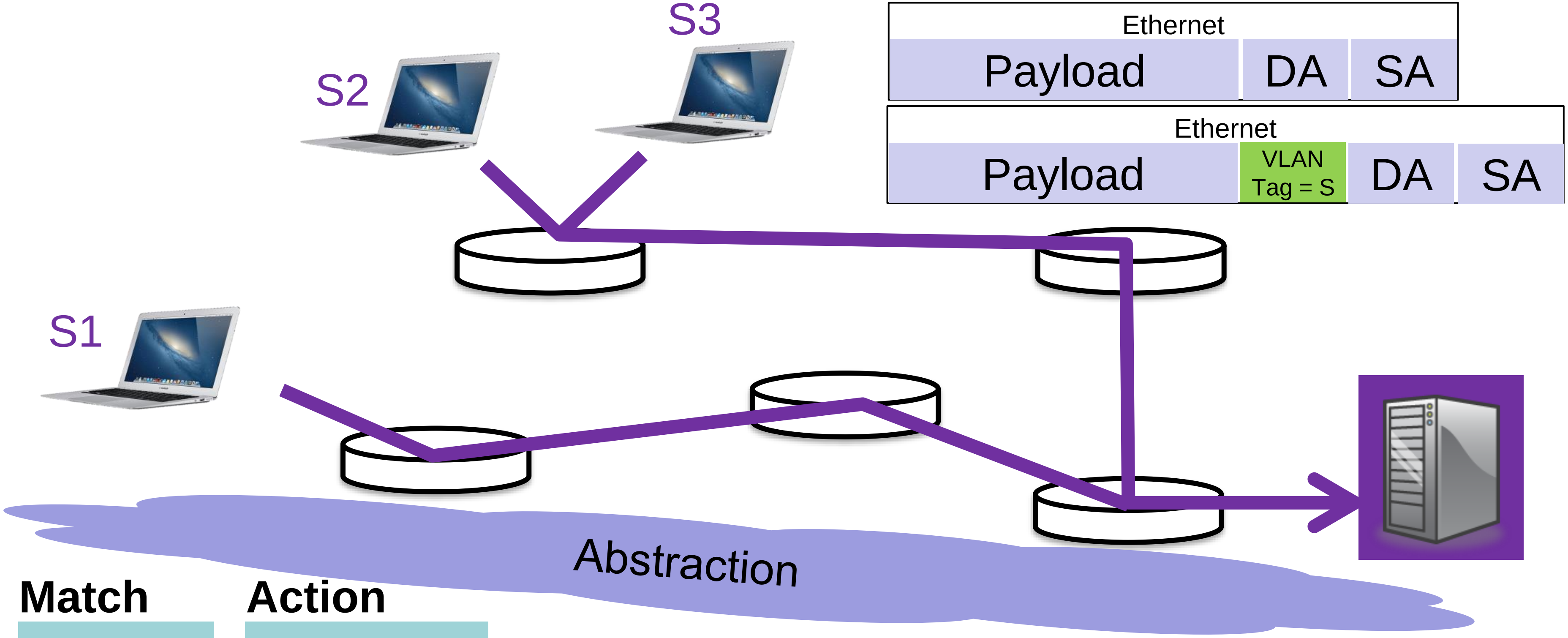


Goals

Packets on VLAN A never delivered to hosts on VLAN S

Packets in each VLAN follow their own spanning tree

Virtual LAN Abstraction



Mechanism

Ethernet

Payload	DA	SA

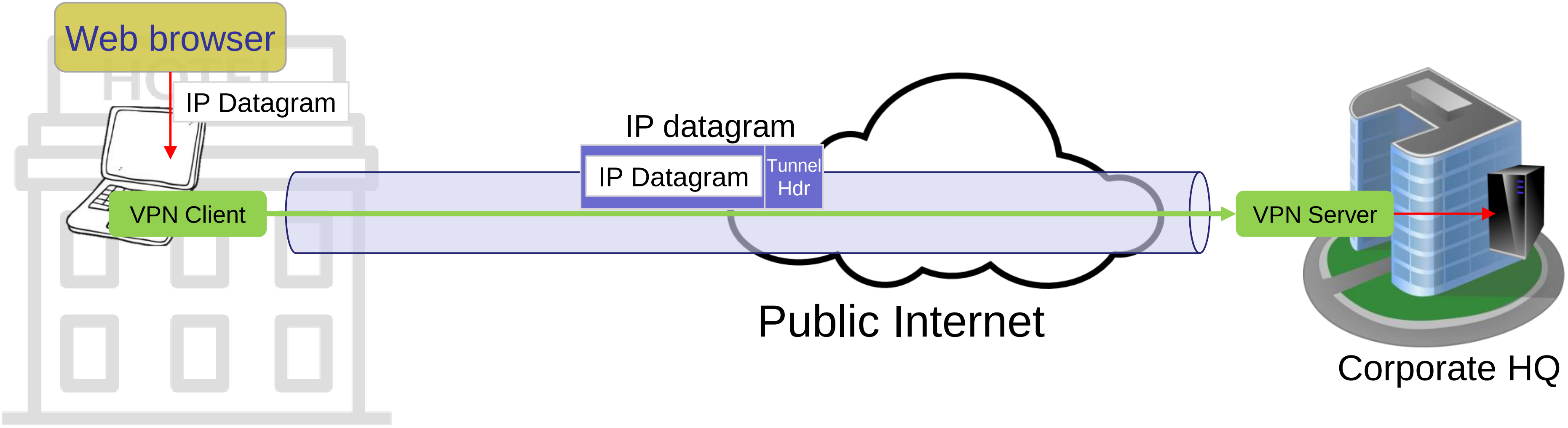
Ethernet

Payload	VLAN Tag = S	DA	SA

Match	Action
VLAN Tag==S ?	Forward on VLAN S

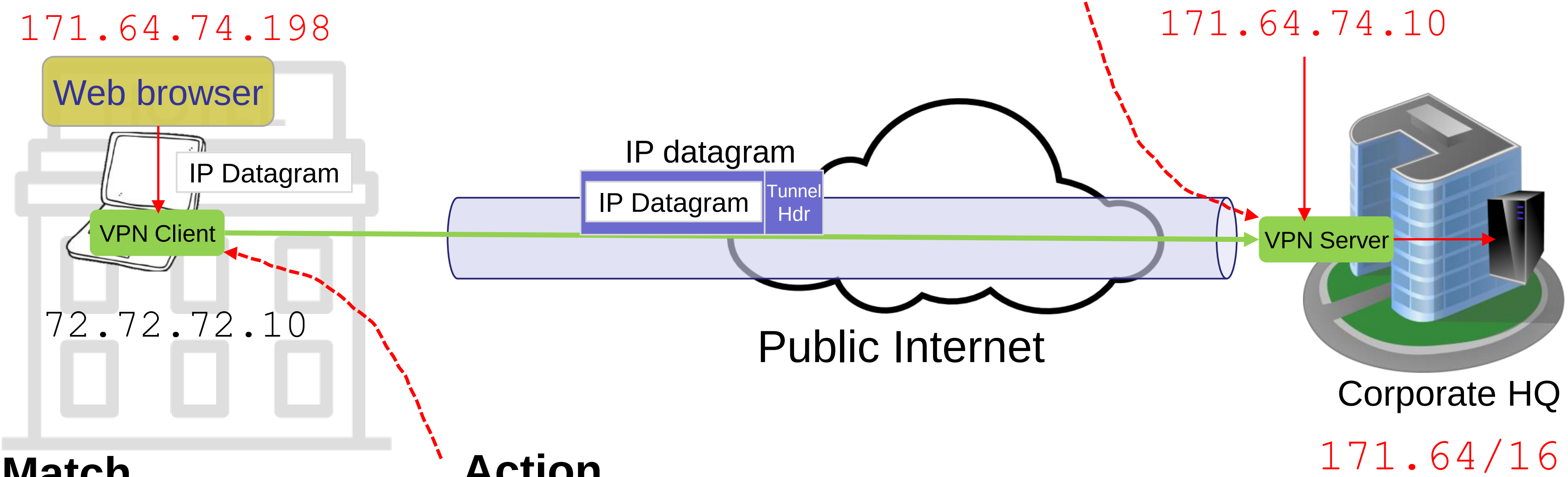
Example: Virtual Private Network (VPN)

Remote client “appears to be” on corporate network



Example: Virtual Private Network (VPN)

Decapsulate incoming
Encapsulate outgoing



Match

IP SA ==
171.64.74.198

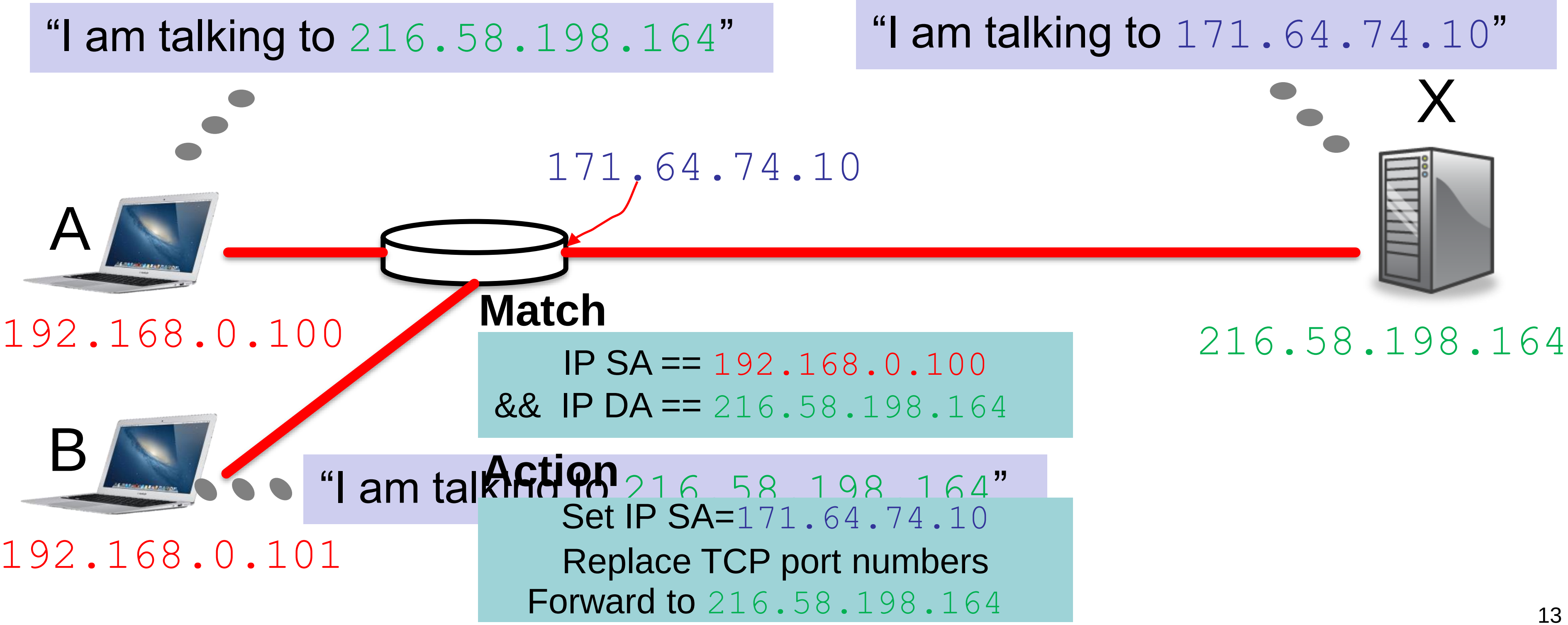
Action

Encapsulate in IP DA=171.64.74.10, SA=72.72.72.10
Forward to 171.64.74.10

Example: Network Address Translation (NAT)

Multiple clients share a common IP address

Q: Why does NAT use translation instead of tags or tunnels?



"I am talking to 216.58.198.164"

"I am talking to 171.64.74.10"

"I am talking to 216.58.198.164"

Match

IP SA == 192.168.0.100
&& IP DA == 216.58.198.164

Action

Set IP SA=171.64.74.10
Replace TCP port numbers
Forward to 216.58.198.164

“Modularity based on abstraction is the way things are done!”

Barbara Liskov (MIT)
Turing Award Lecture 2009

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Network Virtualization

Abstractions in computer systems

Virtual memory

Abstract illusion of infinite, private physical memory

File system

Uniform illusion of read/write data store.

Virtual Machine User application cannot tell if it is running on a physical or virtual machine.

…

Virtual Network: The abstraction

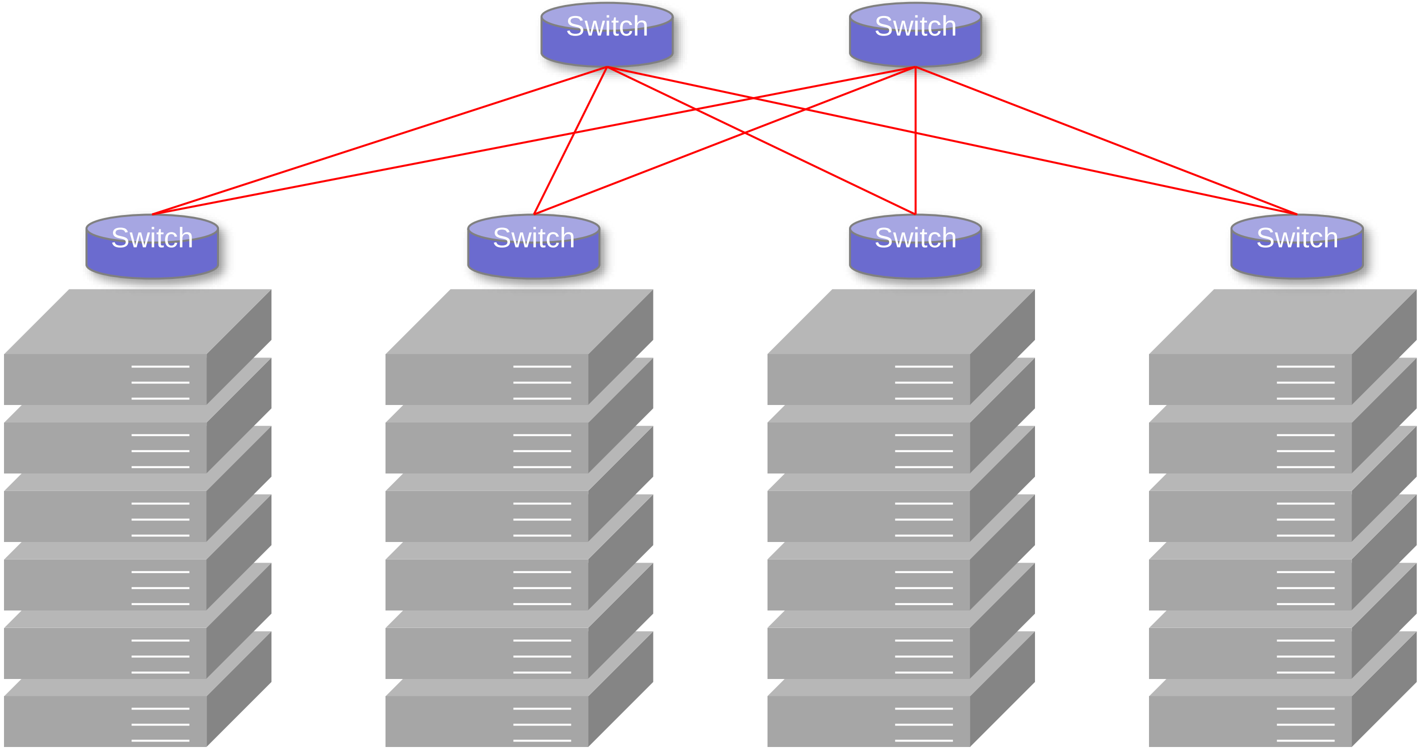
The abstraction (or illusion) of a physical network: The user, application (and possibly the network administrator too) cannot tell if the network is physical or virtual.

Virtual Network: The abstraction

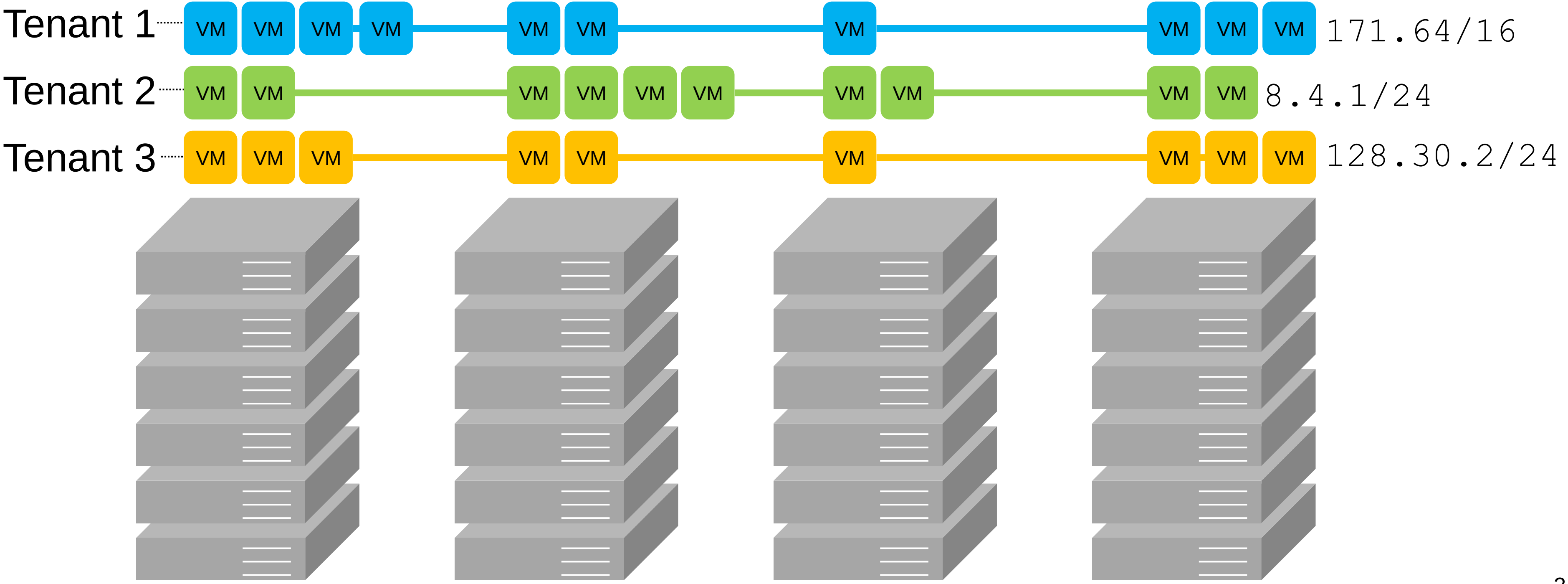
A set of VMs operating as if connected to the same physical network.

1. Typically belonging to the same tenant.
2. VMs communicate with each other using their own address space.
3. Virtual networks are isolated from each other: They cannot communicate, except through a gateway.
4. VMs can migrate to a different server without changing IP address.
5. A virtual network has a SLO expressed as a desired quality of service (e.g. data rate, reliability, latency)
6. A VM can operate as if on the tenant’s home network.
7. Used for containers too

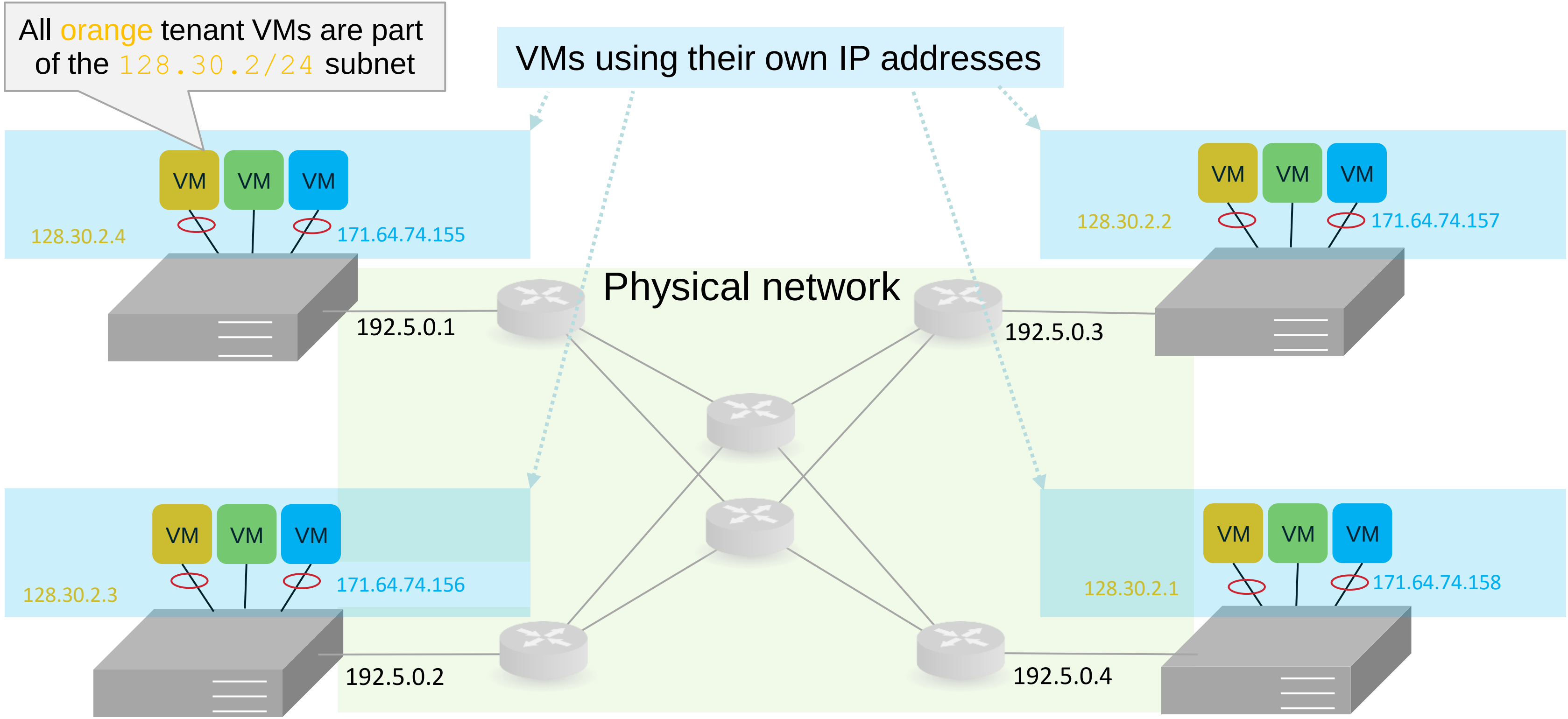
Virtualized Data Center



Abstraction for tenant VMs


Tenant 1
VM VM VM VM VM VM VM VM VM VM
171.64/16
Tenant 2
VM VM VM VM VM VM VM VM VM VM
8.4.1/24
Tenant 3
VM VM VM VM VM VM VM VM VM
128.30.2/24

VMs using their own IP addresses



Q: Which mechanism Tag, tunnel or translation?

Mechanism: Tags, Tunnels or Translation?

Any mechanism could be made to work.

Tags: Switches contain a forwarding table per tenant.

- Tag in every packet indicates the tenant and therefore the forwarding table to use.
- But: We need to change the switches to recognize the tag and forward based on it.

Translation: Use NAT, with port numbers identifying VMs.

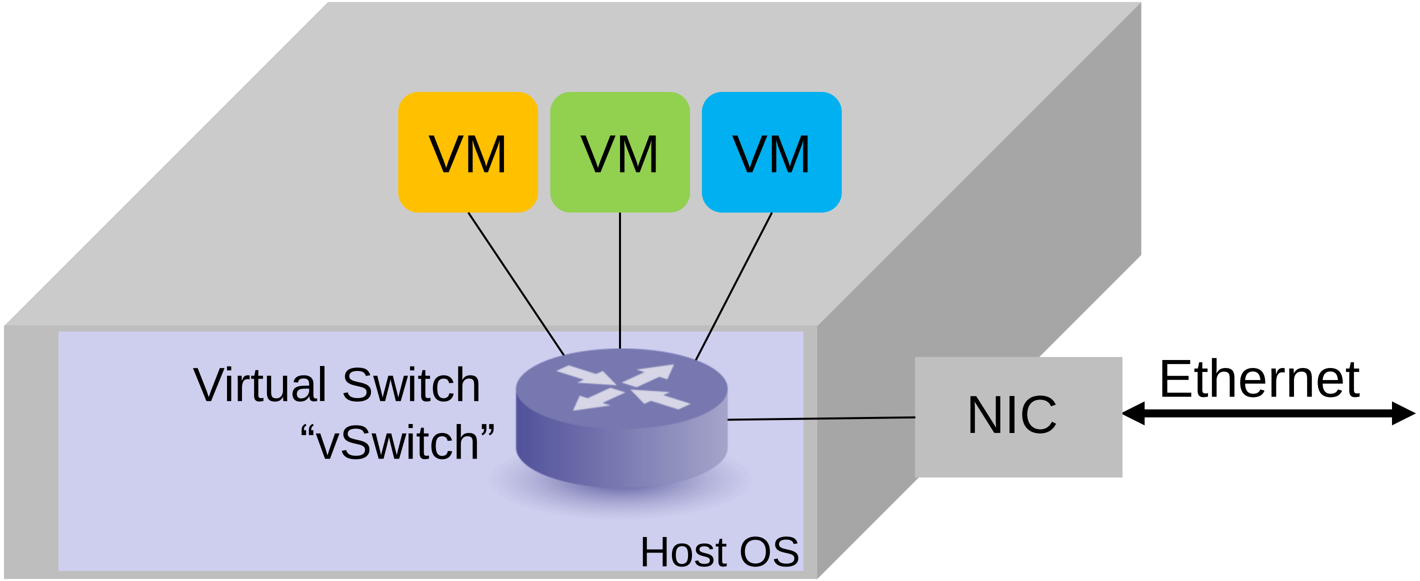
- But: Both ends behind NATs, therefore need NAT traversal everywhere – complicated.
- But: With thousands of VMs per server, quickly run out of port numbers for mapping.

Tunnel: Create tunnel between every pair of servers.
Forward traffic between VMs through the tunnel.

- But: We need to change switches to create tunnels.
- But: Server will receive packets for all addresses used by its VMs.

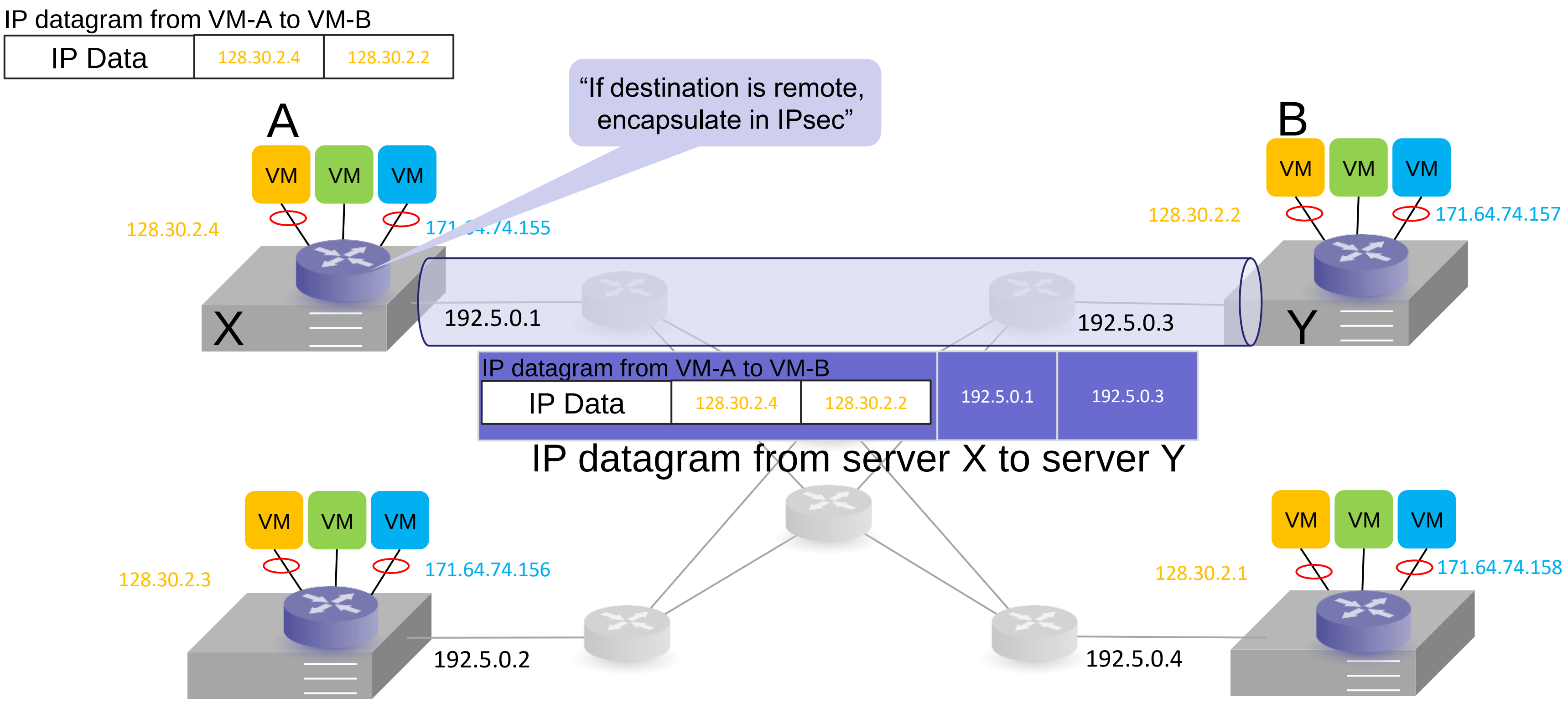
How it is done in virtualized data centers

1: Use the software “vSwitch” in every server



- Maintains tunnel to every other server’s vSwitch
- Tags packets with tenant ID
- Forwards packets into tunnel

2: Forward packets in tunnels between vSwitches



IP datagram from VM-A to VM-B

“If destination is remote, encapsulate in IPsec”

IP datagram from server X to server Y

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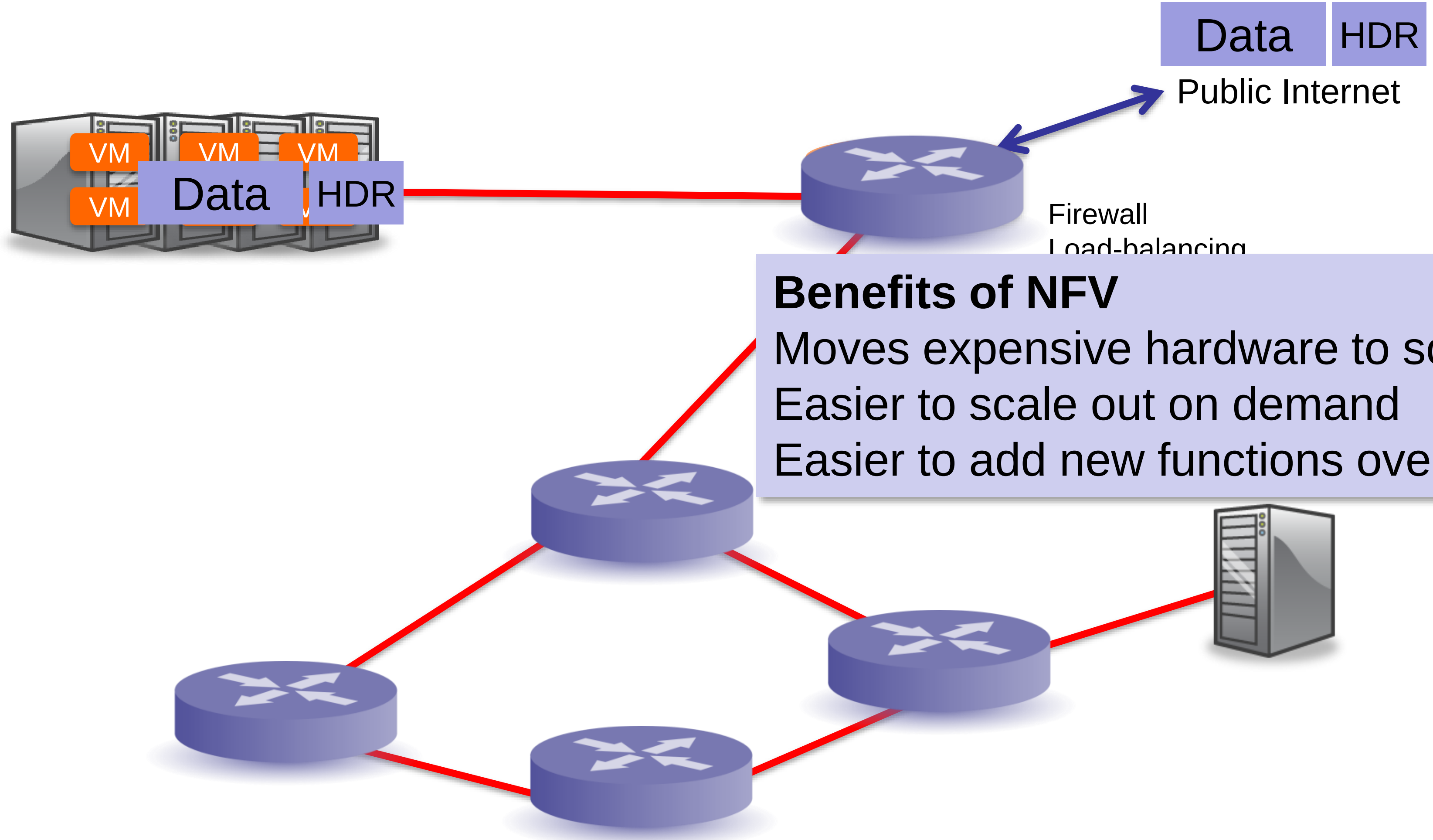
Network Function Virtualization (NFV)



Benefits of NFV

Moves expensive hardware to software

Easier to scale out on demand

Easier to add new functions over time

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Thank you!