工業技術研究院
Industrial Technology Research Institute

Ethernet-based Software Defined Network (SDN)

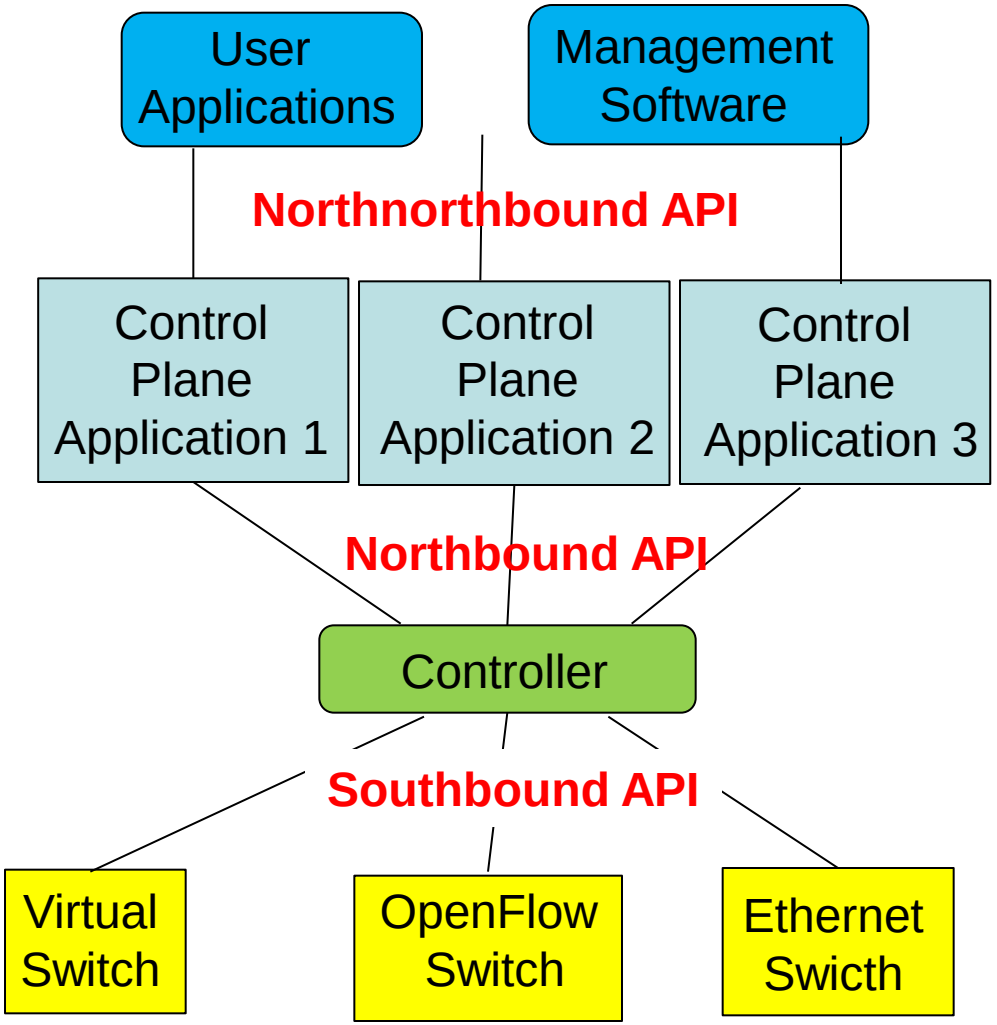
Cloud Computing Research Center for Mobile Applications (CCMA), ITRI
雲端運算行動應用研究中心

SDN Introduction

- Decoupling of control plane from data plane
  - Breaks the existing vertical integration model in network equipment industries
  - Enables quick development and deployment of innovative third-party control plane applications
- Centralization of control plane
  - Management vs. Control vs. Data plane
  - Facilitates fast deployment and upgrade of control protocols
  - Enables global allocation of a network's resources
- Software in software-defined network
  - User applications
  - Control protocols

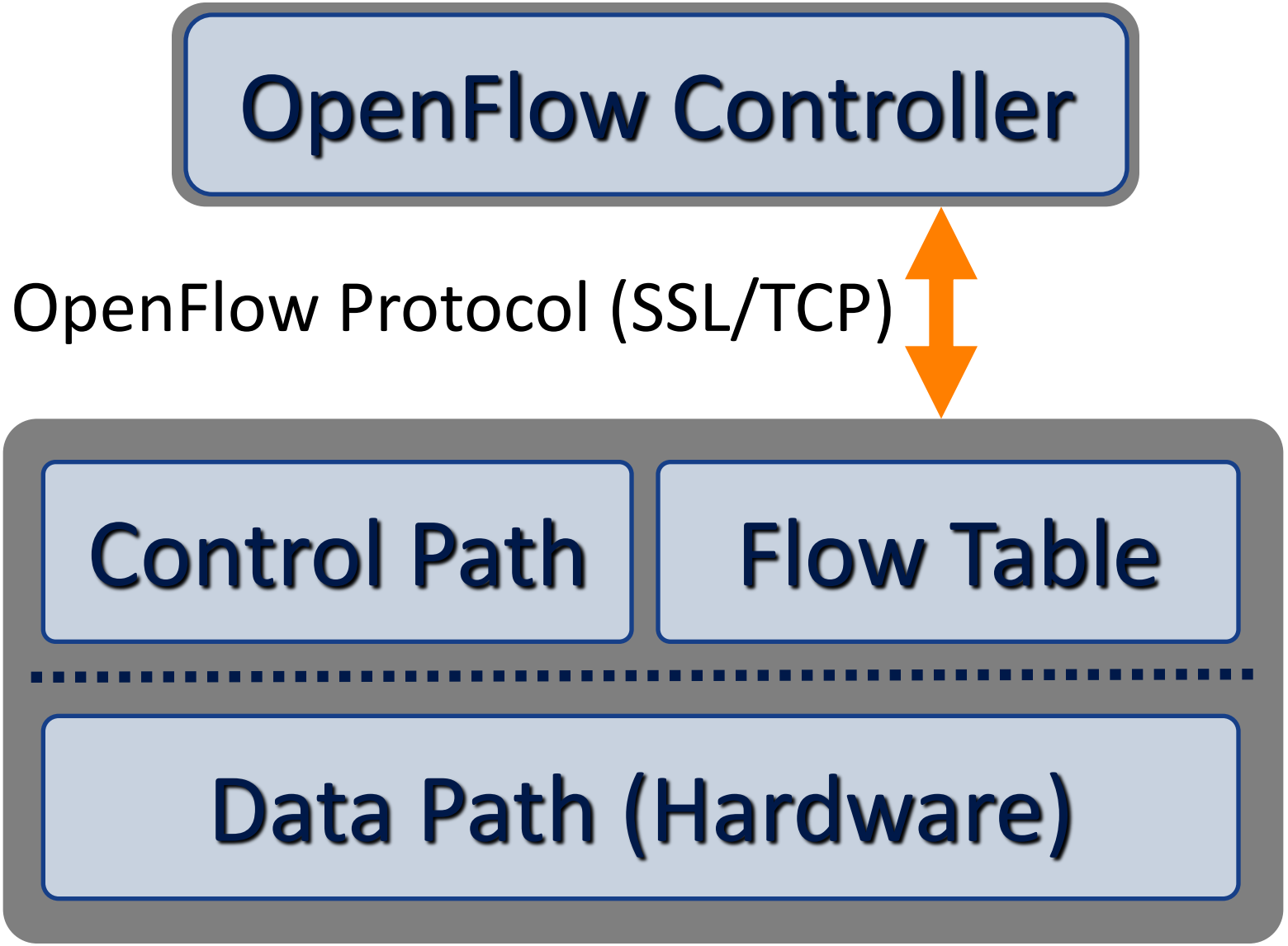
SDN Software Architecture

- Data plane
- Controller
- Control plane applications
- Southbound AP
- Northbound API
- NorthNorthbound API

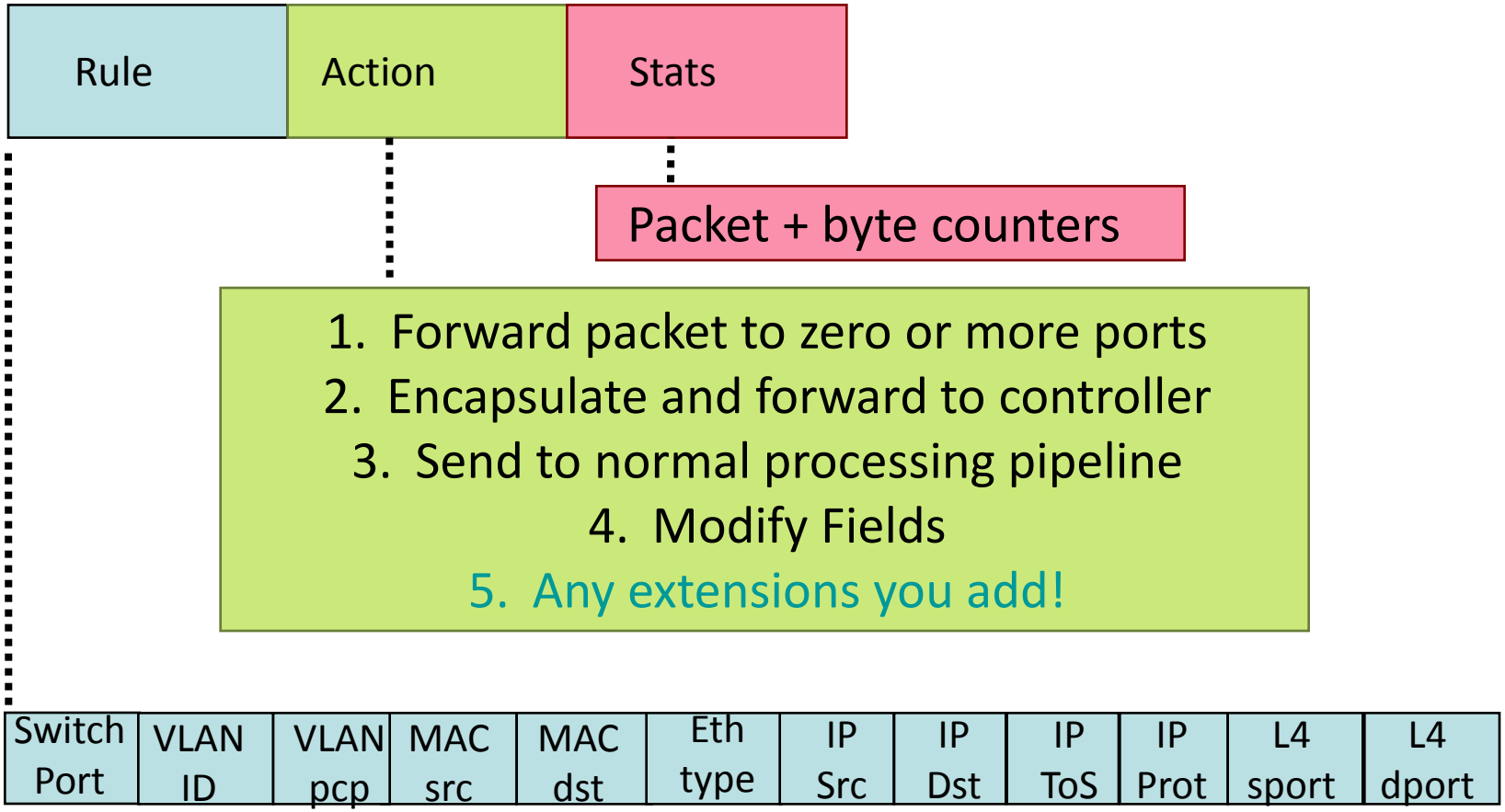


OpenFlow Architecture

- OpenFlow switch: A data plane that implements a set of flow rules specified in terms of the OpenFlow instruction set
- OpenFlow controller: A control plane that sets up the flow rules in the flow tables of OpenFlow switches
- OpenFlow protocol: A secure protocol for an OpenFlow controller to set up the flow tables in OpenFlow switches


OpenFlow Controller
OpenFlow Protocol (SSL/TCP)
Control Path
Flow Table
Data Path (Hardware)

OpenFlow Basics



+ mask what fields to match

Examples

Switching

Switch Port	MAC src	MAC dst	Eth type	VLAN ID	IP Src	IP Dst	IP Prot	TCP sport	TCP dport	Action
*	*	00:1f:..	*	*	*	*	*	*	*	port6

Flow Switching

Switch Port	MAC src	MAC dst	Eth type	VLAN ID	IP Src	IP Dst	IP Prot	TCP sport	TCP dport	Action
port3	00:20..	00:1f..	0800	vlan1	1.2.3.4	5.6.7.8	4	17264	80	port6

Firewall

Switch Port	MAC src	MAC dst	Eth type	VLAN ID	IP Src	IP Dst	IP Prot	TCP sport	TCP dport	Action
*	*	*	*	*	*	*	*	*	22	drop

Examples

Routing

Switch Port	MAC src	MAC dst	Eth type	VLAN ID	IP Src	IP Dst	IP Prot	TCP sport	TCP dport	Action
*	*	*	*	*	*	5.6.7.8	*	*	*	port6

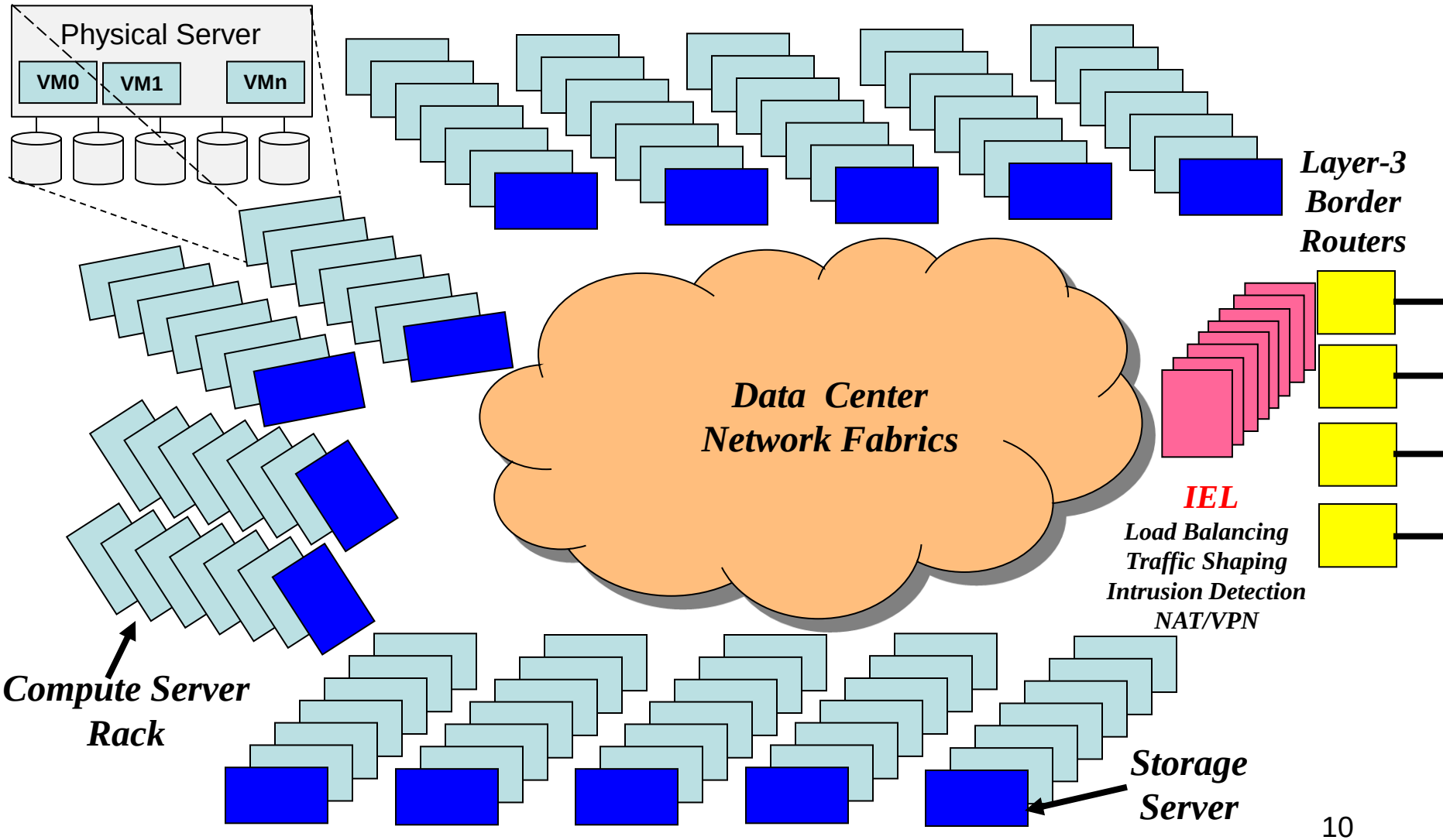
VLAN Switching

Switch Port	MAC src	MAC dst	Eth type	VLAN ID	IP Src	IP Dst	IP Prot	TCP sport	TCP dport	Action
*	*	00:1f..	*	vlan1	*	*	*	*	*	port6, port7, port9

SDN ≠ OpenFlow

- Can we apply SDN to Ethernet switches, especially in cloud data center space? Peregrine

Cloud Data Center Architecture



Cloud Data Center Network

- Cloud data centers are Big and Shared
- Scalable and available data center fabrics
  - Not all links are used
  - No load-sensitive routing
  - Fail-over latency is high (> 5 seconds)
- Network virtualization: Each virtual data center (VDC) gets to define its own network
  - VMs in a VDC belong to one or multiple subnets (broadcast domains)
  - Each VDC has its own private IP address space
  - Each VDC has a set of public IP addresses for service entry points and for VPN connections with external sites
  - Each VDC has its Internet traffic shaping policy, intra-VDC and inter-VDC firewalling policy, and server load balancing policy

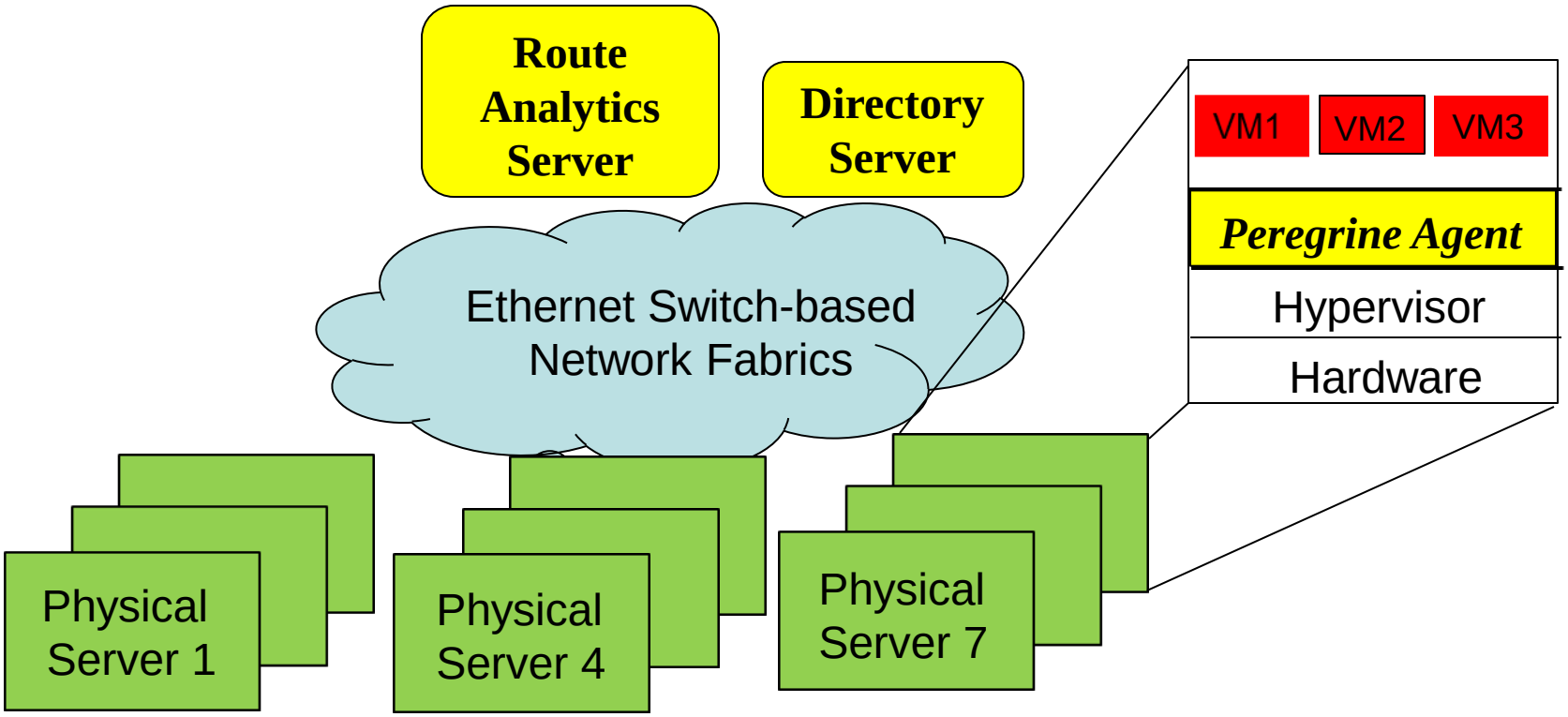
What's Wrong with Ethernet?

- Spanning tree-based
  - Not all physical links are used
  - No load-sensitive dynamic routing
  - Fail-over latency is high (> 5 seconds)
- Cannot scale to a large number of VMs (e.g. 1M)
  - Forwarding table is too small: 16K to 64K
- Does not support VM migration and visibility
- Does not support network virtualization

Peregrine

- A unified Layer-2-only data center network for LAN and SAN traffic
- A SDN architecture using only commodity Ethernet switches: centralized control plane and distributed data plane
- Turn off Ethernet's control protocol: spanning tree, source learning, flooding of unknown-destination-MAC packets, broadcast of ARP and DHCP
  - VLAN is optional because VLAN ID space is limited
- Centralized load-balancing routing using real-time traffic matrix
- Fast fail-over using pre-computed primary/backup routes
- Native support for network virtualization
  - Private IP address space reuse
  - Multiple subnets per virtual network

Peregrine Software Architecture



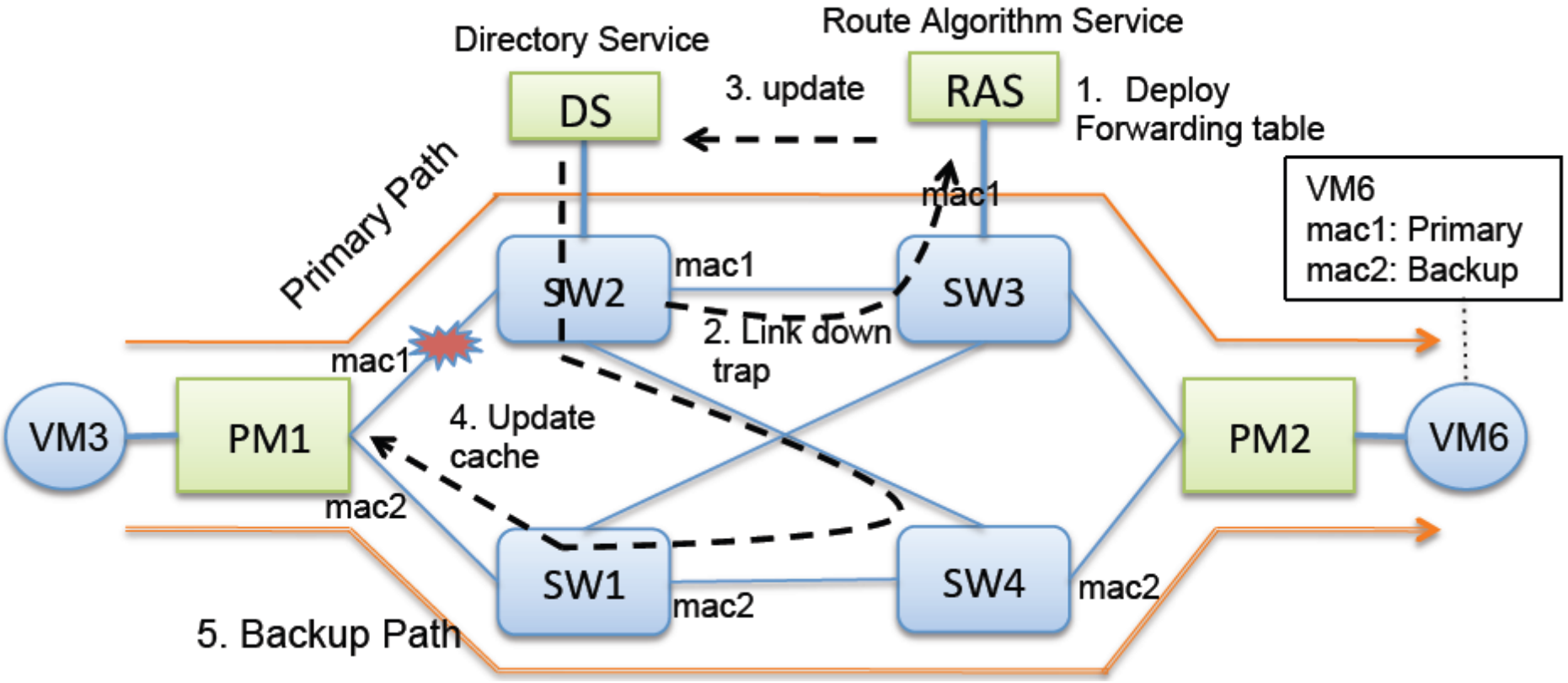
Dynamic Traffic Engineering

- Periodic collection of real-time traffic matrix
  - Traffic volume between each pair of VMs
  - Traffic volume between each pair of PMs
- Load balancing routing algorithm
  - Loads on the physical links
  - Number of hops
  - Forwarding table entries
  - Prioritization
- Computed routes are programmatically installed on the forwarding tables of Ethernet switches

Fast Failure Recovery

- For a given node N, proactively computes two disjoint paths (primary and backup) from every other node to N, and installs them on the associated switches
- All primary (secondary) paths to a given node N form a spanning tree
- Each node has two MAC addresses, which are installed on the switches of its primary and backup trees, respectively
- When a primary path from S to D goes down, S is notified that it should use D's backup MAC address to reach D
- RAS and DS support fail-over

Fast Failure Recovery Example



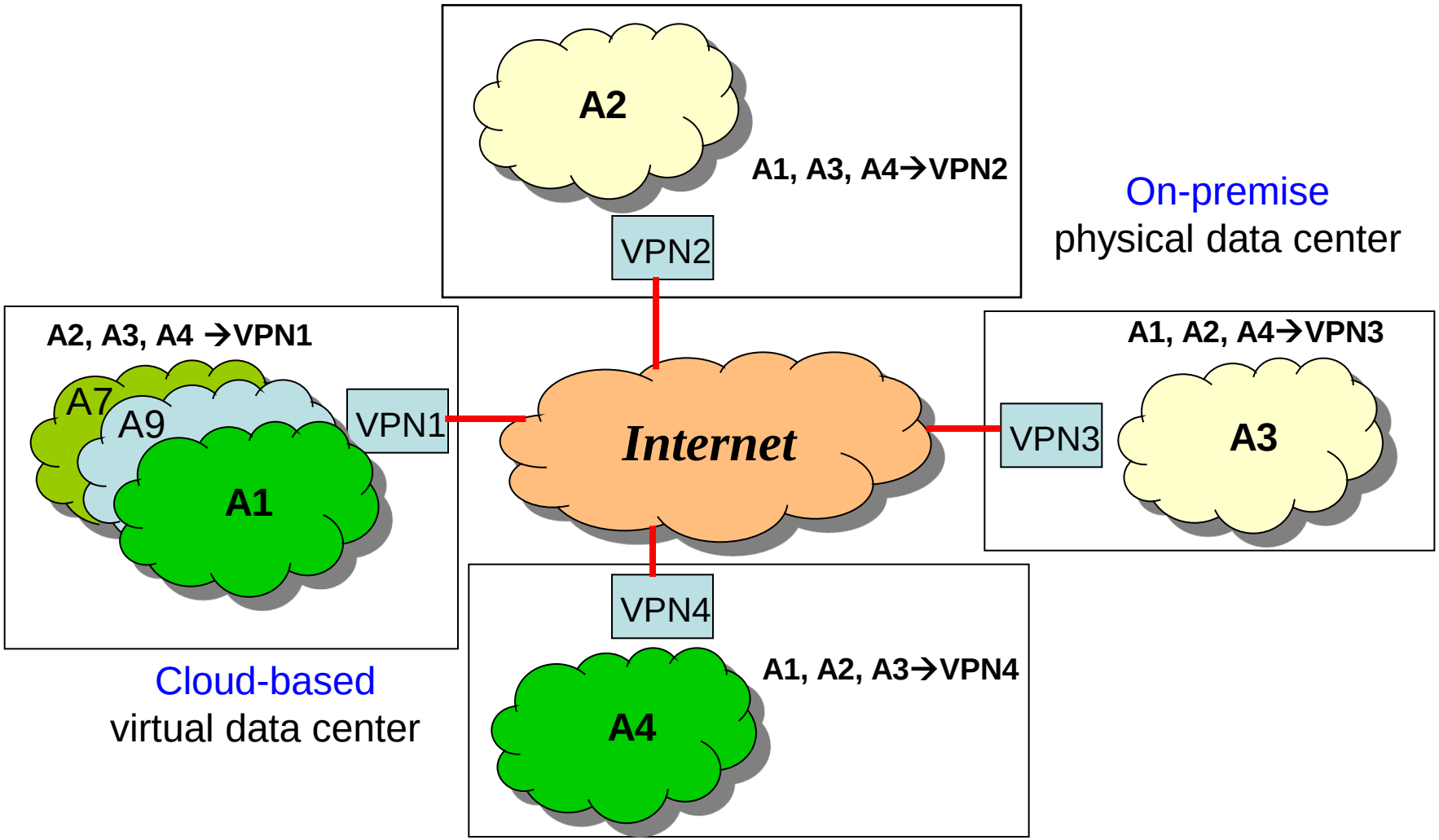
Network Virtualization

- Multiple virtual networks running on a single physical network
- The network of each virtual data center (VDC) consists of
  - VMs' MAC addresses are pre-assigned
  - A single layer-2 network
  - A complete private IP address space, organized into multiple subnets each with its own broadcast domain
  - A set of public IP addresses
  - Its own copy of the DHCP and DNS service
  - Security: Intra-VDC and inter-VDC firewall policy
  - SLA: Traffic shaping policy
  - Scalability: Server load balancing policy

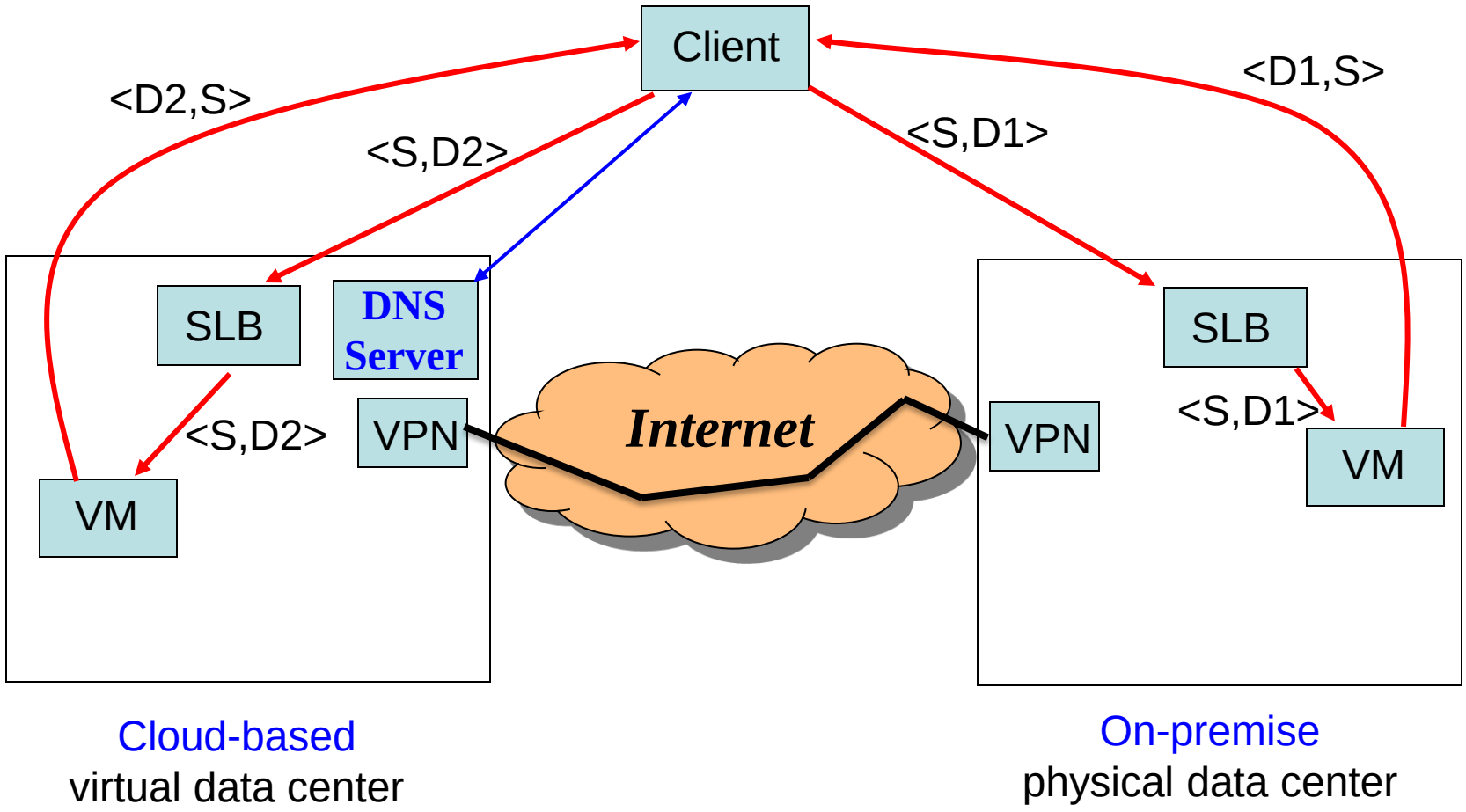
Private IP Address Space Reuse

- Requirement: Every VDC has a VDC ID and its own full 24-bit private IP address space (10.x.x.x), even though multiple VDCs run on top of the same data center network
- Two approaches:
  - Ethernet over TCP/UDP:
    - Every Ethernet packet is encapsulated inside an TCP/UDP packet or TCP/UDP connection as an Ethernet link
    - Needs to implement in software such Ethernet switch functions as source learning, flooding, VLAN, etc.
    - Can work with arbitrary IP networks
  - Multi-tenancy-aware IP-MAC mapping: our approach
    - VDC ID + private IP address ➔ MAC address
    - Runs directly on L2 networks, no need for Ethernet switch emulation
    - Inter-virtual-data-center isolation

Hybrid Cloud Support



Cross-Site Global Load Balancing



Peregrine in SDN Framework

- Data plane: Ethernet switches
- Southbound API: SNMP and CLI
- Controller: (1) Physical network resource set-up, (2) Physical topology record keeping, (3) SNMP trap processing, (4) Ethernet switch configuration, including forwarding table programming, and (5) Traffic load information
- Northbound API:
  - Failure/congestion notification, including SNMP trap packet delivery
  - ARP request packet delivery
  - Forwarding table programming
  - Physical topology/traffic load querying
- Control plane applications:
  - Dynamic traffic engineering
  - Fast fail-over for data/control plane failures
  - Network virtualization

Wish-List Ethernet Switch Features

- Ability to turn off flooding of unicast packets with unknown destination MAC address
- Ability to turn off source MAC address check
  ➔enables asymmetric routing
- Bulk uploading of forwarding table
- Fast link/switch failure detection
- Link traffic load counting
- Interception and redirection of packets of selected type

Comparisons

- Scalable and available data center fabrics
  - IEEE 802.1aq: Shortest Path Bridging
  - IETF TRILL
  - Competitors: Cisco, Juniper, Brocade
  - Differences: commodity switches, centralized load balancing routing and proactive backup route deployment
- Network virtualization
  - OpenFlow protocol: between OpenFlow controller and OpenFlow switches
  - Competitors: Nicira, NEC and NTT
  - Generality carries a steep performance price
    - Every virtual network link is a tunnel
  - Differences: Simpler and more efficient because it runs on L2 switches directly
    - Flow table state management and flow table lookup performance overhead

Current Status

- A fully operational Peregrine prototype that works on a 10-switch and 100-server test-bed
  - Start-up and shut-down without out-of-band control network
  - Fast fail-over for both data plane and control plane failures
  - Dynamic traffic engineering
- On-going work:
  - An agentless implementation of Peregrine
  - Encapsulate Peregrine with Internet Edge Logic functionalities as a Quantum plug-in implementation
  - Port dynamic traffic engineering, fast fail-over, and network virtualization to an OpenFlow platform, i.e. OF controller + OF switches

Summary

- Peregrine is a network system technology, not a network device technology, and consists of
  - A hypervisor agent running on every compute node
    - L7/Web application firewall and traffic shaping
  - A centralized route server and directory server
  - A VDC-aware Internet Edge Logic cluster
    - Server load balancing, VPN, NAT, and L4 firewall
- Network virtualization technology that does not use tunneling or VLAN
- A software defined network (SDN) architecture that runs on commodity Ethernet switches, and is able to manage both legacy Ethernet and OpenFlow switches

Thank You!

For More Information:

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