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# Enterprise Campus Design: Multilayer Architectures and Design Principles

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BRKCRS-2031

Cisco live!

# Our Vision and Strategy

**Vision**

Change the way the world works, lives, plays, and learns

**Strategy**

We create solutions built on intelligent networks that solve our customers' challenges

# Digital Transformation is Moving IT to the Boardroom

# Digital Transformation is Moving IT to the Boardroom

3X

more organisations intend to be digital ready in

2 YEARS

– IDC[1]

# Business at the Speed of Digital

*"Digital business requires faster delivery of services to the business, ultimately requiring enterprises to change* ***network operations processes and tooling.****"*

– Gartner[2]

# Unprecedented Demands on the Network

## Digital Disruption

63 million new devices online every second by 2020[1]

Lack of Business and IT Insights

## Complexity

3X spend on network operations vs network[2]

Slow and Error Prone Operations

## Security

6 months to detect breach[3]

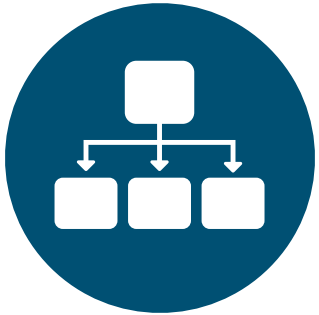
Unconstrained Attack Surface

1: Gartner Report - Gartner's 2017 Strategic Roadmap for Networking
2. McKinsey Study of Network Operations for Cisco – 2016
3. Ponemon Research Institute Study on Malware Detection, Mar 2016

# Cisco's Enterprise SDN Strategy

## Policy and Intent to Unlock the Power of your Distributed System

**Unlock the Power that Exists in the Network** through **Abstraction, Automation, and Policy Enforcement**



**Leverage the Power** of Existing **Distributed Systems**

**Enable Network Wide Fidelity** to an Expressed Intent **(Policy)**

# Automation at Scale

IDC Analyze the Future

More Efficient Networking Staff
28%

Faster Delivery of New Applications
17%

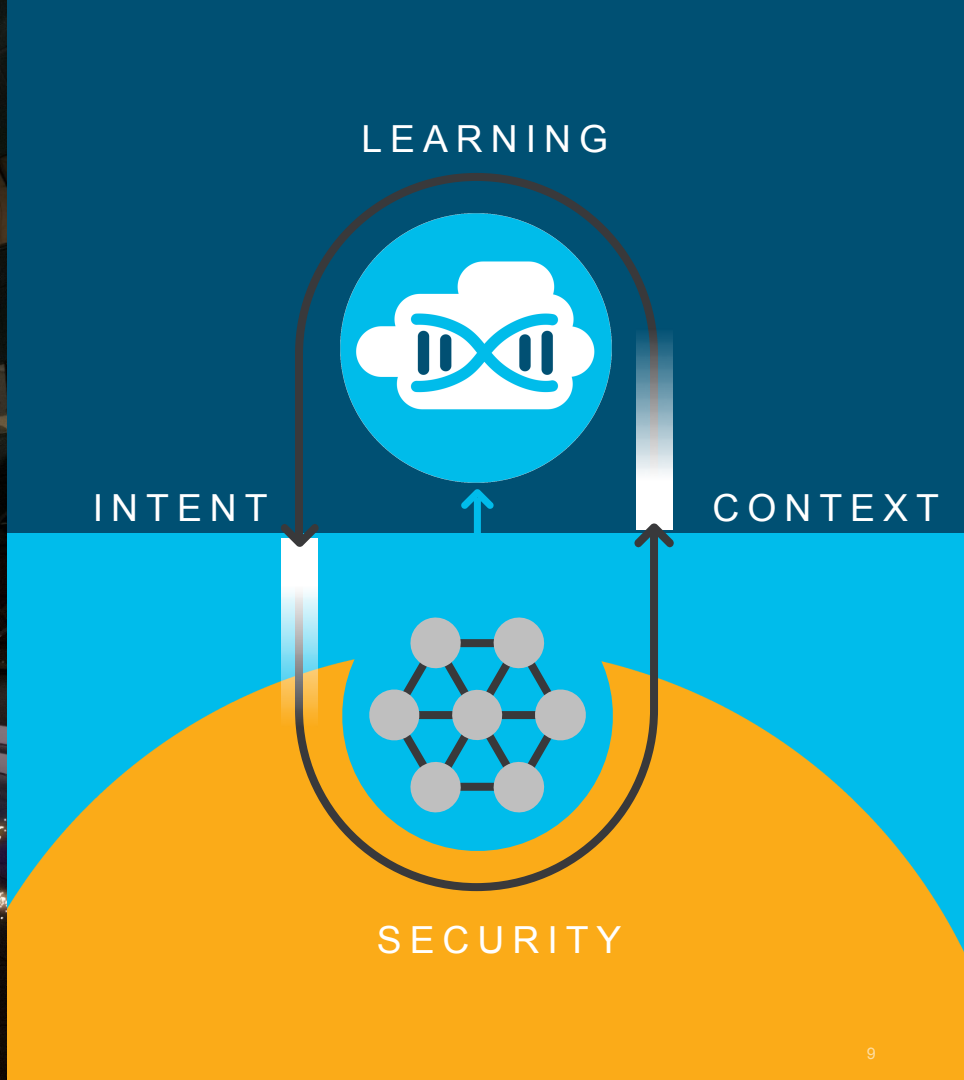
Faster WAN Branch Deployments
42%

Average Annual Benefit
$48K
Per 100 Employees

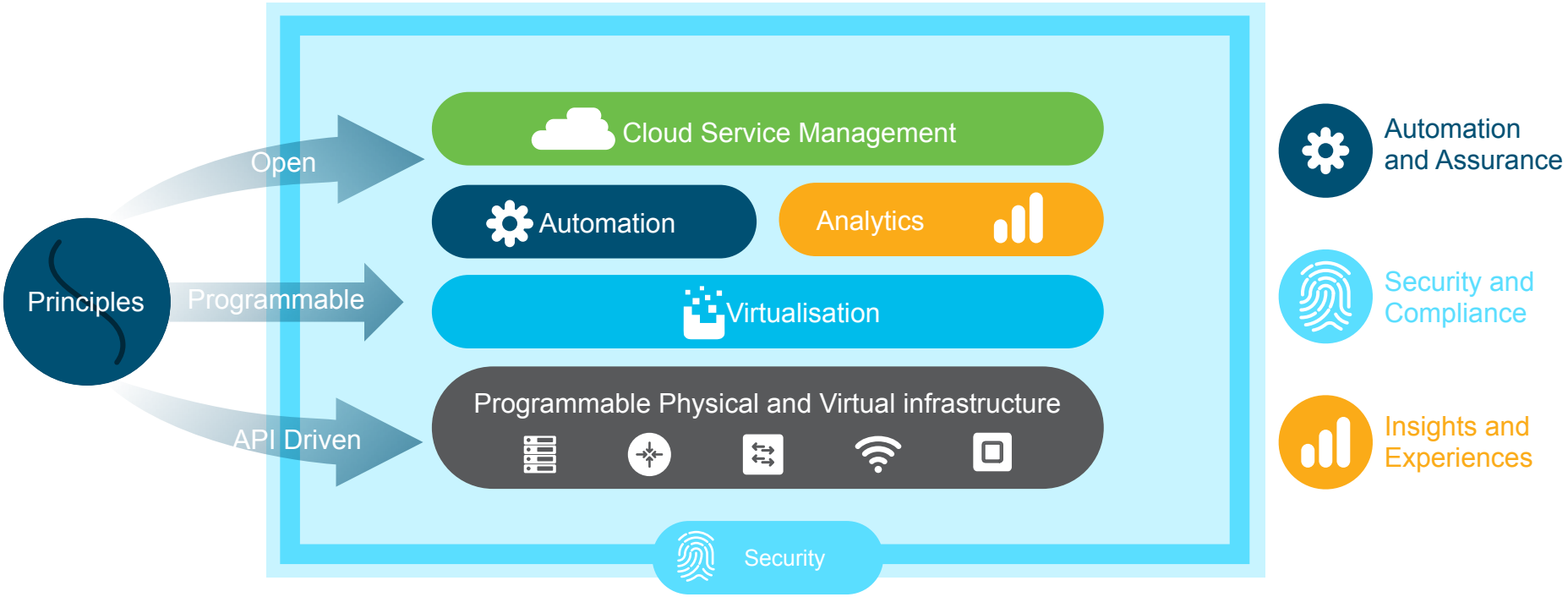
5 Year ROI
402%

# THE NETWORK. INTUITIVE.

Powered by intent, informed by context.



# Built on Cisco Digital Network Architecture



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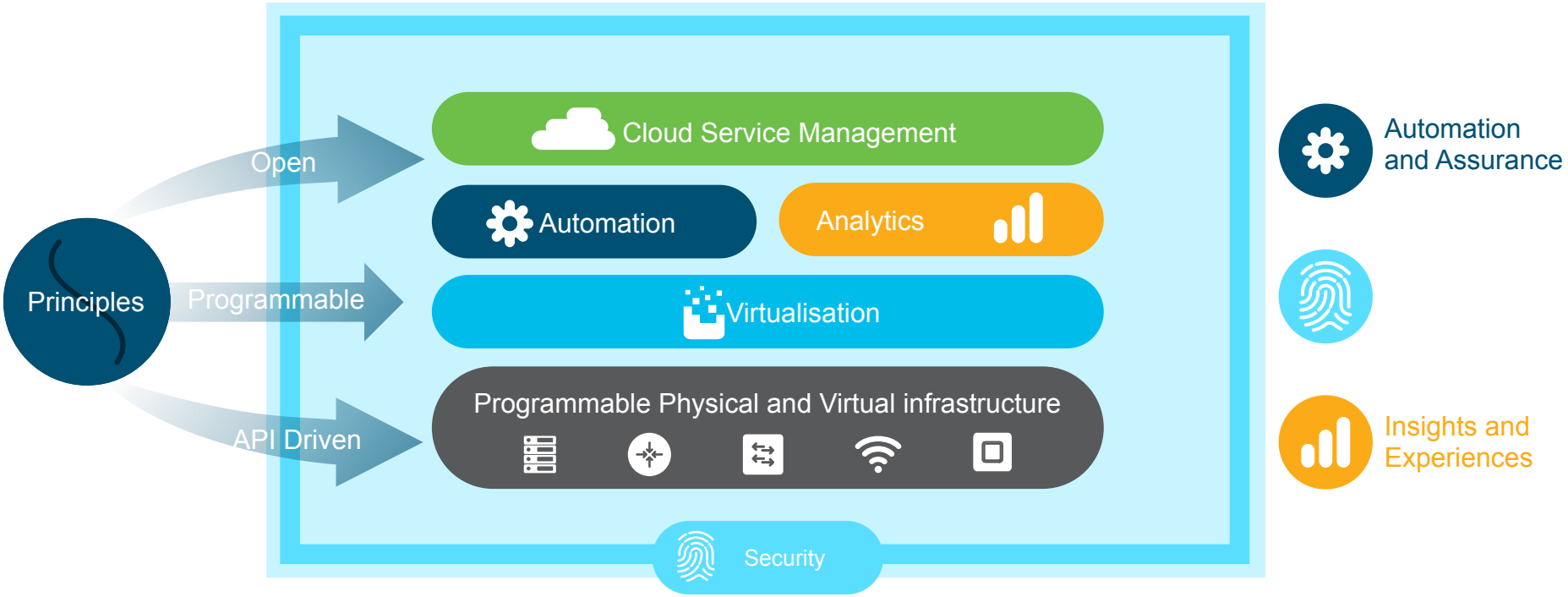

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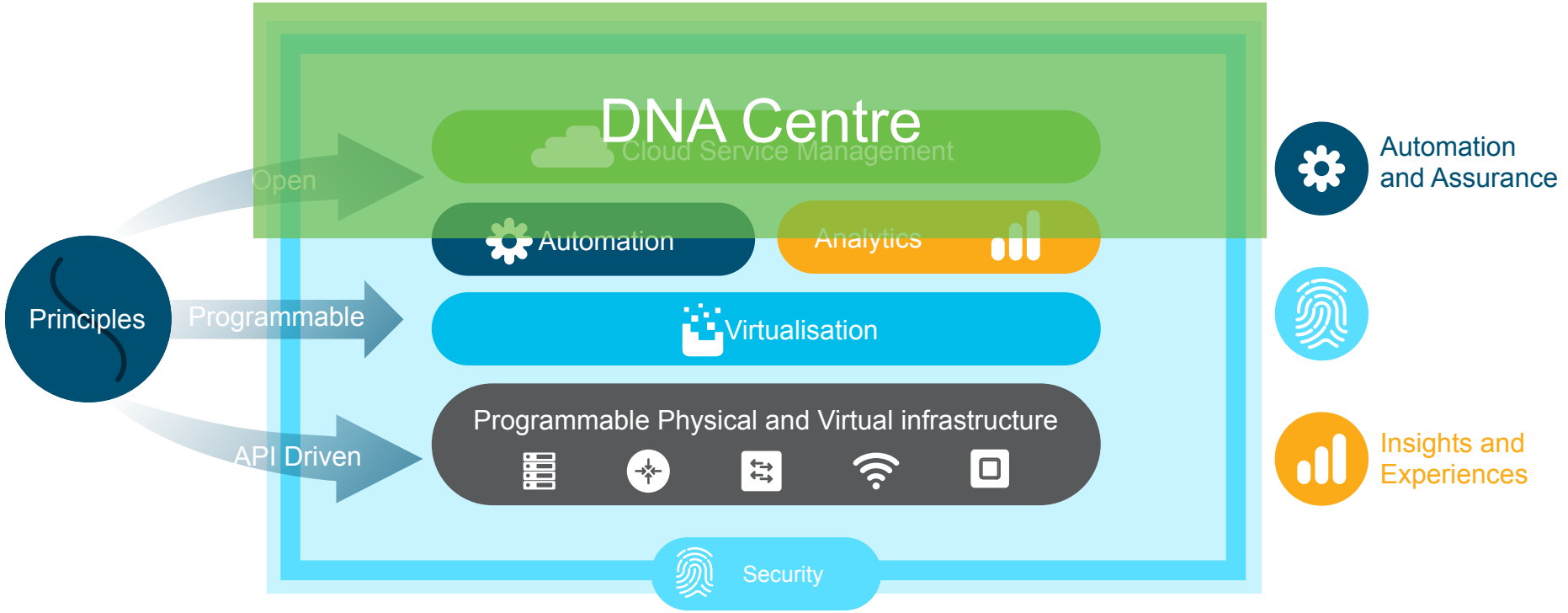

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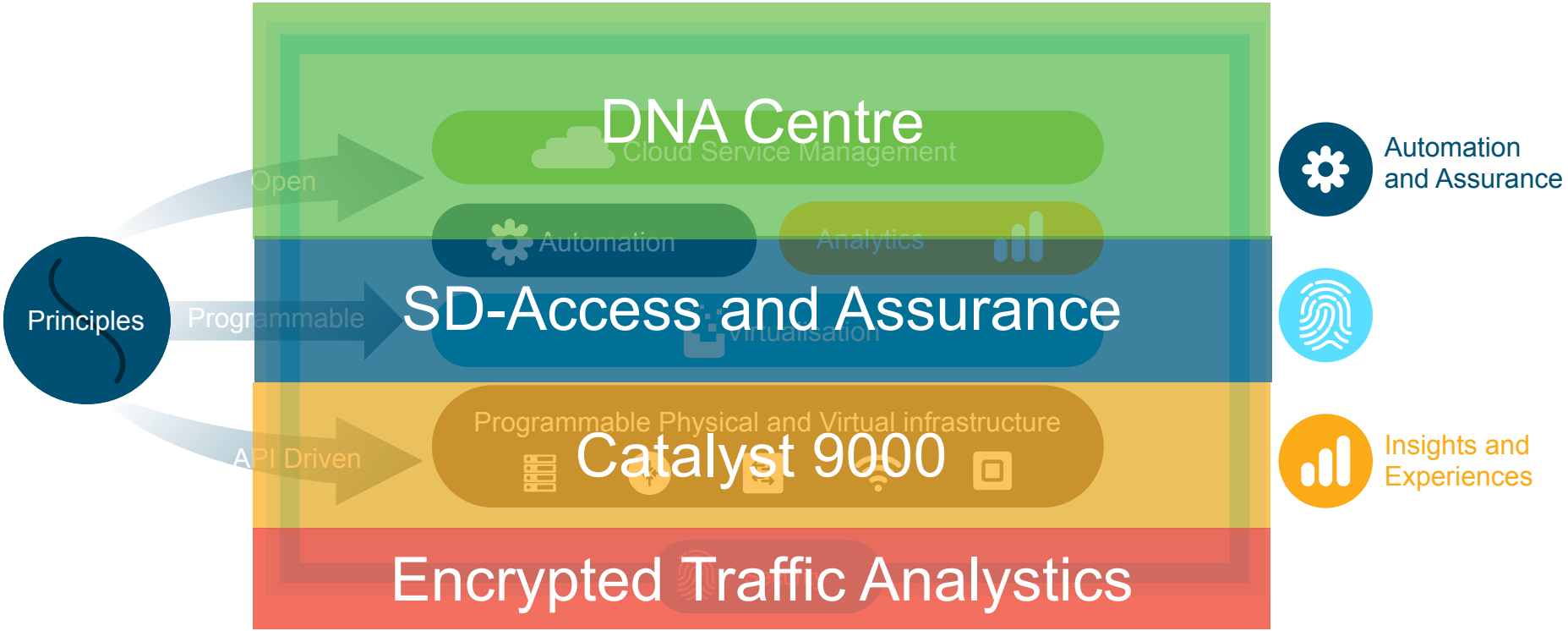
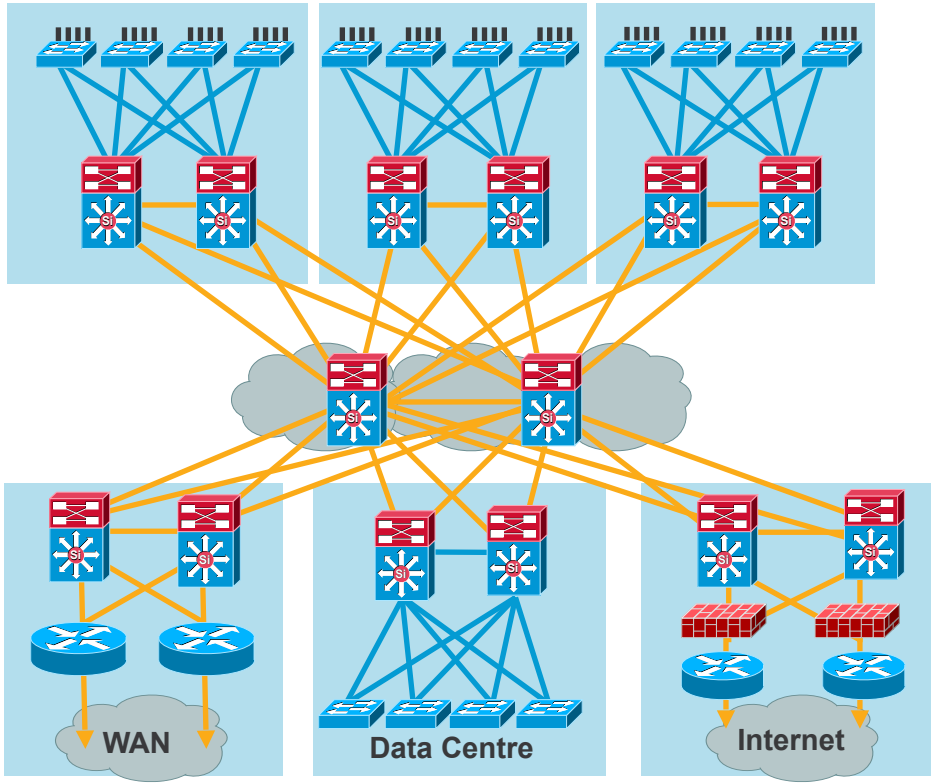


# Agenda

- Multilayer Campus Design Principles
- Foundation Services
- Campus Design Best Practices
- QoS Considerations
- Security Considerations
- Putting It All Together
- Summary

# High-Availability Campus Design

## Structure, Modularity, and Hierarchy



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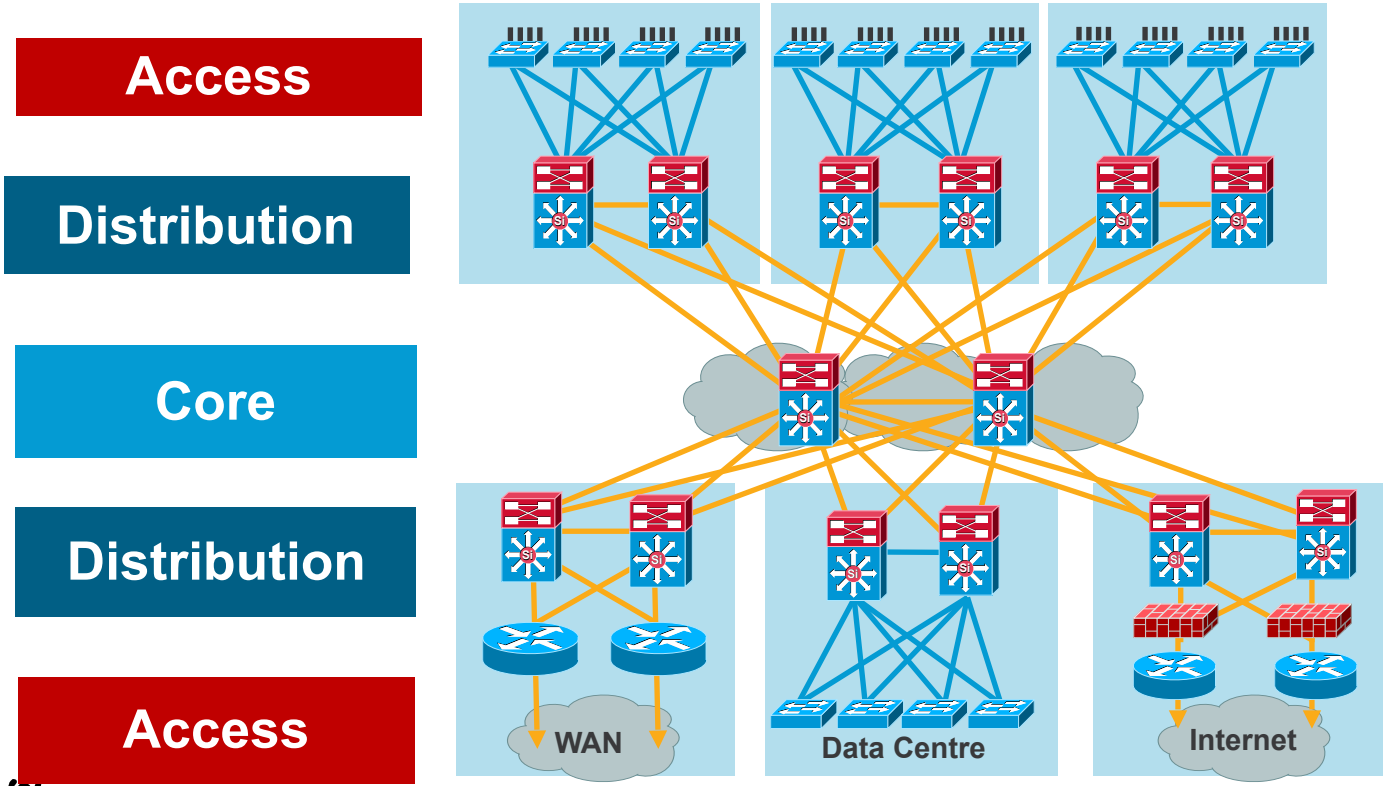
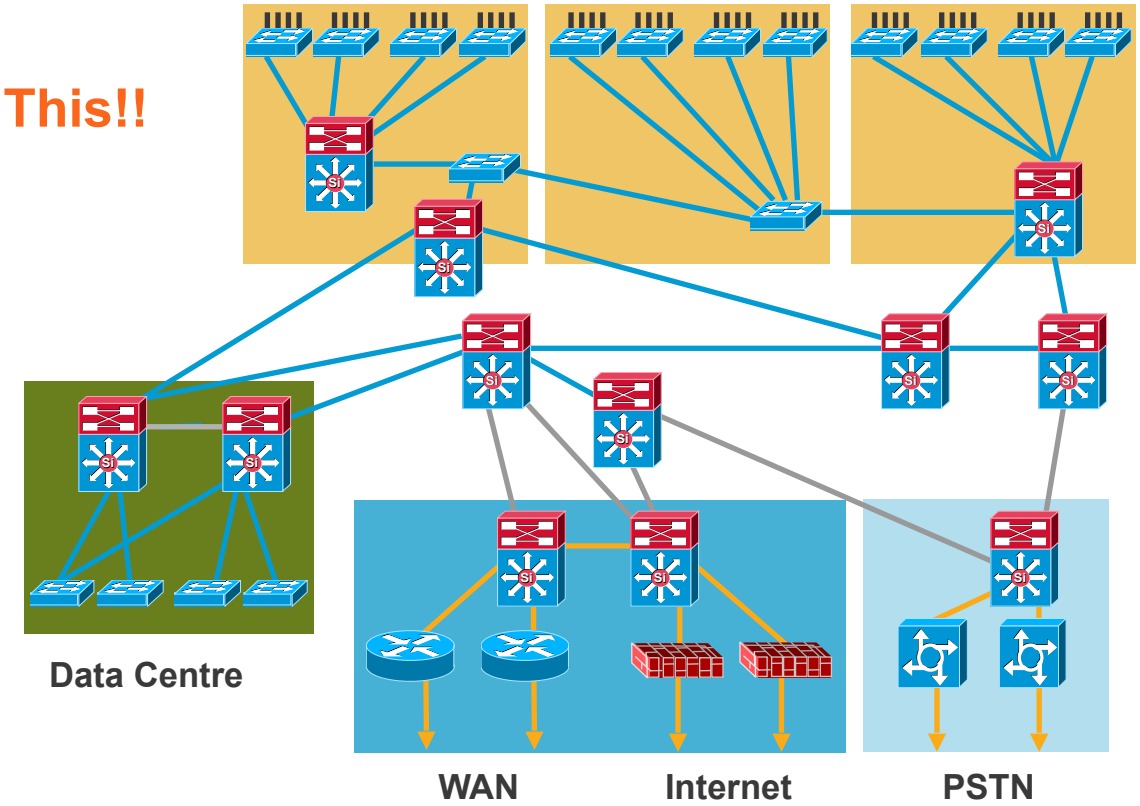


# Hierarchical Campus Network

## Structure, Modularity and Hierarchy



# Hierarchical Network Design

## Without a Rock Solid Foundation the Rest Doesn't Matter

Access

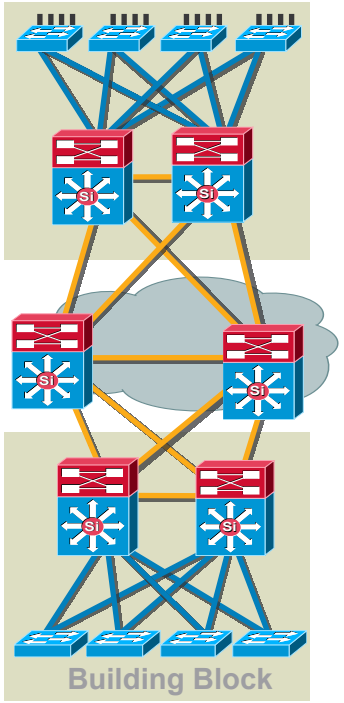
Distribution

Core

Distribution

Access

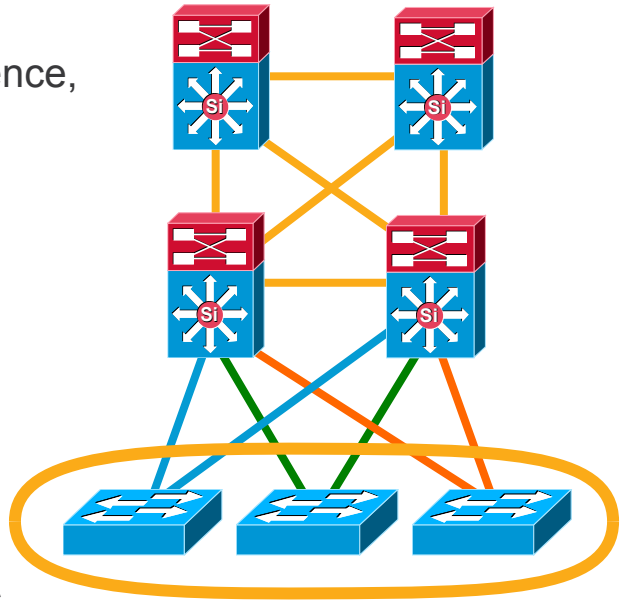
- Offers hierarchy—each layer has specific role
- Modular topology—building blocks
- Easy to grow, understand, and troubleshoot
- Creates small fault domains— clear demarcations and isolation
- Promotes load balancing and redundancy
- Promotes deterministic traffic patterns
- Incorporates balance of both Layer 2 and Layer 3 technology, leveraging the strength of both
- Utilises Layer 3 routing for load balancing, fast convergence, scalability, and control



# Access Layer

## Feature Rich Environment

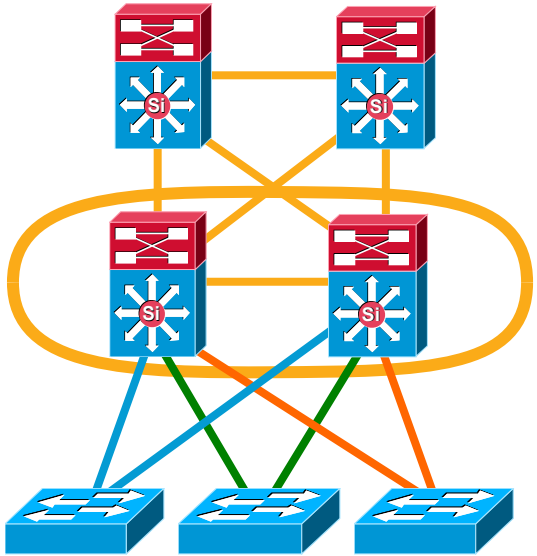
- It's not just about connectivity
- Layer 2/Layer 3 feature rich environment; convergence, HA, security, QoS, IP multicast, etc.
- Intelligent network services: QoS, trust boundary, broadcast suppression, IGMP snooping
- Intelligent network services: PVST+, Rapid PVST+, EIGRP, OSPF, DTP, PAgP/LACP, UDLD, FlexLink, etc.
- Cisco Catalyst® integrated security features IBNS (802.1x), (CISF): port security, DHCP snooping, DAI, IPSG, etc.
- Automatic phone discovery, conditional trust boundary, power over Ethernet, auxiliary VLAN, etc.
- Spanning tree toolkit: PortFast, UplinkFast, BackboneFast, LoopGuard, BPDU Guard, BPDU Filter, RootGuard, etc.



# Distribution Layer

## Policy, Convergence, QoS, and High Availability

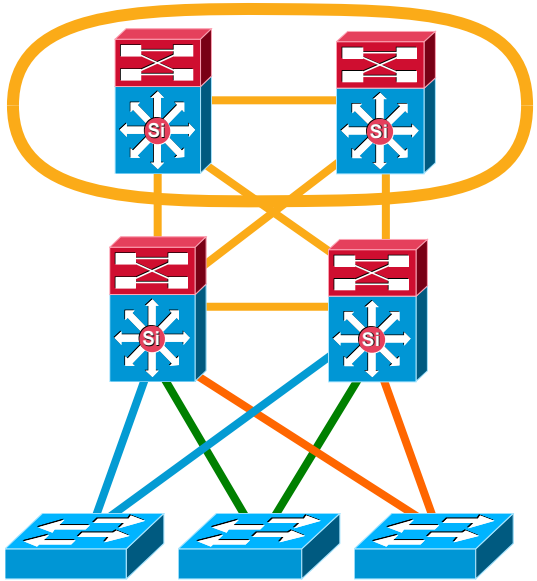
- Availability, load balancing, QoS and provisioning are the important considerations at this layer
- Aggregates wiring closets (access layer) and uplinks to core
- Protects core from high density peering and problems in access layer
- Route summarisation, fast convergence, redundant path load sharing
- HSRP or GLBP to provide first hop redundancy



# Core Layer

## Scalability, High Availability, and Fast Convergence

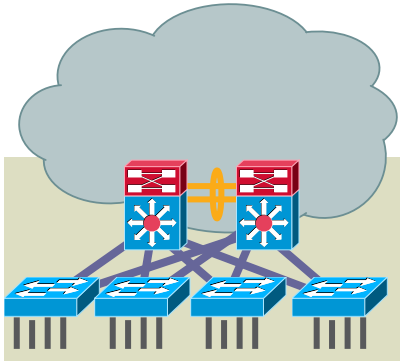
- Backbone for the network—connects network building blocks
- Performance and stability vs. complexity—less is more in the core
- Aggregation point for distribution layer
- Separate core layer helps in scalability during future growth
- Keep the design technology-independent



# Do I Need a Core Layer?

## It's Really a Question of Scale, Complexity, and Convergence

- No Core
- Fully-meshed distribution layers
- Physical cabling requirement
- Routing complexity



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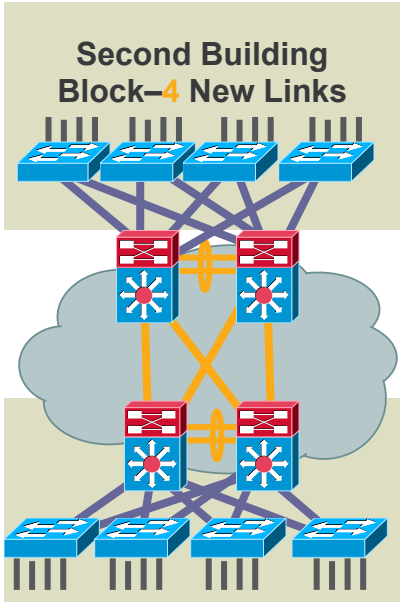

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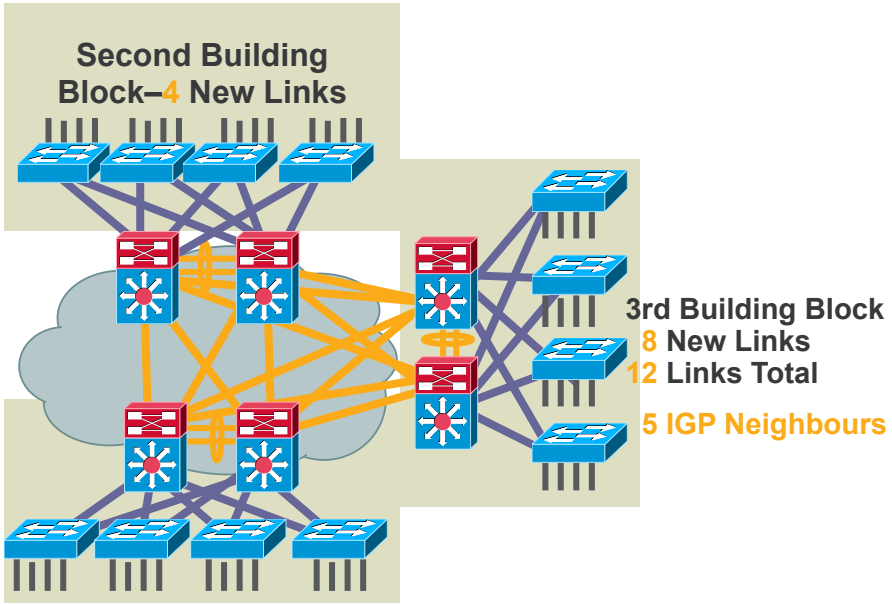

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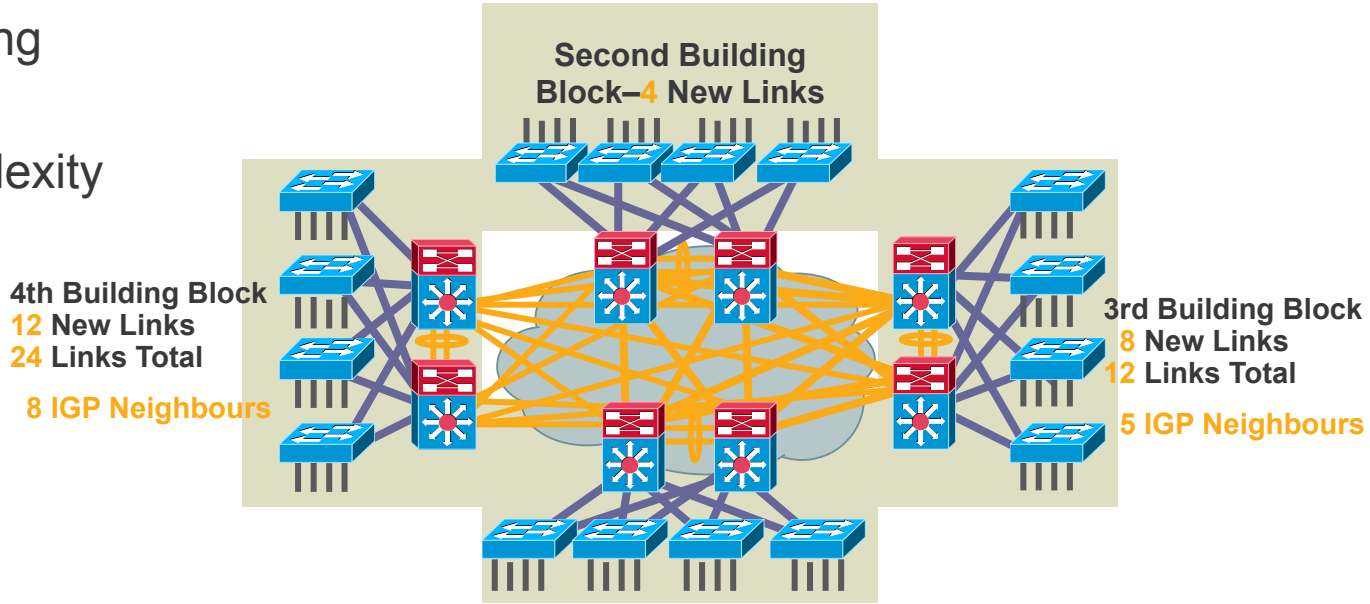
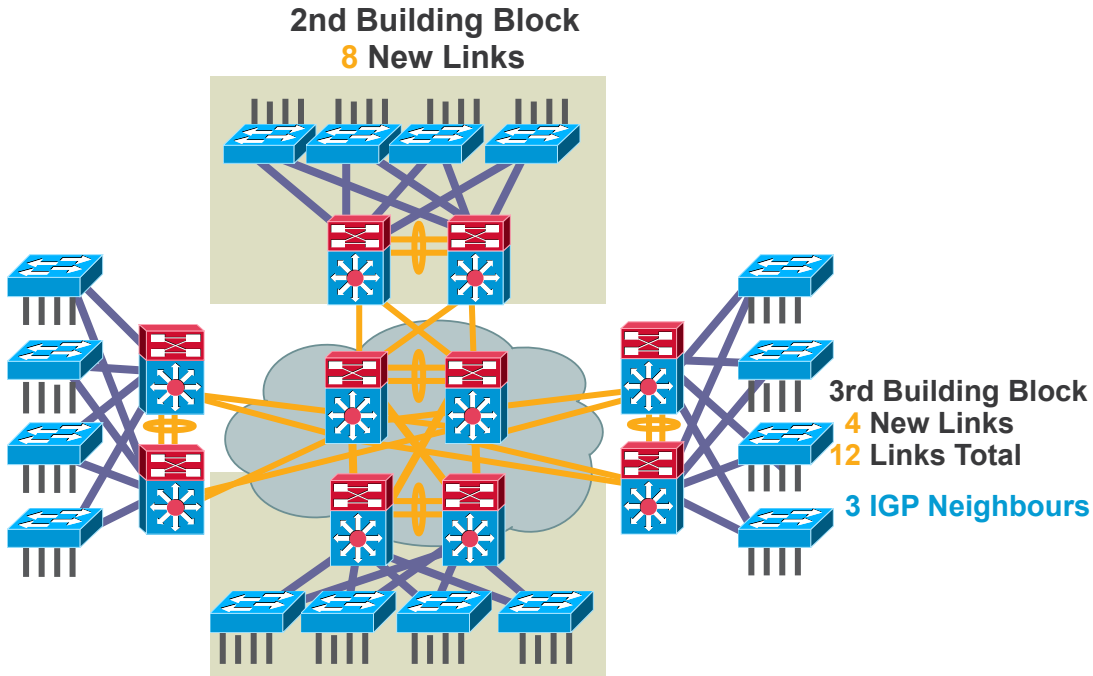


# Do I Need a Core Layer?

## It's Really a Question of Scale, Complexity, and Convergence

- Dedicated Core Switches
- Easier to add a module
- Fewer links in the core
- Easier bandwidth upgrade
- Routing protocol peering reduced
- Equal cost Layer 3 links for best convergence



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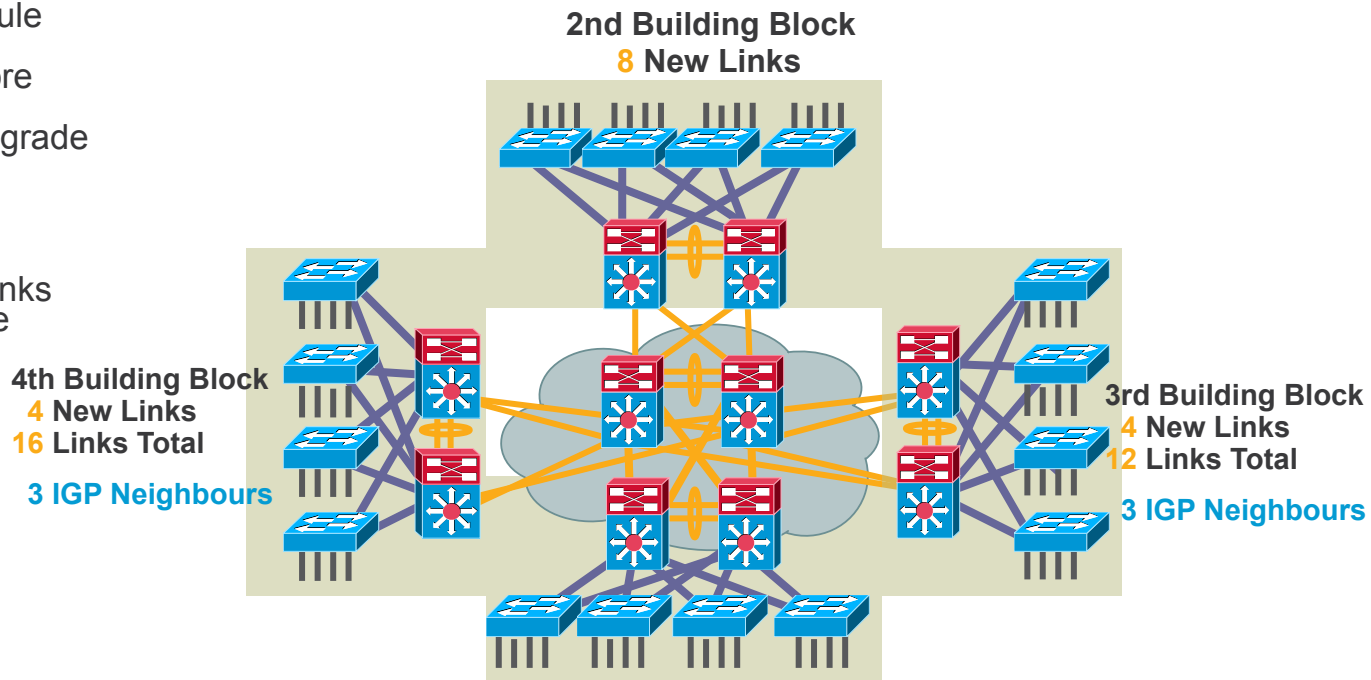
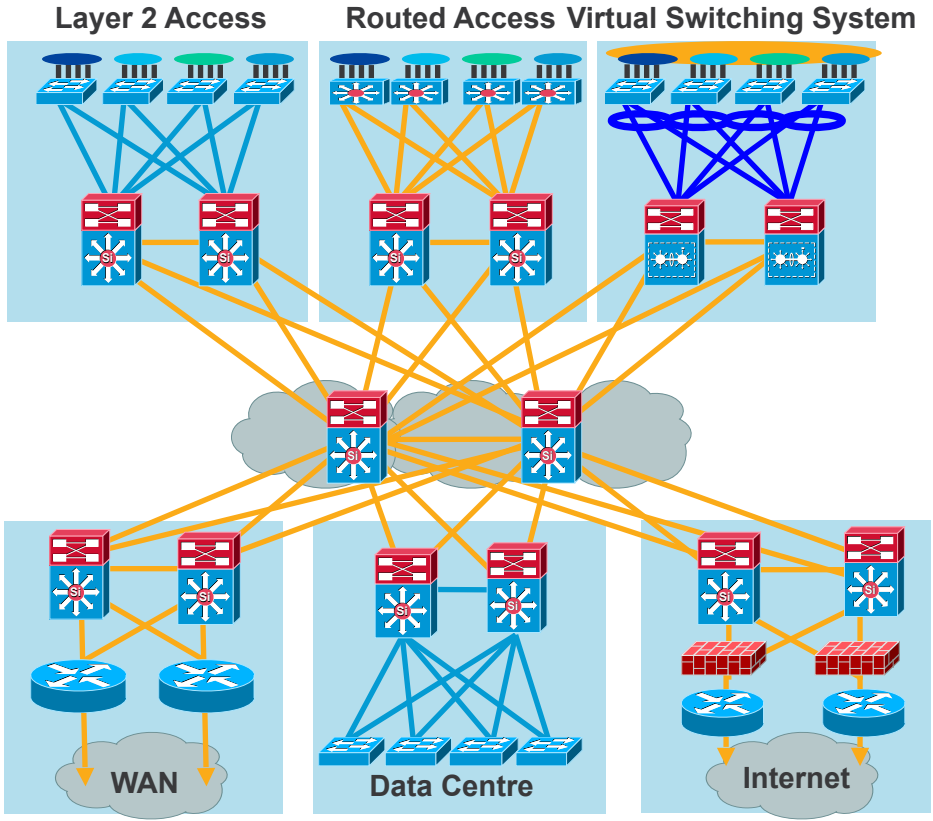


# Design Alternatives Come Within a Building (or Distribution) Block



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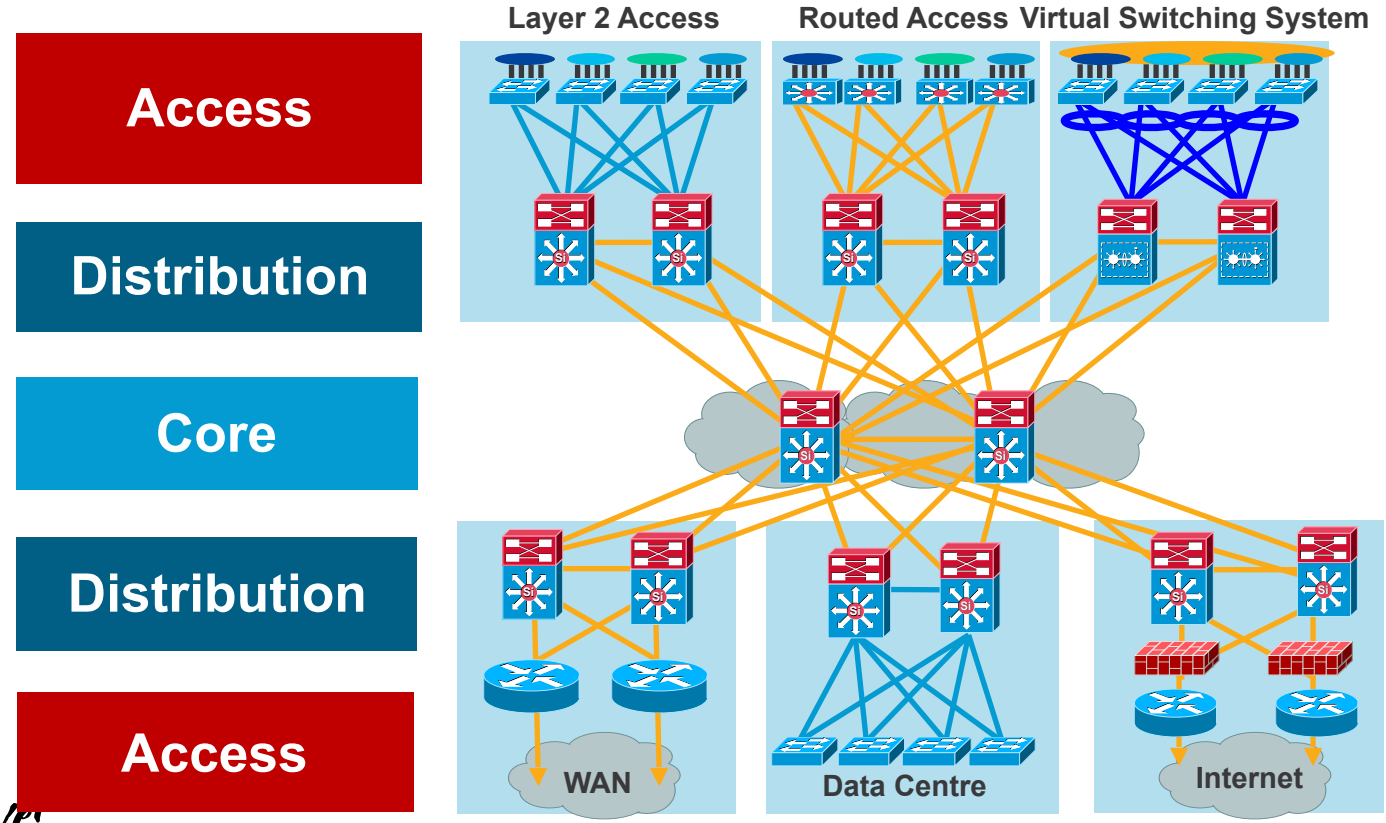
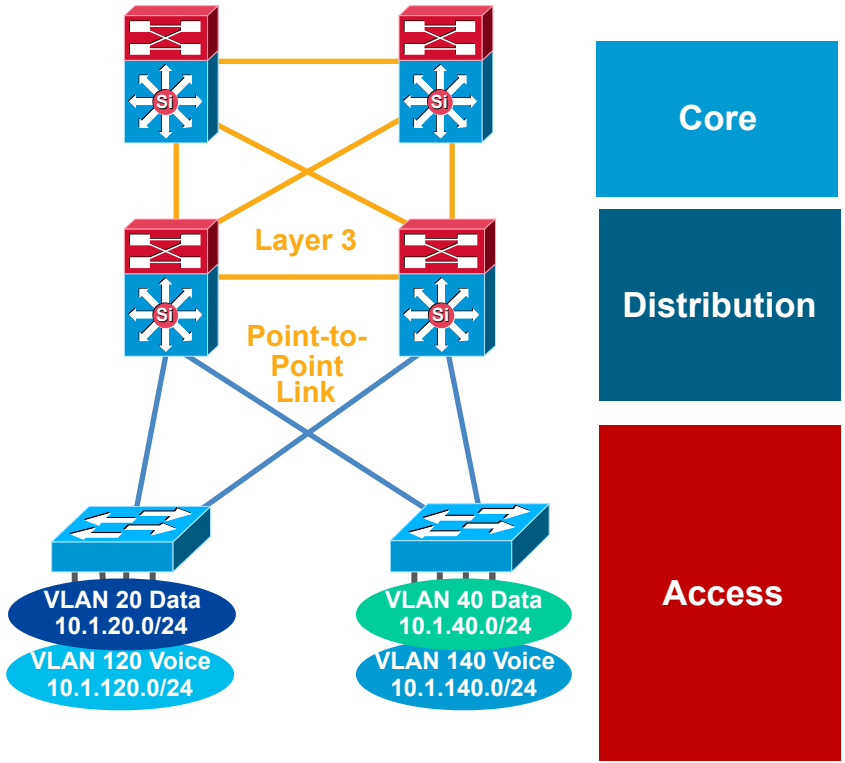


# Layer 3 Distribution Interconnection

## Layer 2 Access—No VLANs Span Access Layer

- Tune CEF load balancing
- Summarise routes towards core
- Limit redundant IGP peering
- STP Root and HSRP primary tuning or GLBP to load balance on uplinks
- Set trunk mode on/no-negotiate
- Disable Ether Channel unless needed
- Set port host on access layer ports:
  - Disable trunking
    Disable Ether Channel
    Enable PortFast
- RootGuard or BPDU-Guard
- Use security features



# Layer 2 Distribution Interconnection

## Layer 2 Access—Some VLANs Span Access Layer

- Tune CEF load balancing
- Summarise routes towards core
- Limit redundant IGP peering
- STP Root and HSRP primary or GLBP and STP port cost tuning to load balance on uplinks
- Set trunk mode on/no-negotiate
- Disable Ether Channel unless needed
- RootGuard on downlinks
- LoopGuard on uplinks
- Set port host on access Layer ports:
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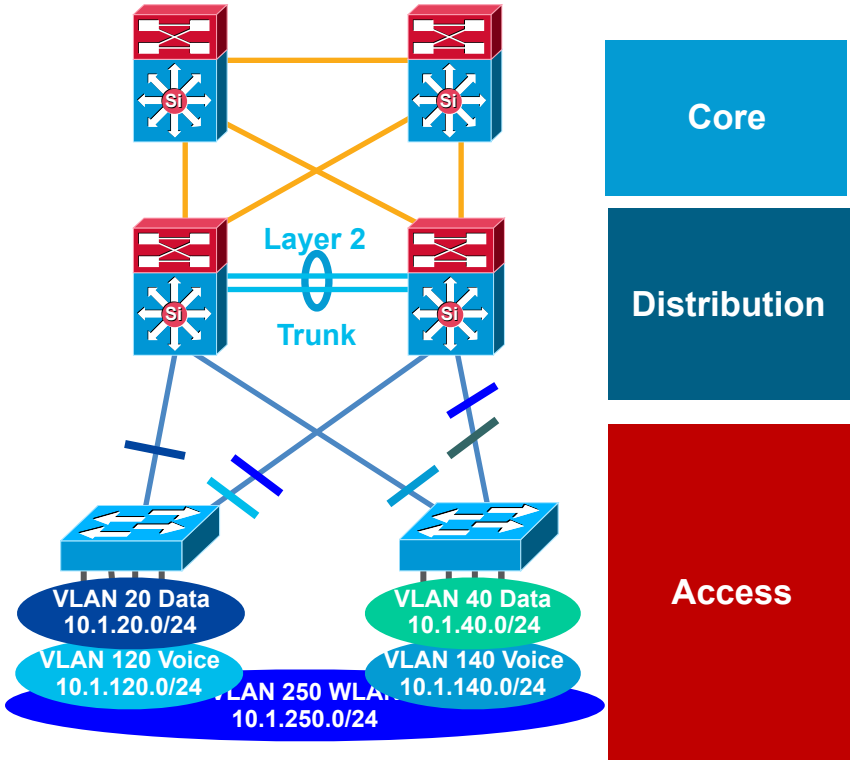
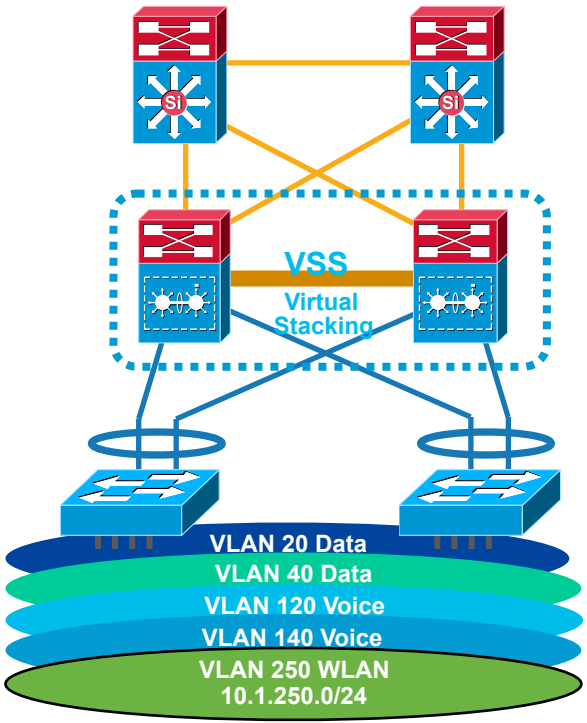
- RootGuard or BPDU-Guard
- Use security features



# Virtual Switching System & Virtual Stacking

## L2 with-out a STP Liability




- Tune CEF load balancing
- Summarise routes towards core
- Limit redundant IGP peering
- Set trunk mode on/no-negotiate
- MUST Ether Channel else blocked ports
- Set port host on access layer ports:
  - Disable trunking
    Disable Ether Channel
    Enable PortFast
- RootGuard or BPDU-Guard
- Use security features

Core

Distribution

Access

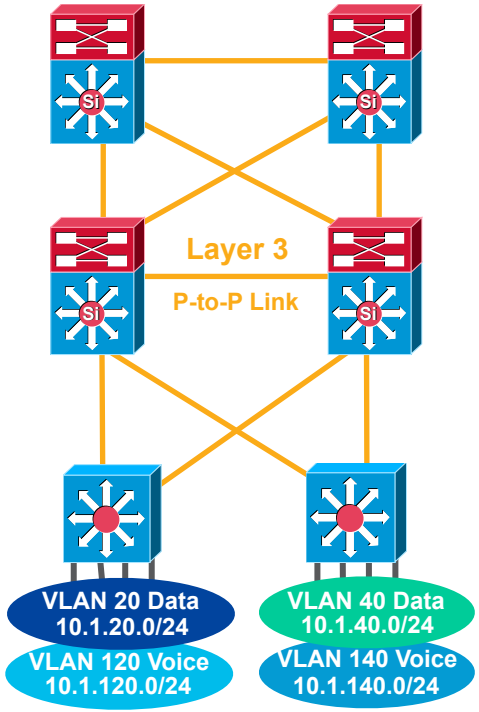
# Routing to the Edge
## Advantages, Yes in the Right Environment

Advantages:

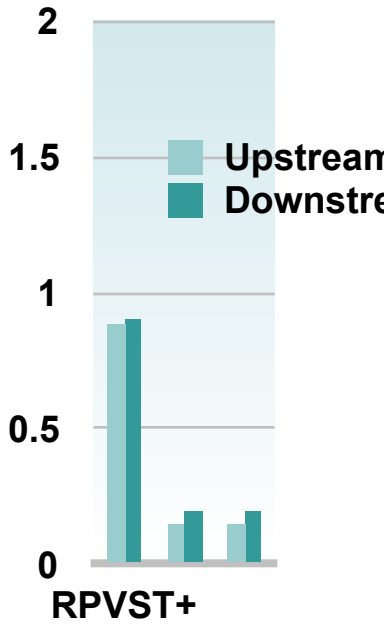
- Ease of implementation, less to get right
  - No matching of STP/HSRP/GLBP priority
  - No L2/L3 Multicast topology inconsistencies
- Single Control Plane and well known tool set
  - traceroute, show ip route, show ip eigrp neighbour, etc.…
- Most Catalysts support L3 Switching today
- EIGRP converges in <200 msec
- OSPF with sub-second tuning converges in <200 msec
- RPVST+ convergence times dependent on GLBP / HSRP tuning

Considerations:

- Do you have any Layer 2 VLAN adjacency requirements between access switches?
- IP addressing—Do you have enough address space and the allocation plan to support a routed access design?

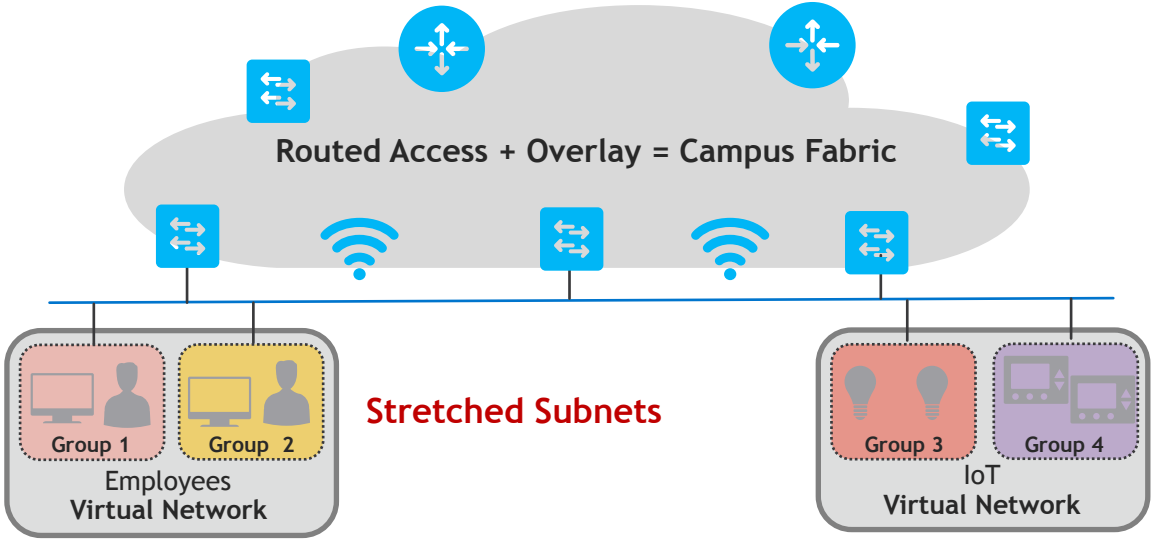



Both L2 and L3 Can Provide Sub-Second Convergence



# Campus Fabric – The Foundation for SDA

## Architecture for the Digital Enterprise



# Why Use an Overlay?

**Separate the “Forwarding Plane” from the “Services Plane”**

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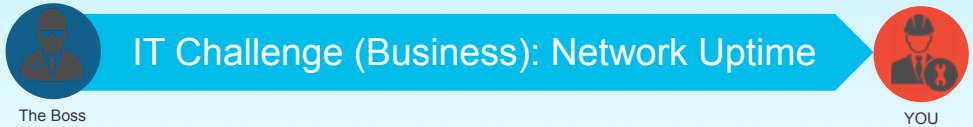

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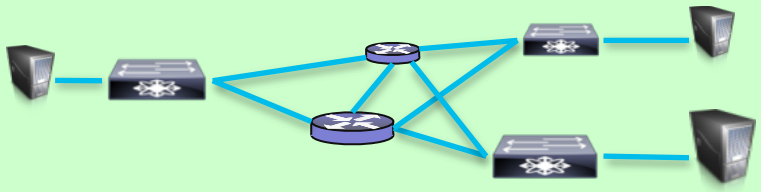


## Simple Transport Forwarding

- Redundant Devices and Paths
- Keep It Simple and Manageable
- Optimise Packet Handling
- Maximise Network Reliability (HA)

# Why Use an Overlay?

**Separate the "Forwarding Plane" from the "Services Plane"**

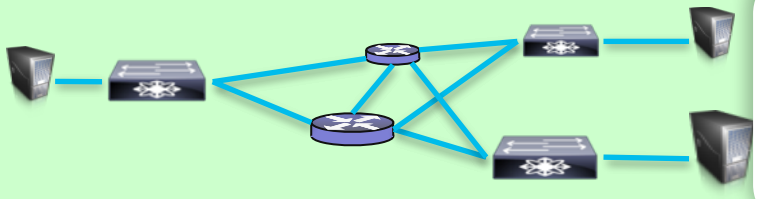
IT Challenge (Business): Network Uptime

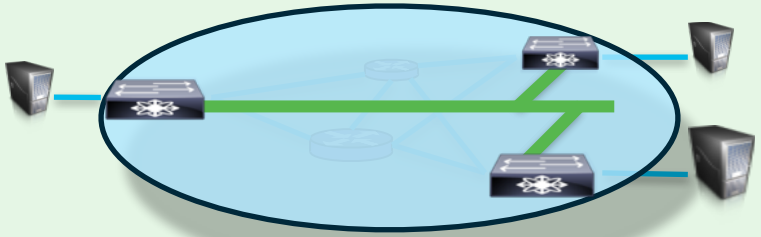
The Boss

YOU

IT Challenge (Employee): New Services

The User





## Simple Transport Forwarding

- Redundant Devices and Paths
- Keep It Simple and Manageable
- Optimise Packet Handling
- Maximise Network Reliability (HA)

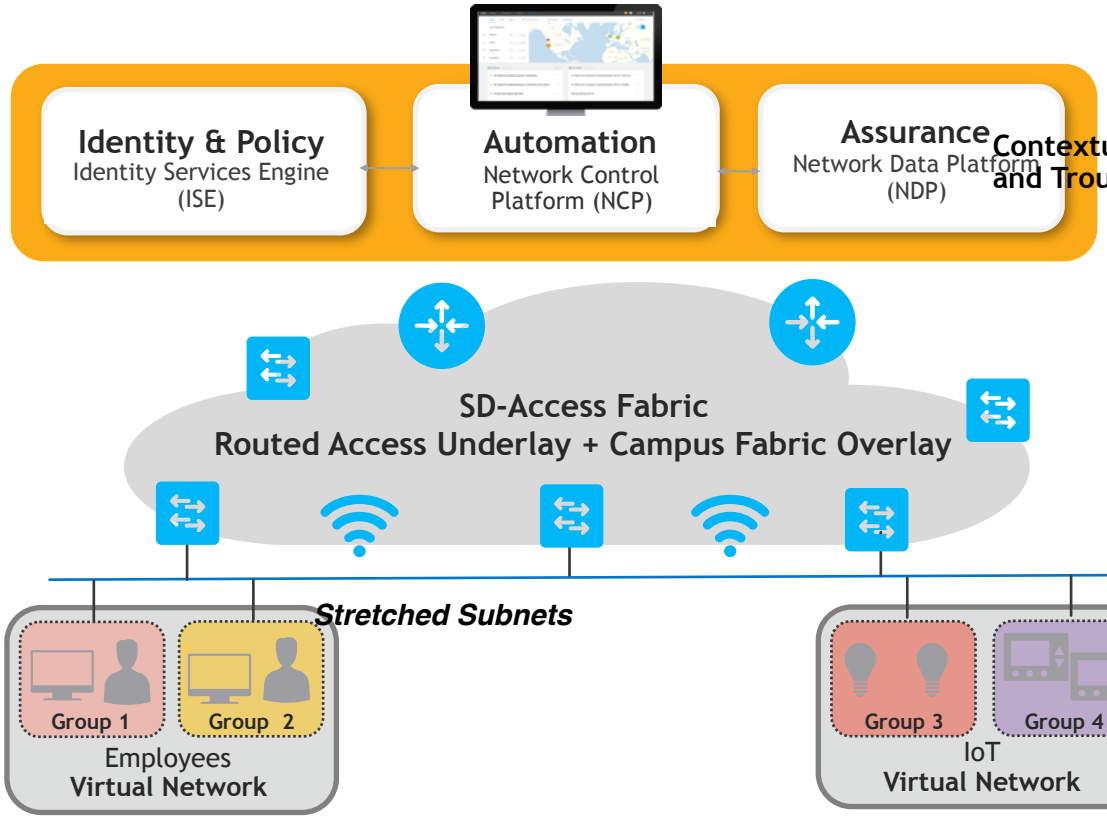
## Flexible Virtual Services

- Mobility - Map Endpoints to Edges
- Services - Deliver using Overlay
- Scalability - Reduce Protocol State
- Flexible and Programmable

# SD-Access = Automated Campus Fabric

## Architecture for the Digital Enterprise

**Policy Mobility with no Topology Dependence**



# Agenda

- Multilayer Campus Design Principles
- Foundation Services
- Campus Design Best Practices
- QoS Considerations
- Security Considerations
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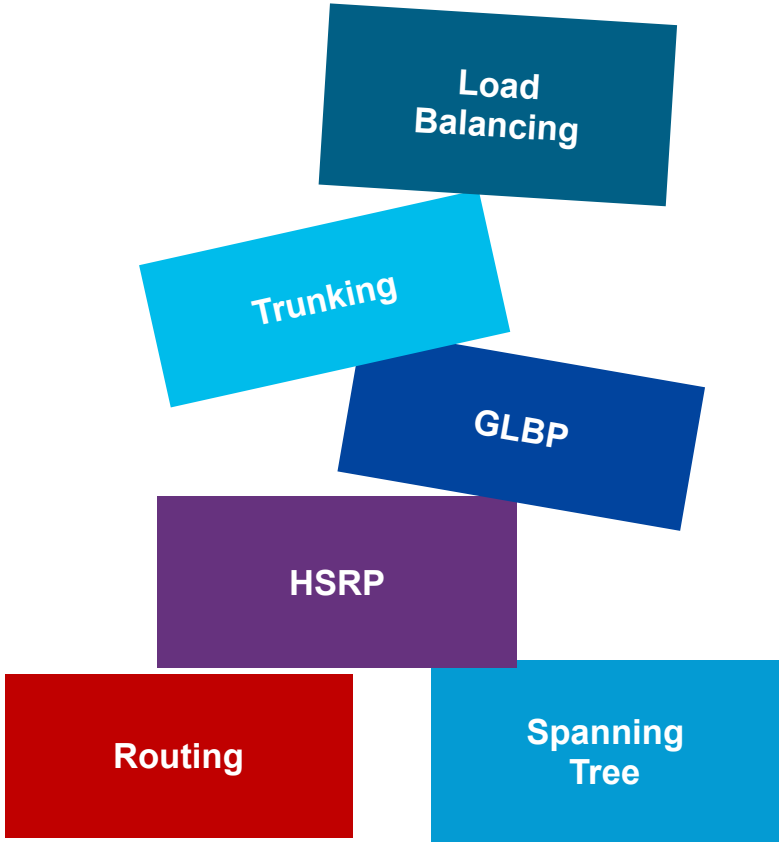
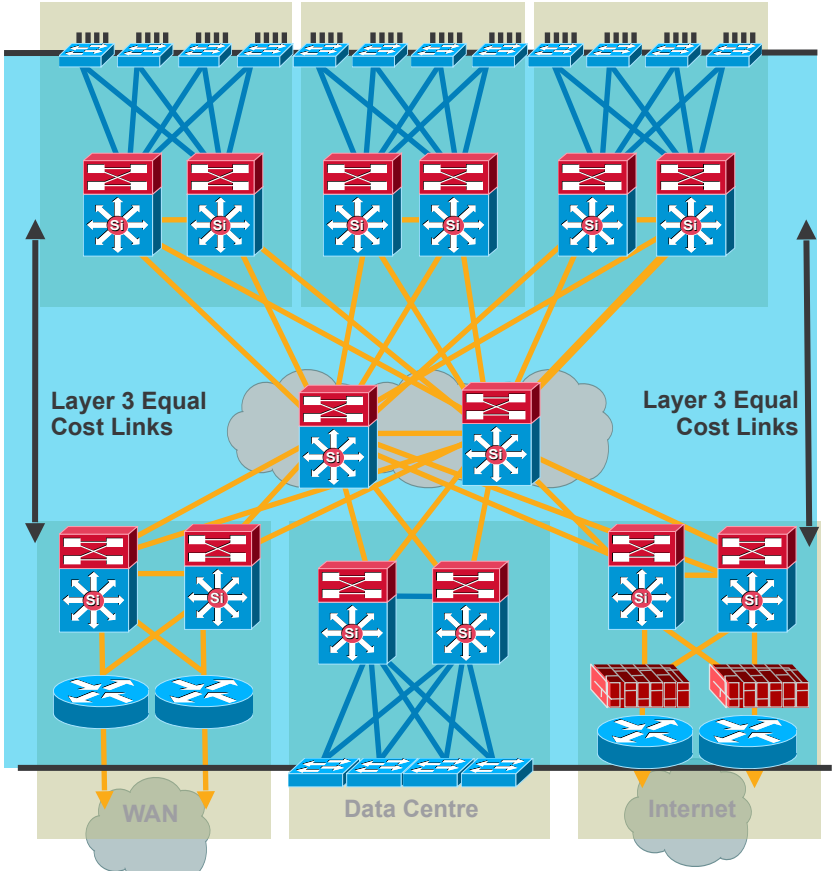
# Foundation Services

- Layer 1 physical things
- Layer 2 redundancy—spanning tree
- Layer 3 routing protocols
- Trunking protocols—(ISL/.1q)
- Unidirectional link detection
- Load balancing
  - Ether Channel link aggregation
  - CEF equal cost load balancing
- First hop redundancy protocols
  - VRRP, HSRP, and GLBP



# Best Practices - Layer 1 Physical Things

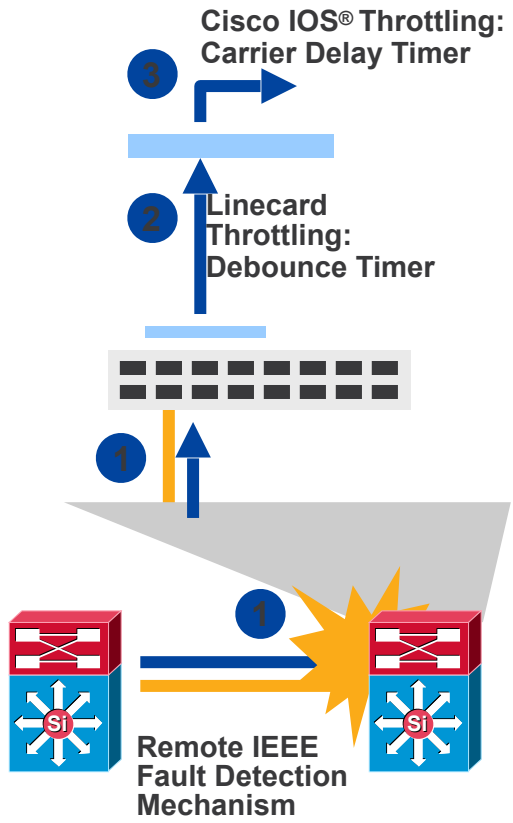
- Use point-to-point interconnections - no L2 aggregation points between nodes
- Use fibre for best convergence (debounce timer)
- Tune carrier delay timer
- Use configuration on the physical interface not VLAN/SVI when possible



# Redundancy and Protocol Interaction

## Link Redundancy and Failure Detection

- Direct point-to-point fibre provides for fast failure detection
- IEEE 802.3z and 802.3ae link negotiation define the use of remote fault indicator and link fault signalling mechanisms
- Bit D13 in the Fast Link Pulse (FLP) can be set to indicate a physical fault to the remote side
- Do not disable auto-negotiation on GigE and 10GigE interfaces
- The default debounce timer on GigE and 10GigE fibre linecards is 10 msec
- The minimum debounce for copper is 300 msec
- Carrier-delay
  - 3560, 3750, and 4500—0 msec
  - 6500—leave it set at default



# Redundancy and Protocol Interaction

## Layer 2 and 3 - Why Use Routed Interfaces

- Configuring L3 routed interfaces provides for faster convergence than an L2 switch port with an associated L3 SVI


1. Link Down
2. Interface Down
3. Routing Update

~ 8 msec loss

21:38:37.042 UTC: %LINEPROTO-5-UPDOWN: Line protocol on Interface GigabitEthernet3/1, changed state to down
21:38:37.050 UTC: %LINK-3-UPDOWN: Interface GigabitEthernet3/1, changed state to down
21:38:37.050 UTC: IP-EIGRP(Default-IP-Routing-Table: 100): Callback: route_adjust GigabitEthernet3/1

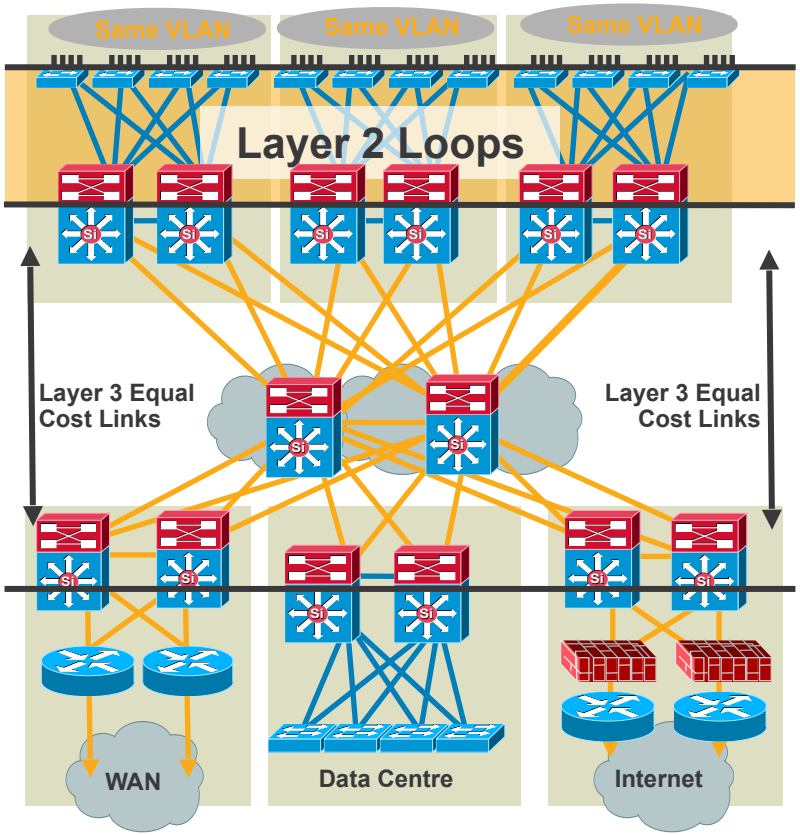

1. Link Down
2. Interface Down
3. Autostate
4. SVI Down
5. Routing Update

~ 150–200 msec loss

21:32:47.813 UTC: %LINEPROTO-5-UPDOWN: Line protocol on Interface GigabitEthernet2/1, changed state to down
21:32:47.821 UTC: %LINK-3-UPDOWN: Interface GigabitEthernet2/1, changed state to down
21:32:48.069 UTC: %LINK-3-UPDOWN: Interface Vlan301, changed state to down
21:32:48.069 UTC: IP-EIGRP(Default-IP-Routing-Table:100): Callback: route, adjust Vlan301

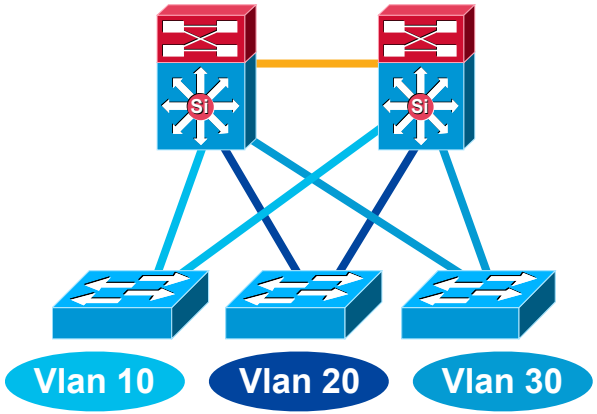
# Best Practices - Spanning Tree Configuration

- Only span VLAN across multiple access layer switches when you have to!
- Use rapid PVST+ for best convergence
- More common in the data centre
- Required to protect against user side loops
- Required to protect against operational accidents (misconfiguration or hardware failure)
- Take advantage of the spanning tree toolkit

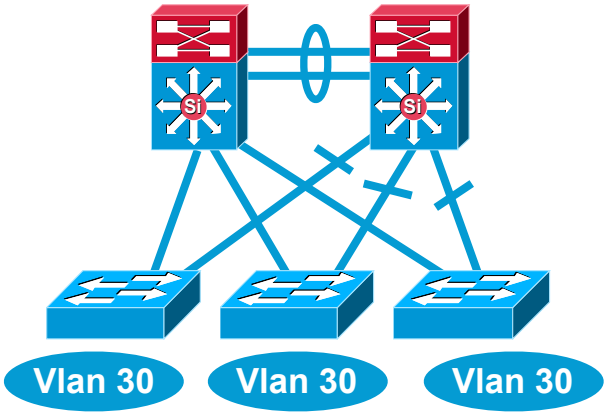


# Multilayer Network Design

## Layer 2 Access with Layer 3 Distribution




- Each access switch has unique VLANs
- No Layer 2 loops
- Layer 3 link between distribution
- No blocked links

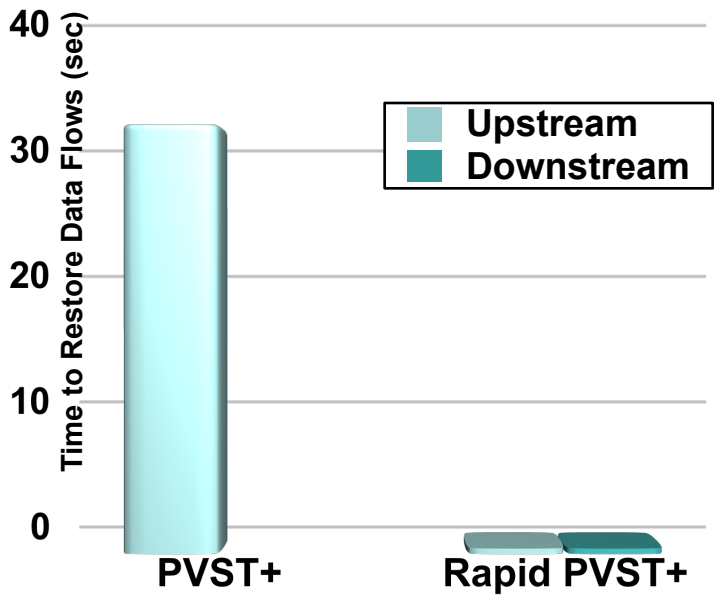



- At least some VLANs span multiple access switches
- Layer 2 loops
- Layer 2 and 3 running over link between distribution
- Blocked links

# Optimising L2 Convergence

## PVST+, Rapid PVST+ or MST

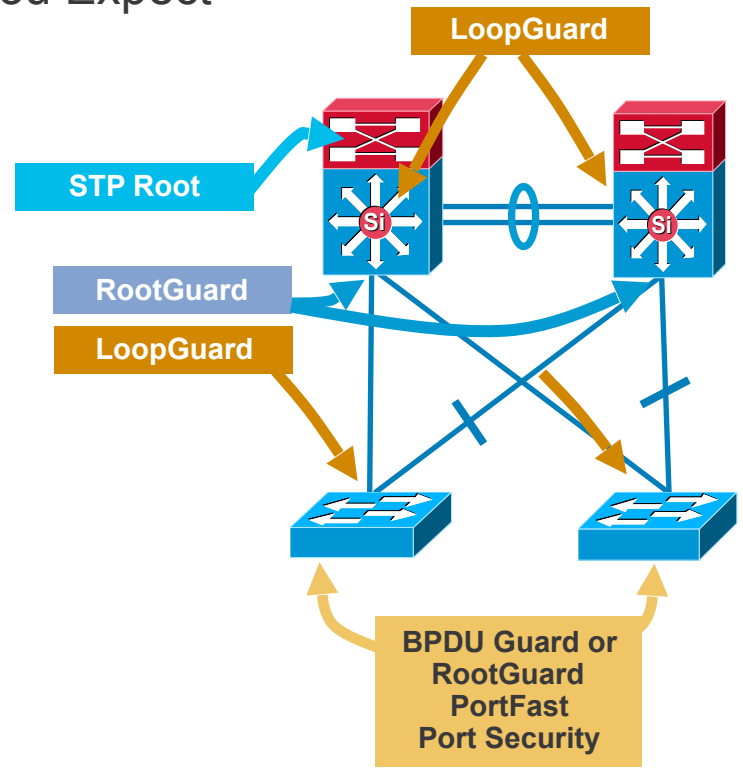
- Rapid-PVST+ greatly improves the restoration times for any VLAN that requires a topology convergence due to link UP
- Rapid-PVST+ also greatly improves convergence time over backbone fast for any indirect link failures
- PVST+ (802.1d)
  - Traditional spanning tree implementation
- Rapid PVST+ (802.1w)
  - Scales to large size (~10,000 logical ports)
  - Easy to implement, proven, scales
- MST (802.1s)
  - Permits very large scale STP implementations (~30,000 logical ports)
  - Not as flexible as rapid PVST+



# Layer 2 Hardening

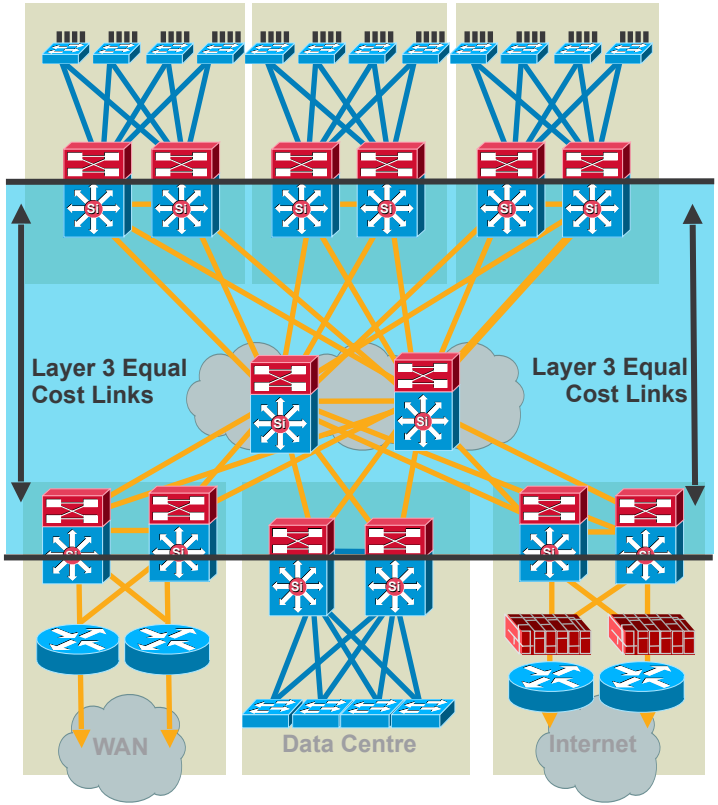
## Spanning Tree Should Behave the Way You Expect

- Place the root where you want it
  - Root primary/secondary macro
- The root bridge should stay where you put it
  - RootGuard
  - LoopGuard
  - UplinkFast
  - UDLD
- Only end-station traffic should be seen on an edge port
  - BPDU Guard
  - RootGuard
  - PortFast
  - Port-security



# Best Practices
## Layer 3 Routing Protocols

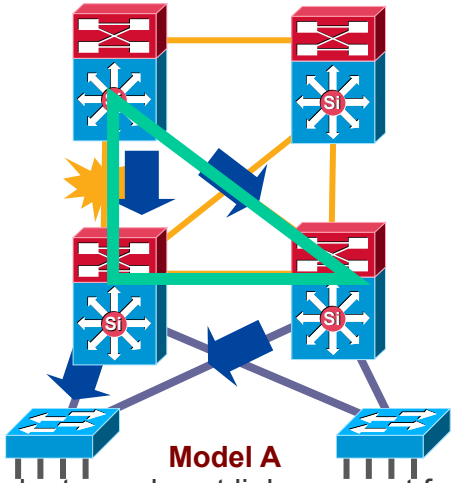
- Typically deployed in distribution to core, and core-to-core interconnections
- Used to quickly reroute around failed node/links while providing load balancing over redundant paths
- Build triangles not squares for deterministic convergence
- Only peer on links that you intend to use as transit
- Insure redundant L3 paths to avoid black holes
- Summarise distribution to core to limit EIGRP query diameter or OSPF LSA propagation
- Tune CEF L3/L4 load balancing hash to achieve maximum utilisation of equal cost paths (CEF polarisation)



# Best Practice - Build Triangles not Squares

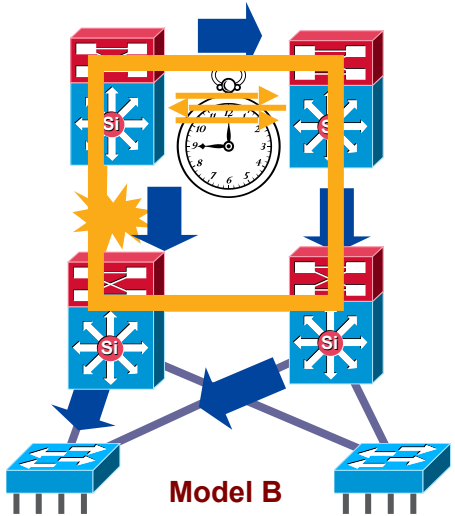
## Deterministic vs. Non-Deterministic

**Triangles: Link/Box Failure Does not Require Routing Protocol Convergence**




Model A

**Squares: Link/Box Failure Requires Routing Protocol Convergence**



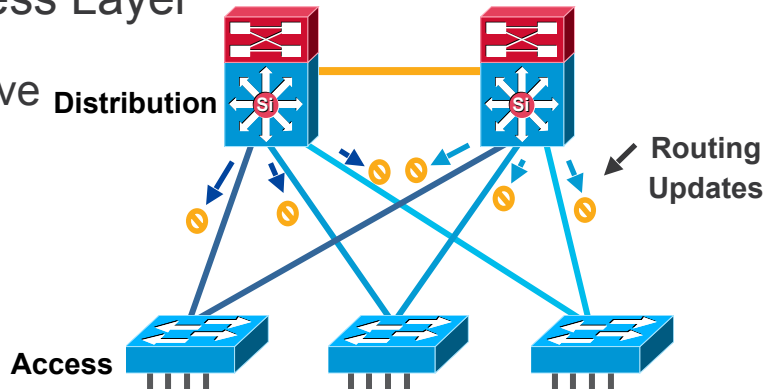

Model B

- Layer 3 redundant equal cost links support fast convergence
- Hardware based—fast recovery to remaining path
- Convergence is extremely fast (dual equal-cost paths: no need for OSPF or EIGRP to recalculate a new path)

# Best Practice - Passive Interfaces for IGP

## Limit IGP Peering Through the Access Layer

- Limit unnecessary peering using passive interface:
  - Four VLANs per wiring closet
  - 12 adjacencies total
  - Memory and CPU requirements increase with no real benefit
  - Creates overhead for IGP




**OSPF Example:**

```
Router(config)#routerospf 1
Router(config-router)#passive-interfaceVlan 99

Router(config)#routerospf 1
Router(config-router)#passive-interface default
Router(config-router)#no passive-interface Vlan 99
```

**EIGRP Example:**

```
Router(config)#routereigrp 1
Router(config-router)#passive-interfaceVlan 99

Router(config)#routereigrp 1
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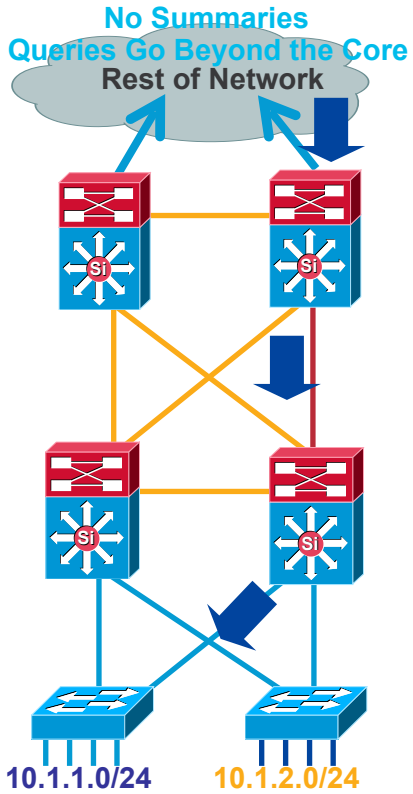
Router(config-router)#no passive-interface Vlan 99
```

# Why You Want to Summarise at the Distribution

## Limit EIGRP Queries and OSPF LSA Propagation

- It is important to force summarisation at the distribution towards the core
- For return path traffic an OSPF or EIGRP re-route is required
- By limiting the number of peers an EIGRP router must query or the number of LSAs an OSPF peer must process we can optimise this reroute
- EIGRP example:

```
interface Port-channel1
description to Core#1
ip address 10.122.0.34
255.255.255.252
ip hello-interval eigrp 100 1
ip hold-time eigrp 100 3
ip summary-address eigrp 100
10.1.0.0 255.255.0.0 5
```

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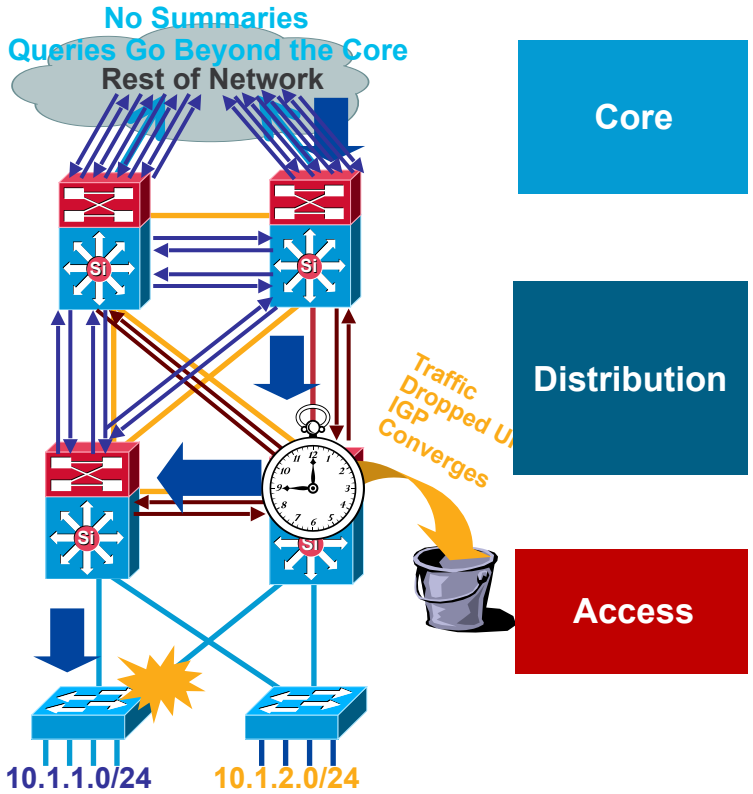
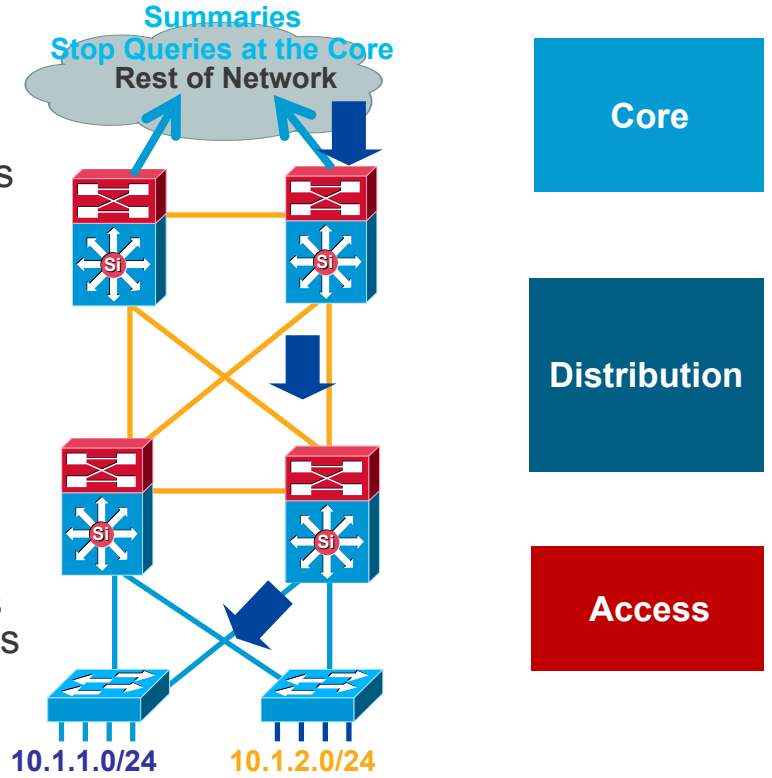


# Why You Want to Summarise at the Distribution

## Reduce the Complexity of IGP Convergence

- It is important to force summarisation at the distribution towards the core
- For return path traffic an OSPF or EIGRP re-route is required
- By limiting the number of peers an EIGRP router must query or the number of LSAs an OSPF | peer must process we can optimise his reroute
- For EIGRP if we summaries at the distribution we stop queries at the core boxes for an access layer flap
- For OSPF when we summarise at the distribution (area border  or L1/L2 border)  the flooding of LSAs is limited to the distribution switches; SPF now deals with one LSA not three



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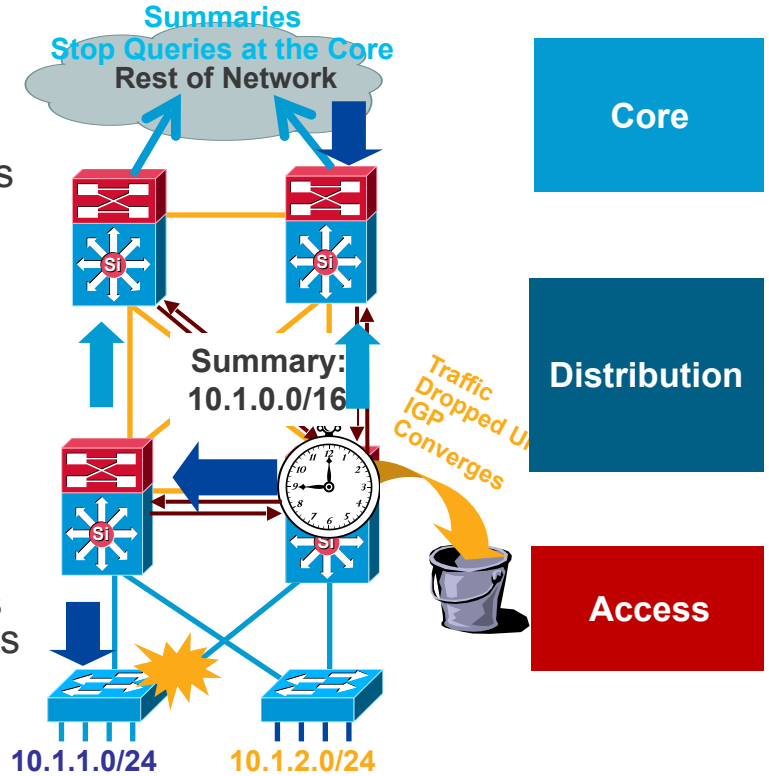
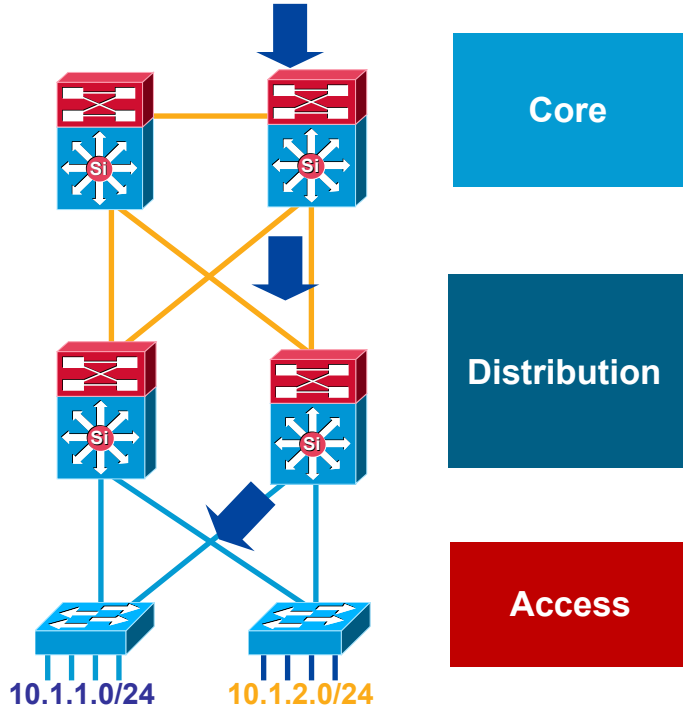


# Best Practice - Summarise at the Distribution

## Gotcha—Distribution-to-Distribution Link Required

- Best practice - summarise at the distribution layer to limit EIGRP queries or OSPF LSA propagation
- Gotcha:
  - Upstream: HSRP on left distribution takes over when link fails
  - Return path: old router still advertises summary to core
  - Return traffic is dropped on right distribution switch
- Summarising requires a link between the distribution switches
- Alternative design: use the access layer for transit



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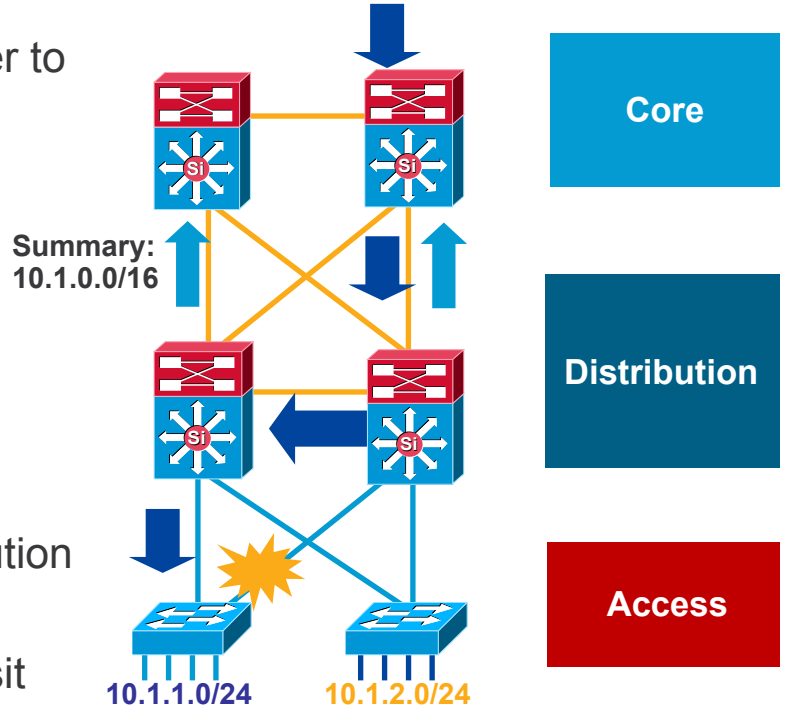
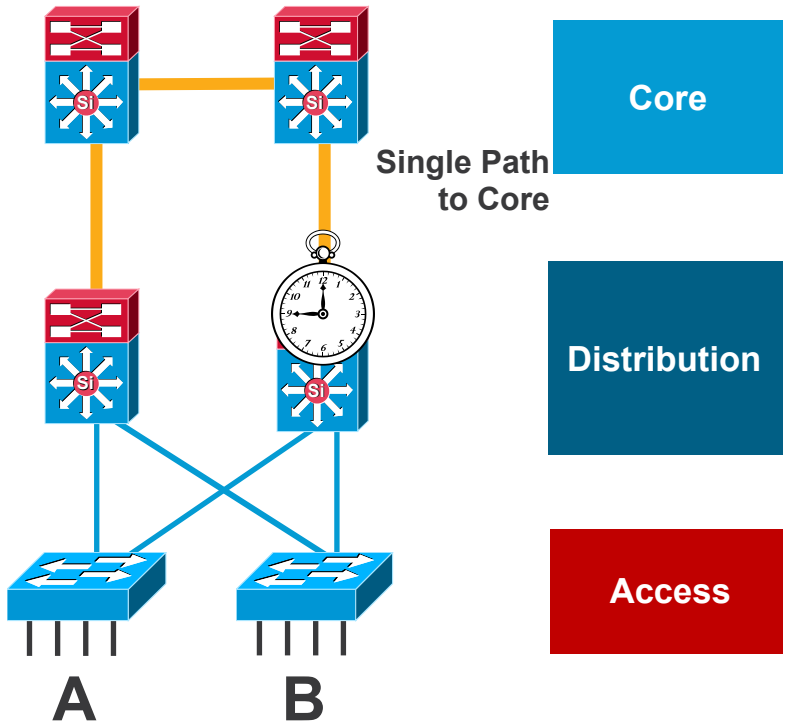


# Provide Alternate Paths



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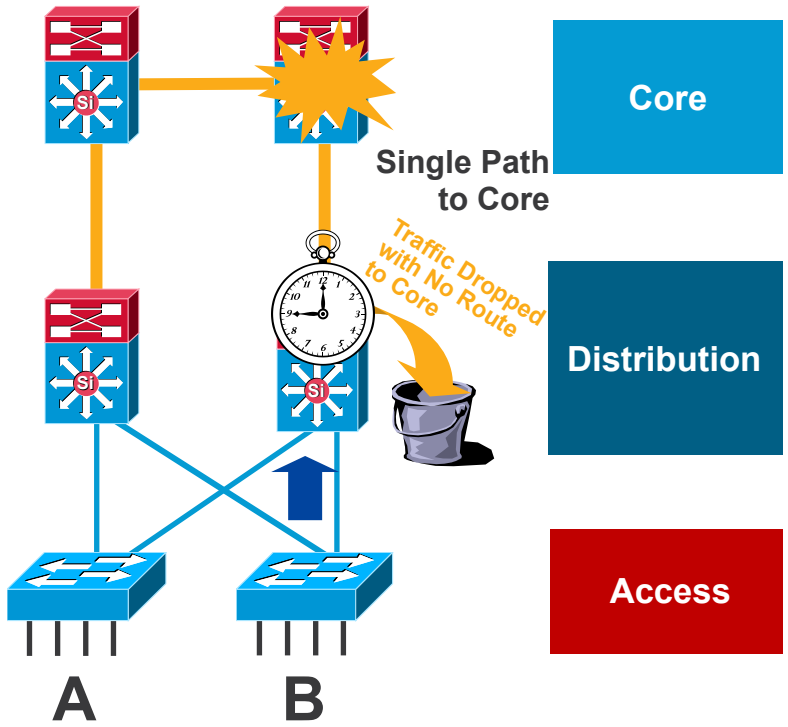
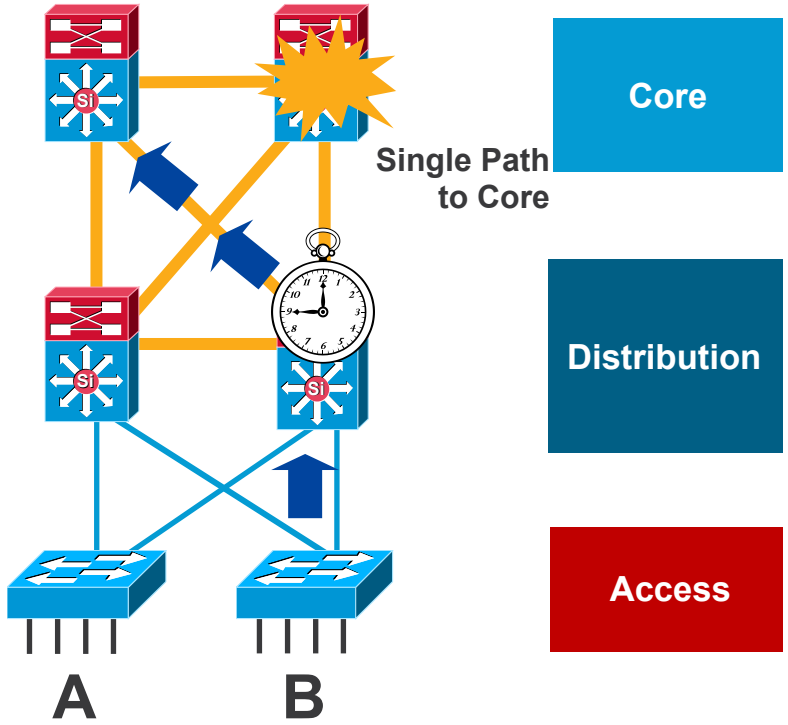


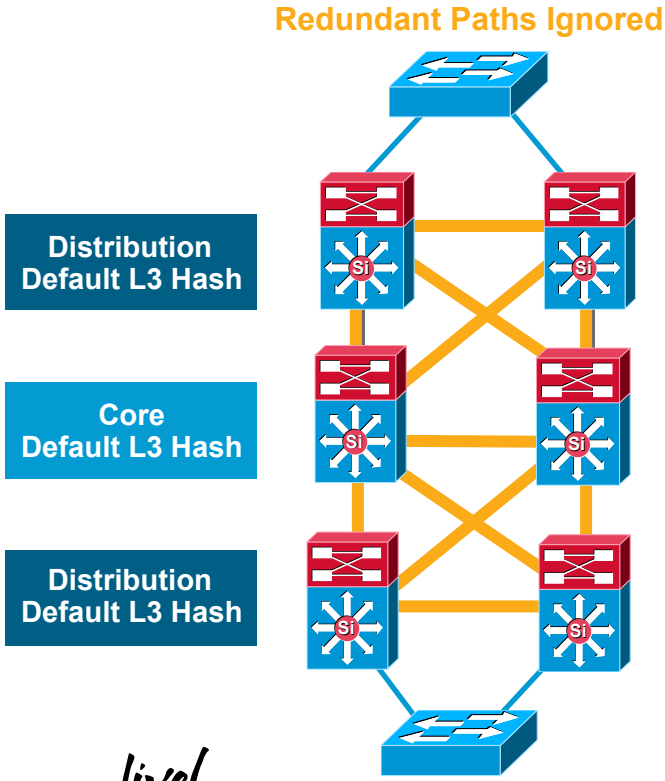
# Provide Alternate Paths

- What happens if  fails?
- No route to the core anymore?
- Allow the traffic to go through the access?
  - Do you want to use your access switches as transit nodes?
  - How do you design for scalability if the access used for transit traffic?
- Install a redundant link to the core
- Best practice: install redundant link to core and utilise L3 link between distribution layer



# CEF Load Balancing

## Avoid Under Utilising Redundant Layer 3 Paths

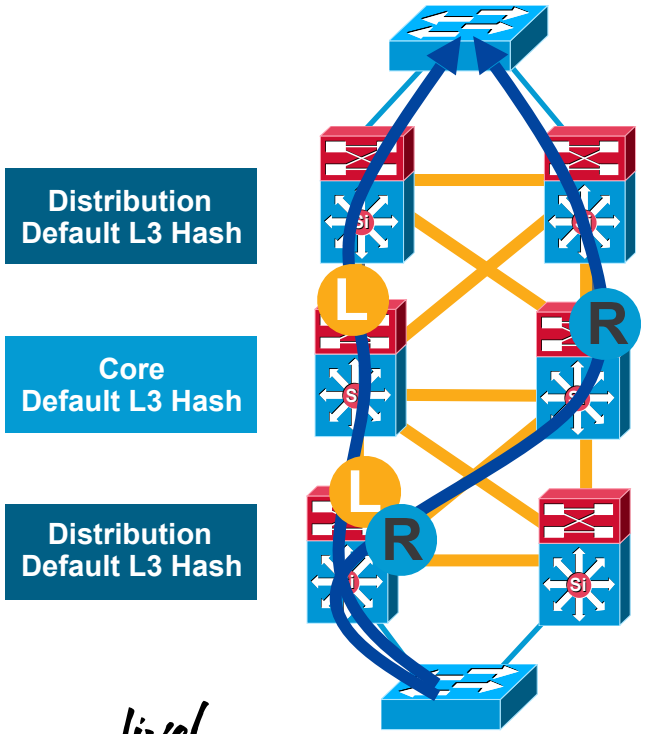



- CEF polarisation: without some tuning CEF will select the same path left/left or right/right
- Imbalance/overload could occur
- Redundant paths are ignored/underutilised
- The default CEF hash input is L3
- We can change the default to use L3 + L4 information as input to the hash derivation

# CEF Load Balancing

## Avoid Under Utilising Redundant Layer 3 Paths

**Redundant Paths Ignored**

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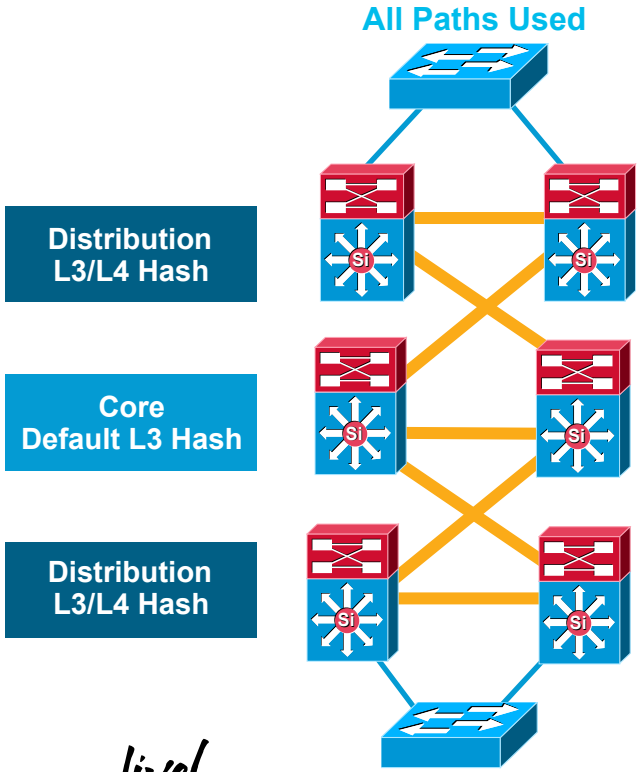
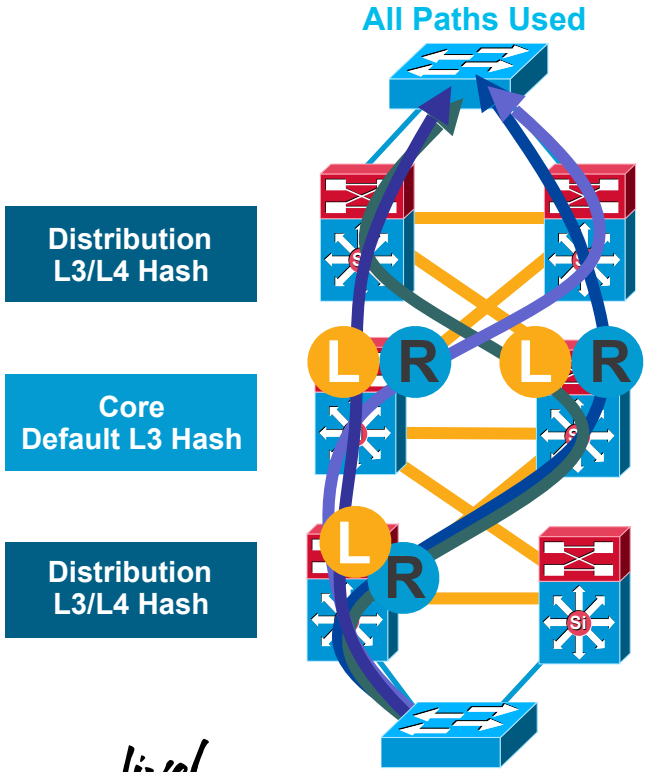



- The default will for Sup720/32 and latest hardware (unique ID added to default). However, depending on IP addressing, and flows imbalance could occur
- Alternating L3/L4 hash and L3 hash will give us the best load balancing results
- Use simple in the core and full simple in the distribution to add L4 information to the algorithm at the distribution and maintain differentiation tier-to-tier

# CEF Load Balancing

## Avoid Under Utilising Redundant Layer 3 Paths

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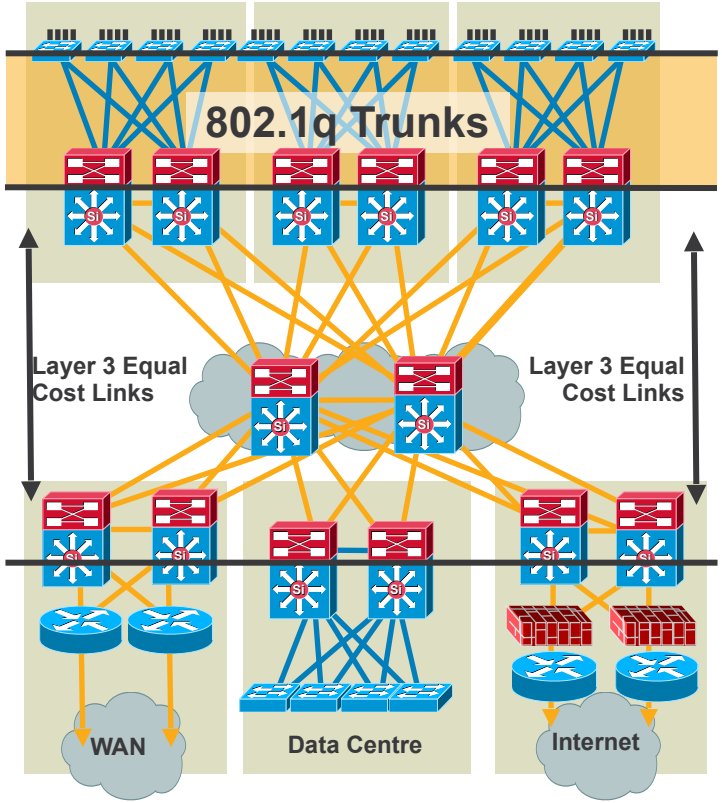
- Use simple in the core and full simple in the distribution to add L4 information to the algorithm at the distribution and maintain differentiation tier-to-tier

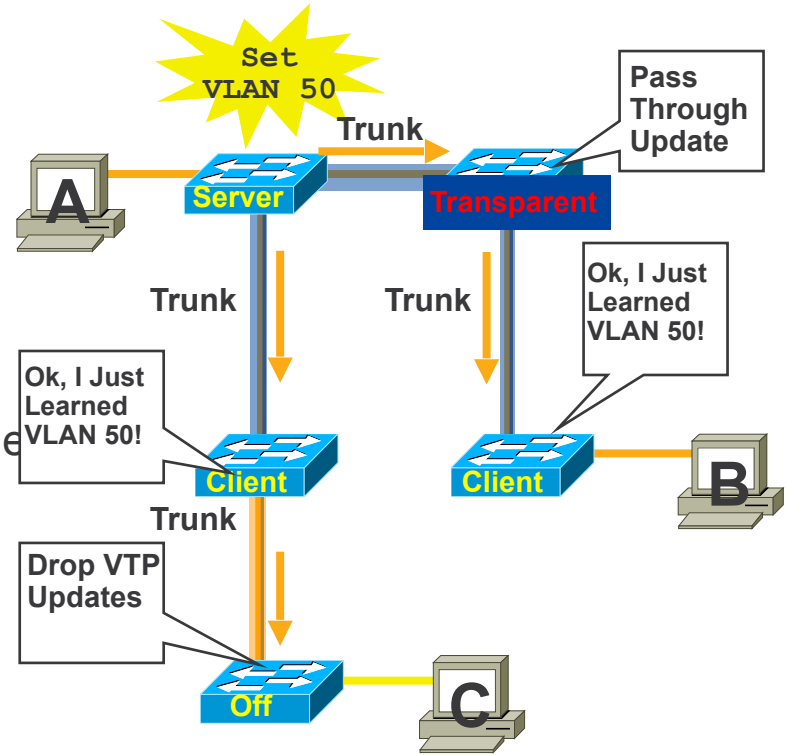
# Best Practices - Trunk Configuration

- Typically deployed on interconnection between access and distribution layers
- Use VTP transparent mode to decrease potential for operational error
- Hard set trunk mode to on and encapsulation negotiate off for optimal convergence
- Change the native VLAN to something unused to avoid VLAN hopping
- Manually prune all VLANS except those needed
- Disable on host ports:
  - Cisco IOS: switchport host



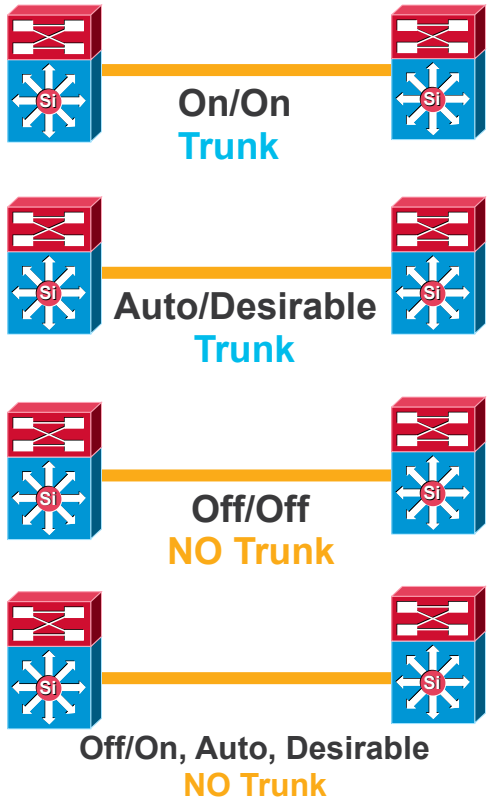
# VTP Virtual Trunk Protocol

- Centralised VLAN management
- VTP server switch propagates VLAN database to VTP client switches
- Runs only on trunks
- Four modes:
  - Server: updates clients and servers
  - Client: receive updates— cannot make change
  - Transparent: let updates pass through
  - Off: ignores VTP updates



# DTP Dynamic Trunk Protocol

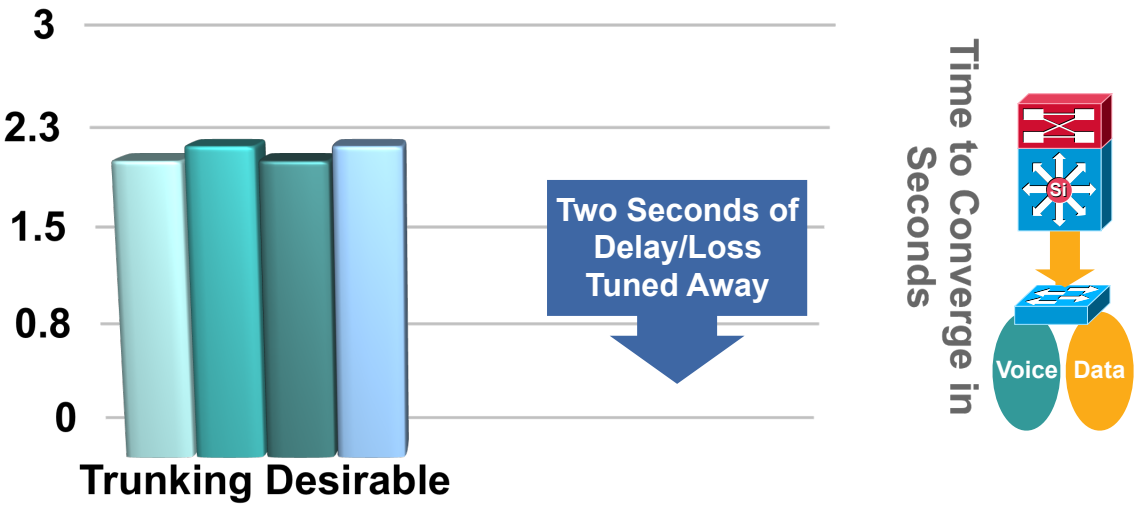
- Automatic formation of trunked switch-to-switch interconnection
  - On: always be a trunk
  - Desirable: ask if the other side can/will
  - Auto: if the other sides asks I will
  - Off: don't become a trunk
- Negotiation of 802.1Q or ISL encapsulation
  - ISL: try to use ISL trunk encapsulation
  - 802.1q: try to use 802.1q encapsulation
  - Negotiate: negotiate ISL or 802.1q encapsulation with peer
  - Non-negotiate: always use encapsulation that is hard set



# Optimising Convergence: Trunk Tuning

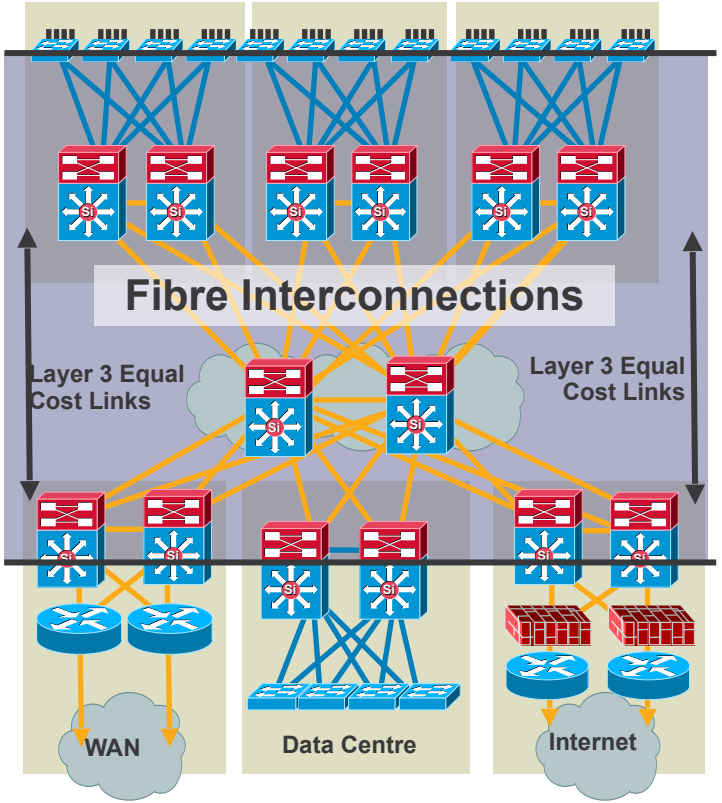
## Trunk Auto/Desirable Takes Some Time

- DTP negotiation tuning improves link up convergence time
  - IOS(config-if)# switchport mode trunk
  - IOS(config-if)# switchport nonegotiate



# Best Practices - UDLD Configuration

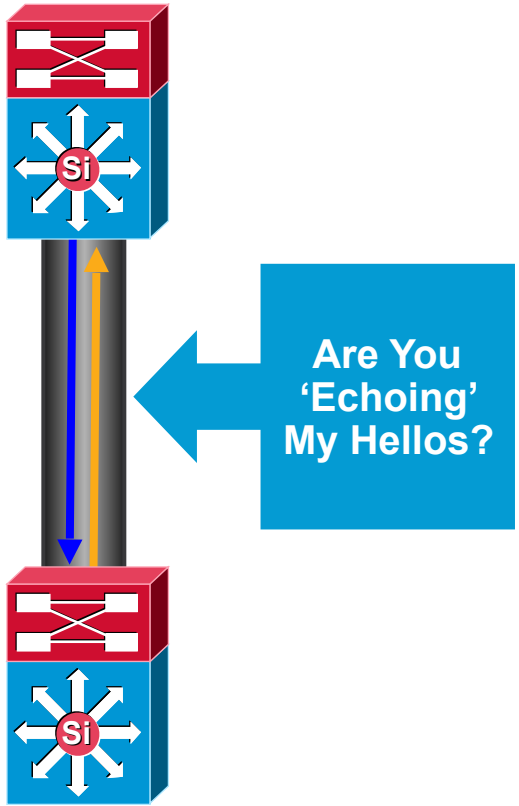
- Typically deployed on any fibre optic interconnection
- Use UDLD aggressive mode for most aggressive protection
- Turn on in global configuration to avoid operational error/misses
- Config example
  - Cisco IOS: udld aggressive



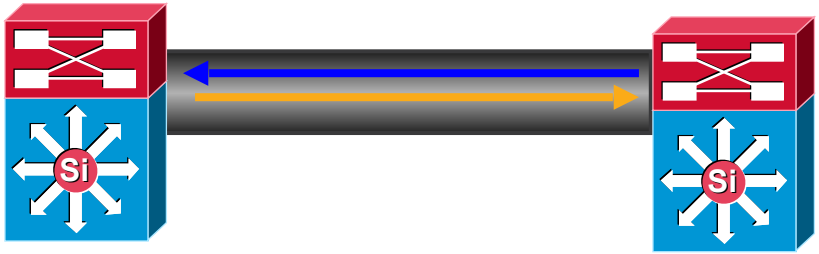
# Unidirectional Link Detection

## Protecting Against One-Way Communication

- Highly-available networks require UDLD to protect against one-way communication or partially failed links and the effect that they could have on protocols like STP and RSTP
- Primarily used on fibre optic links where patch panel errors could cause link up/up with mismatched transmit/receive pairs
- Each switch port configured for UDLD will send UDLD protocol packets (at L2) containing the port's own device/port ID, and the neighbour's device/port IDs seen by UDLD on that port
- Neighbouring ports should see their own device/port ID (echo) in the packets received from the other side
- If the port does not see its own device/port ID in the incoming UDLD packets for a specific duration of time, the link is considered unidirectional and is shutdown

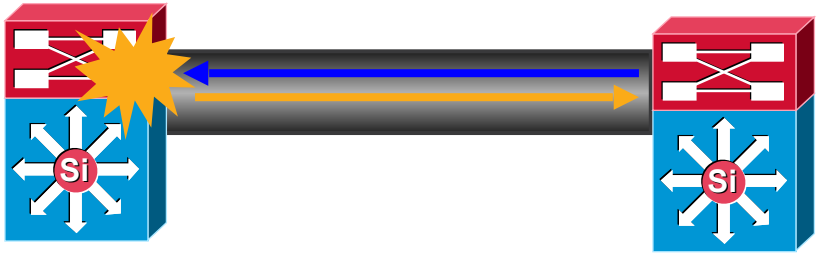


# UDLD Aggressive and UDLD Normal




- Timers are the same—15-second hellos by default
- Aggressive Mode—after aging on a previously bi-directional link—tries eight times (once per second) to reestablish connection then err-disables port

# UDLD Aggressive and UDLD Normal

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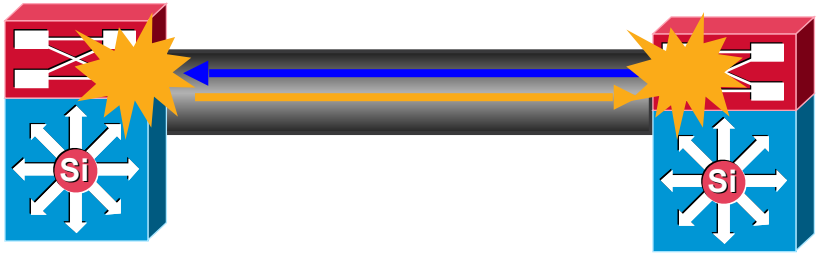


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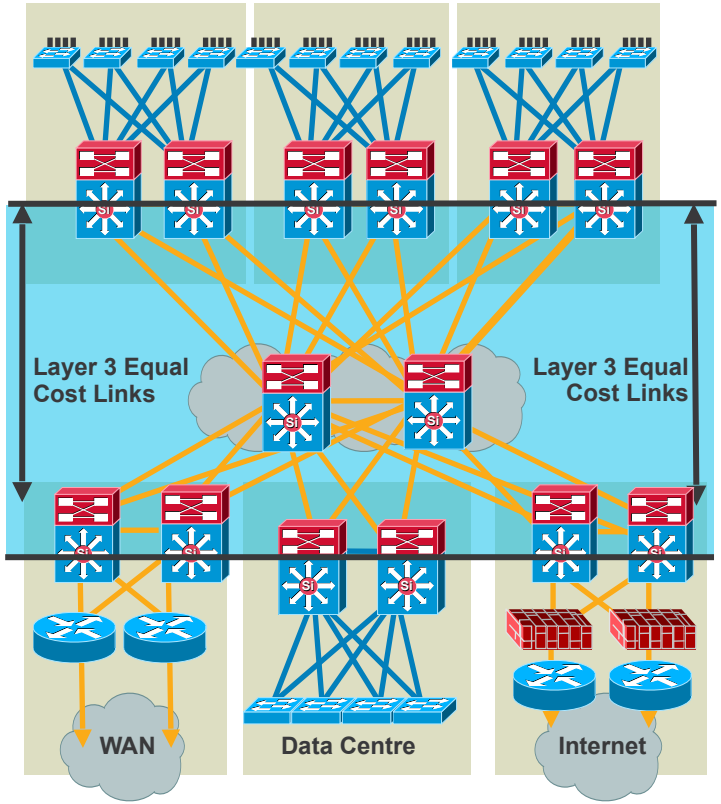
- UDLD—Normal Mode—only err-disable the end where UDLD detected other end just sees the link go down
- UDLD—Aggressive—err-disable both ends of the connection due to err-disable when aging and re-establishment of UDLD communication fails

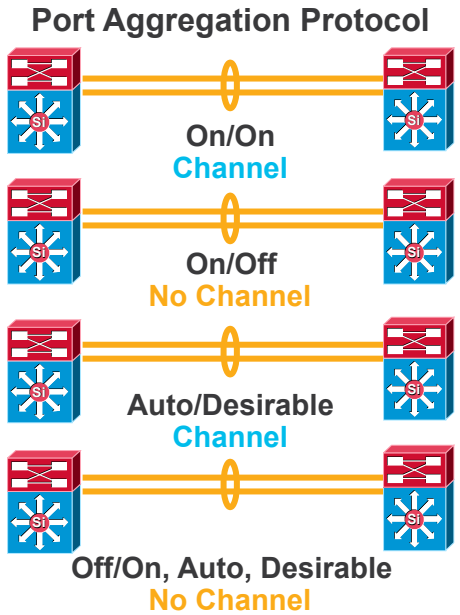
# Best Practices - Ether Channel Configuration

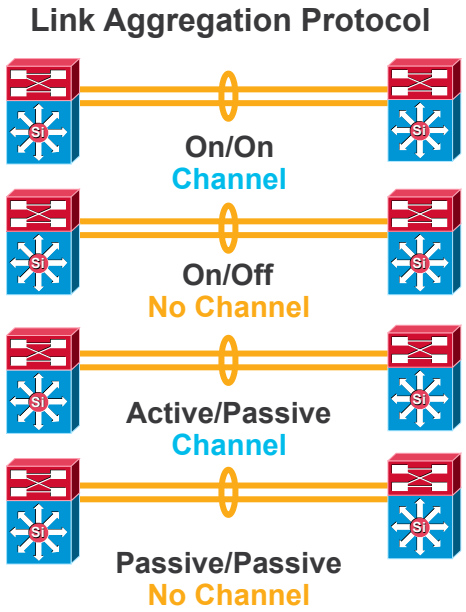
- Typically deployed in distribution to core, and core
  to core interconnections
- Used to provide link redundancy—while reducing peering complexity
- Tune L3/L4 load balancing hash to achieve maximum utilisation of channel members
- Deploy in powers of two (two, four, or eight)
- Match CatOS and Cisco IOS PAgP settings
- 802.3ad LACP for interop if you need it
- Disable unless needed
  - Cisco IOS: switchport host



# Understanding Ether Channel

## Link Negotiation Options—PAgP and LACP



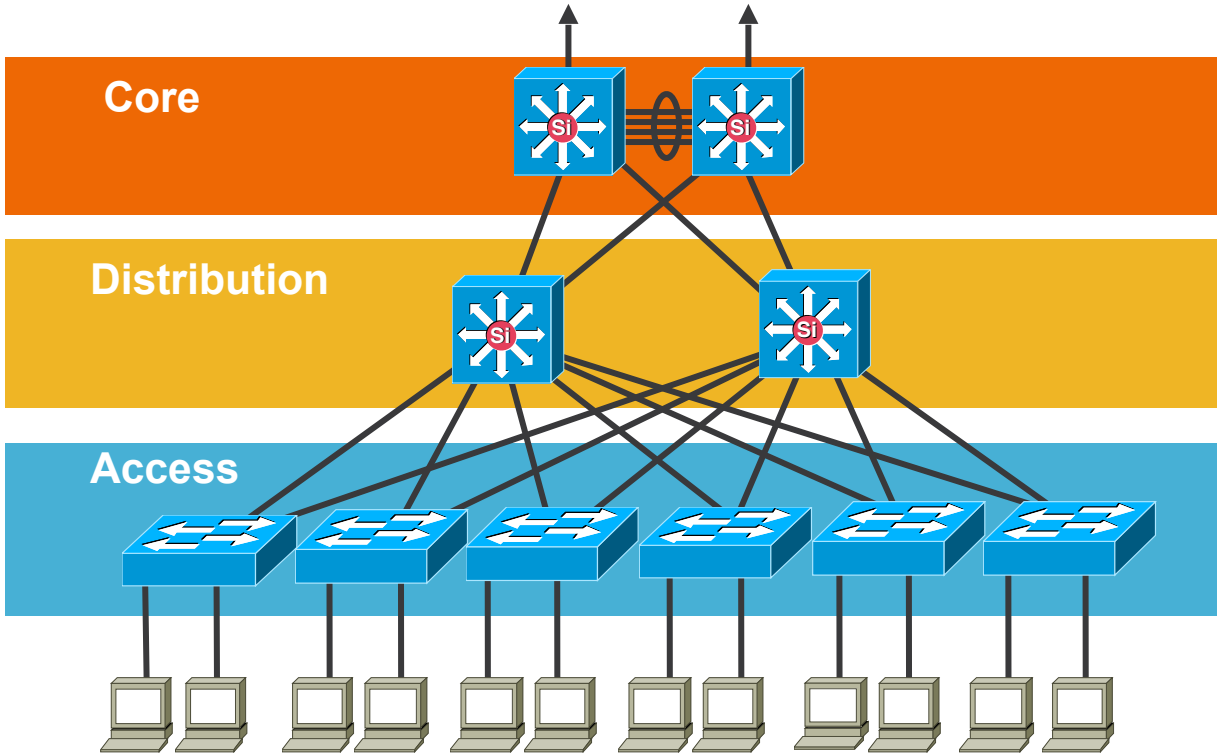




**On:** always be a channel/bundle member
**Desirable:** ask if the other side can/will
**Auto:** if the other side asks I will
**Off:** don't become a member of a channel/ bundle

**On:** always be a channel/bundle member
**Active:** ask if the other side can/will
**Passive:** if the other side asks I will
**Off:** don't become a member of a channel/ bundle

# EtherChannels

## 10/100/1000 How Do You Aggregate It?



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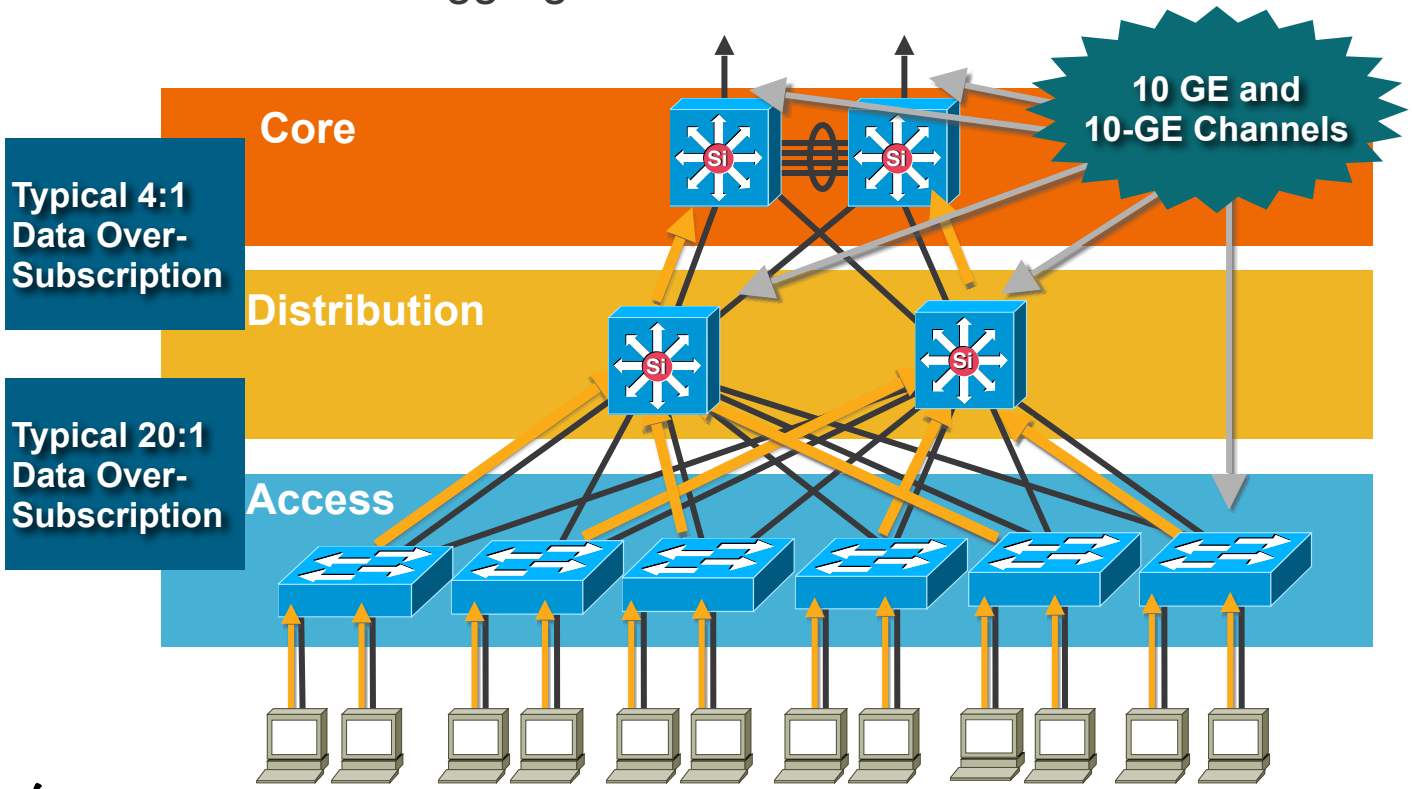
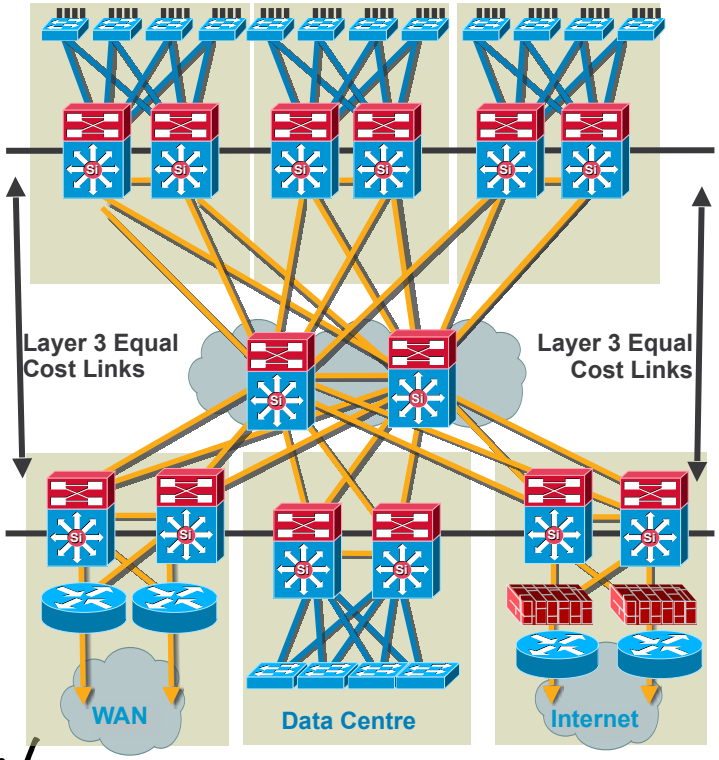


# EtherChannels

## Reduce Complexity/Peer Relationships




- More links = more routing peer relationships and associated overhead
- EtherChannels allow you to reduce peers by creating single logical interface to peer over
- On single link failure in a bundle
  - OSPF running on a Cisco IOS-based switch will reduce link cost and reroute traffic
  - OSPF running on a hybrid switch will not change link cost and may overload remaining links
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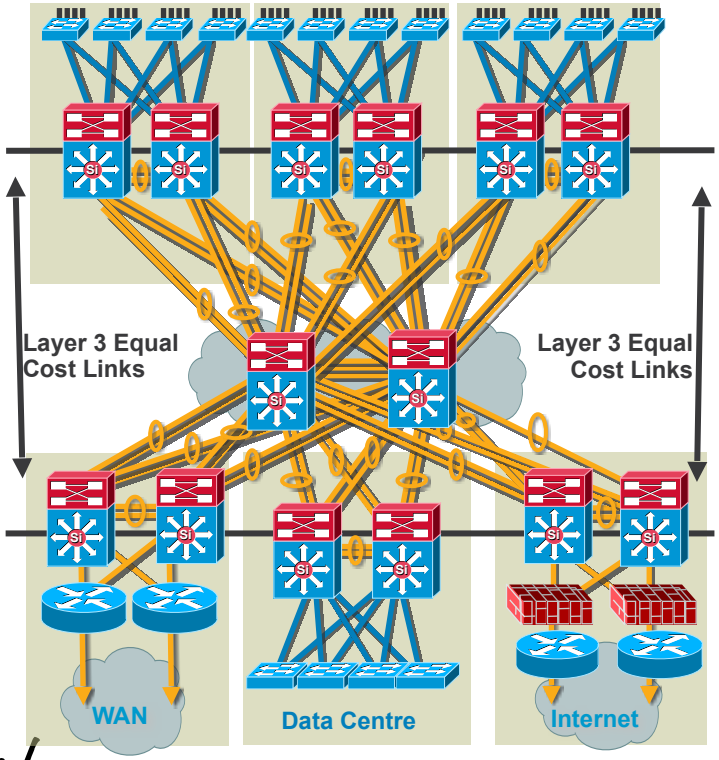


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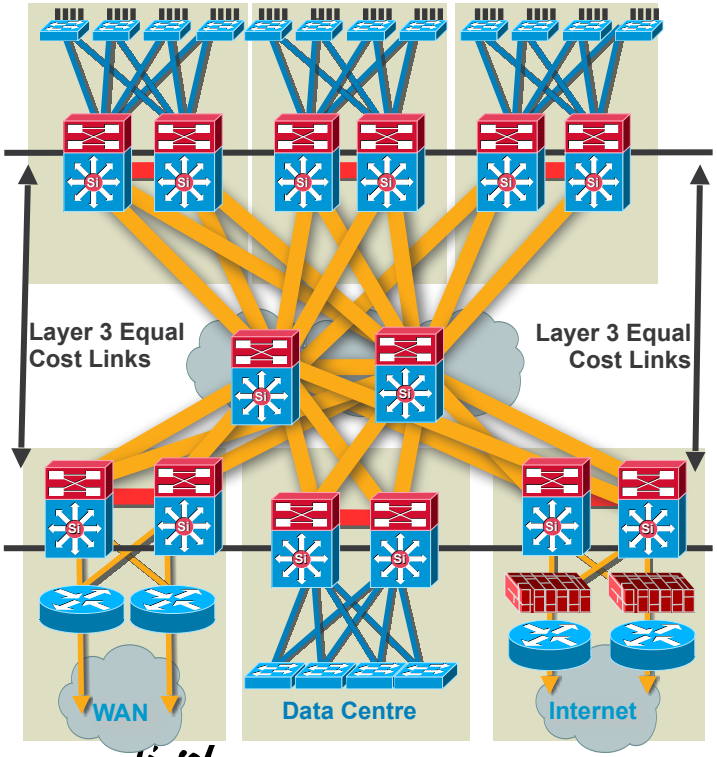
# EtherChannels

## Why 10-Gigabit Interfaces




- More links = more routing peer relationships and associated overhead
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- However, a single link failure is not taken into consideration by routing protocols. Overload possible
- Single 10-gigabit links address both problems. Increased bandwidth without increasing complexity or compromising routing protocols ability to select best path

# EtherChannels

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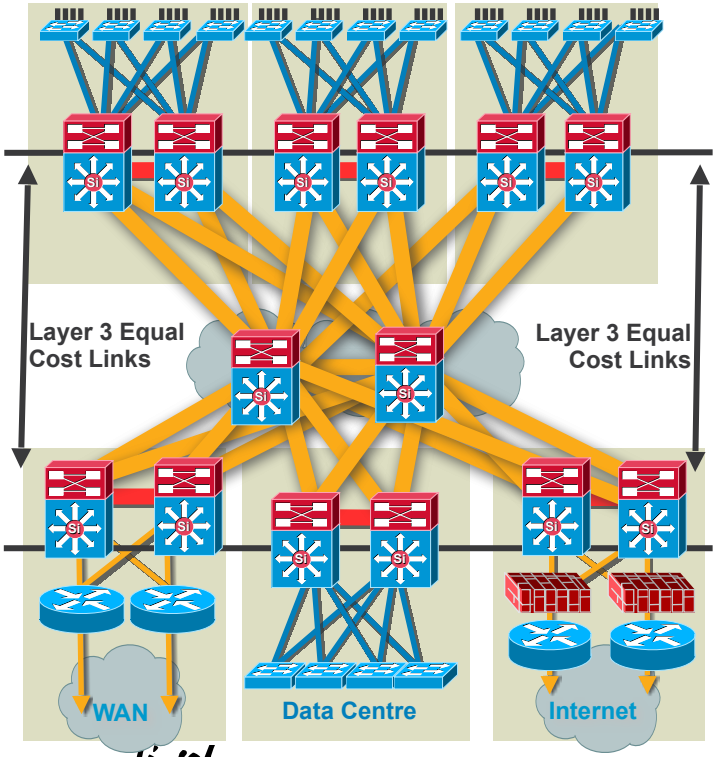


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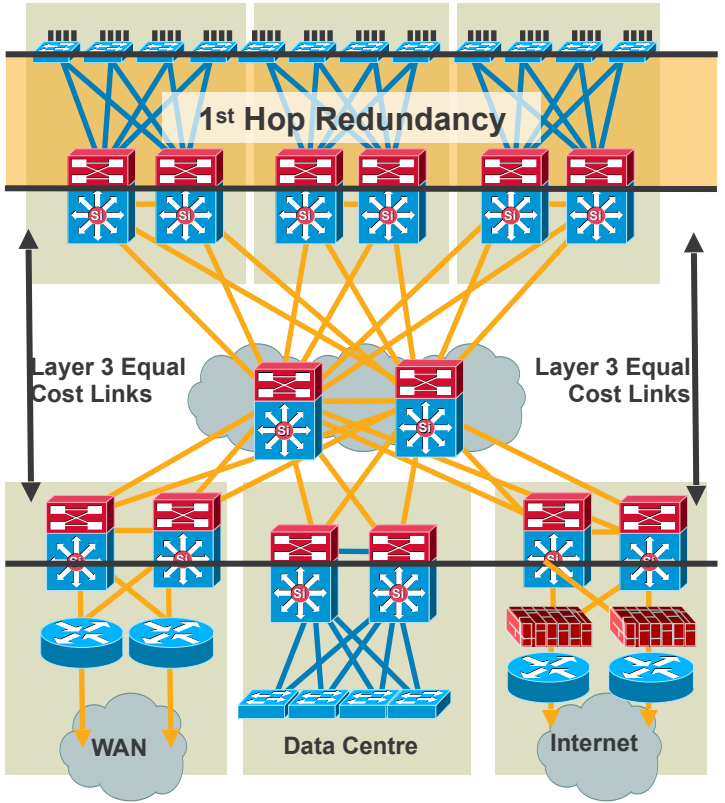
# Best Practices - First Hop Redundancy

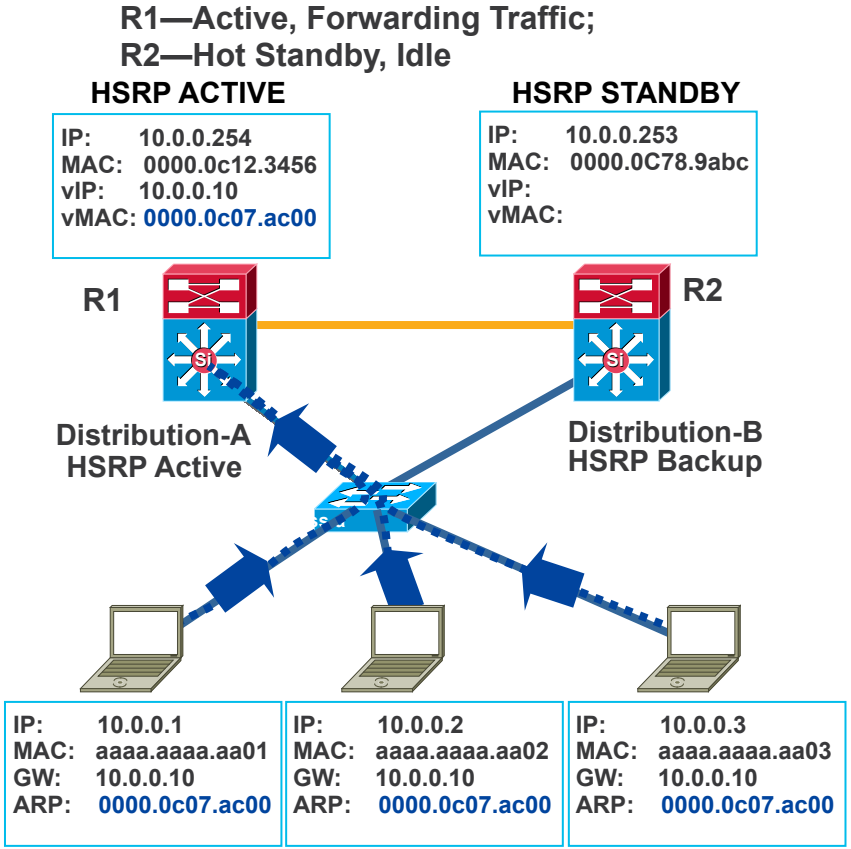
- Used to provide a resilient default gateway/first hop address to end-stations
- HSRP, VRRP, and GLBP alternatives
- VRRP, HSRP, and GLBP provide millisecond timers and excellent convergence performance
- VRRP if you need multivendor interoperability
- GLBP facilitates uplink load balancing
- Preempt timers need to be tuned to avoid black-holed traffic



# First Hop Redundancy with HSRP

RFC 2281 (March 1998)

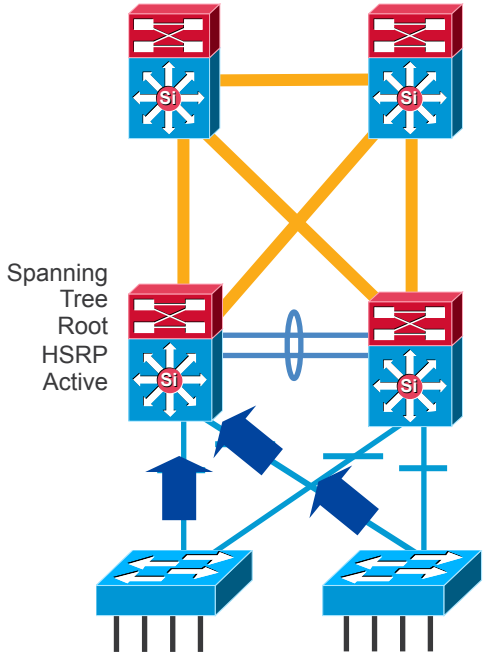
- A group of routers function as one virtual router by sharing one virtual IP address and one virtual MAC address
- One (active) router performs packet forwarding for local hosts
- The rest of the routers provide hot standby in case the active router fails
- Standby routers stay idle as far as packet forwarding from the client side is concerned



# Why You Want HSRP Preemption

## Avoid ‘Black-Hole’ during system startup

- Spanning tree root and HSRP primary aligned
- When spanning tree root is re-introduced, traffic will take a two-hop path to HSRP active
- HSRP preemption will allow HSRP to follow spanning tree topology



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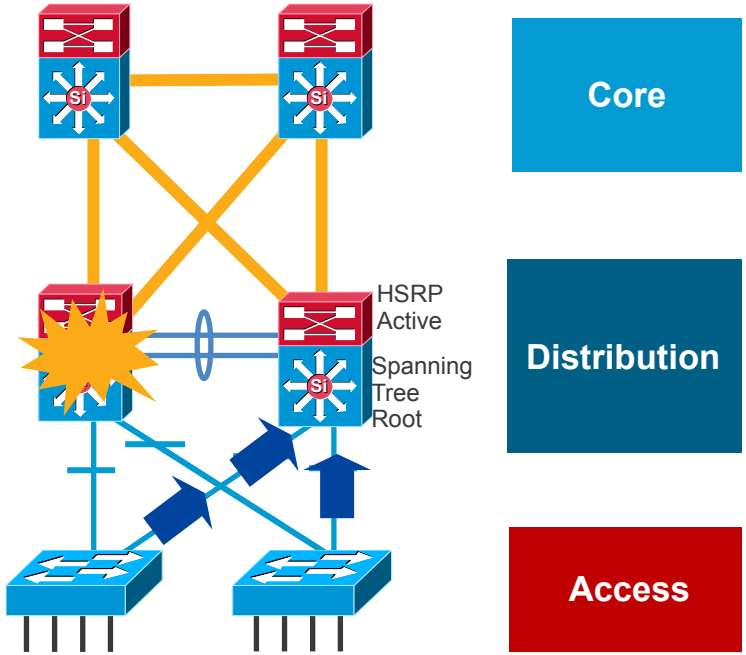

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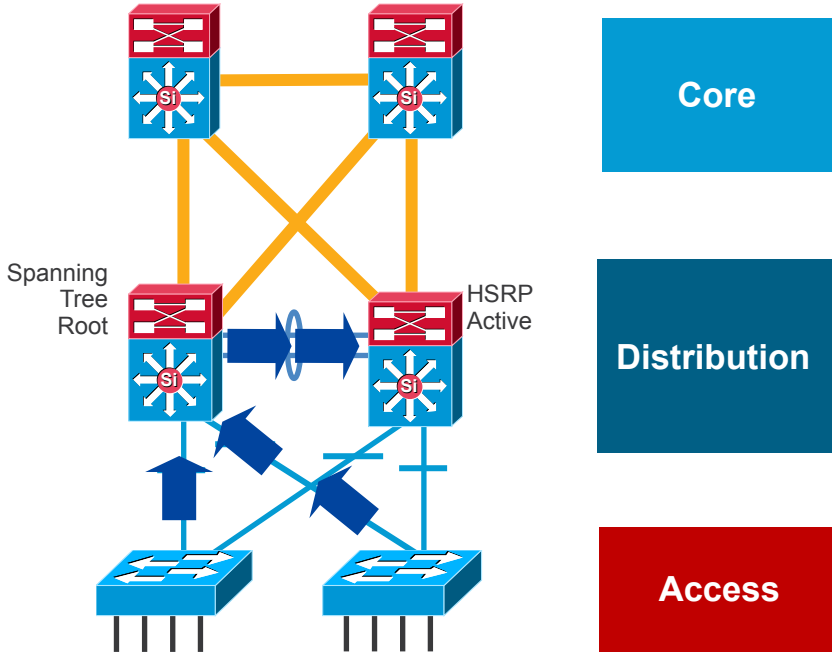

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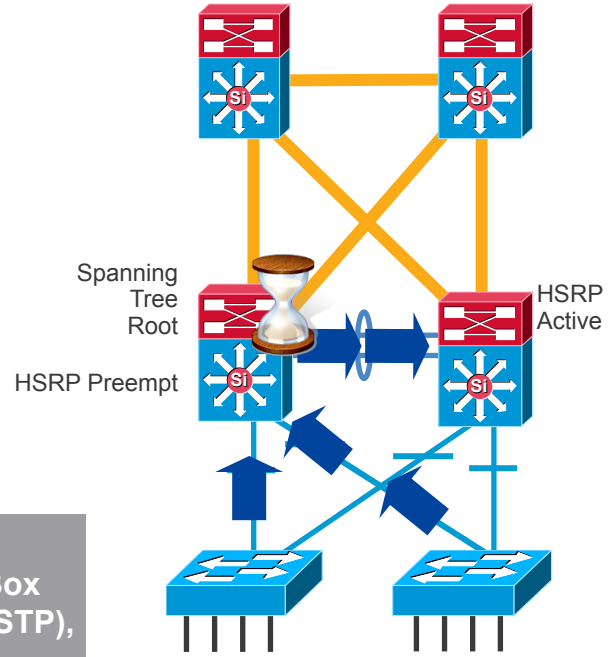


**Without Preempt Delay HSRP Can Go Active Before Box Completely Ready to Forward Traffic: L1 (Boards), L2 (STP), L3 (IGP Convergence)**

```
standby 1 preempt delay minimum 180
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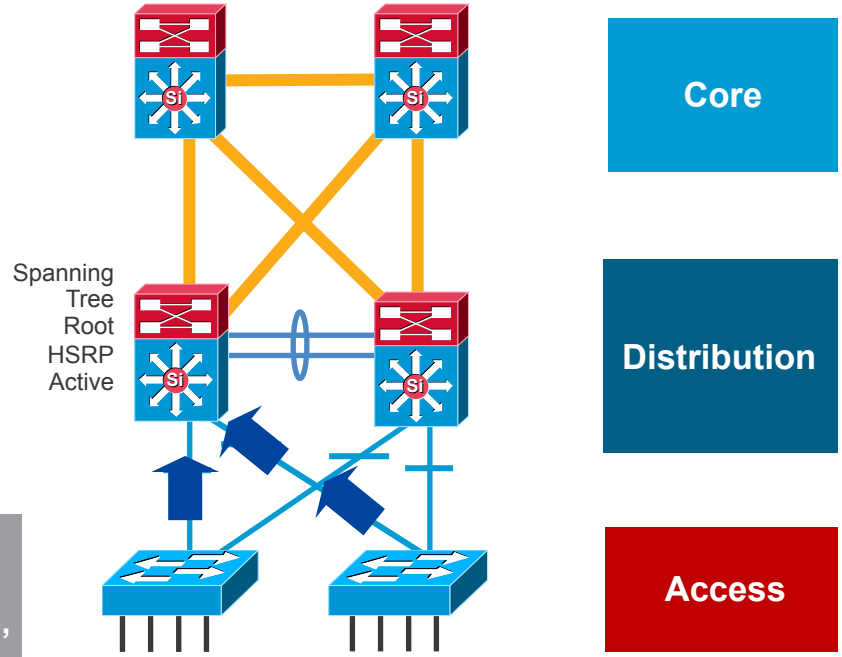


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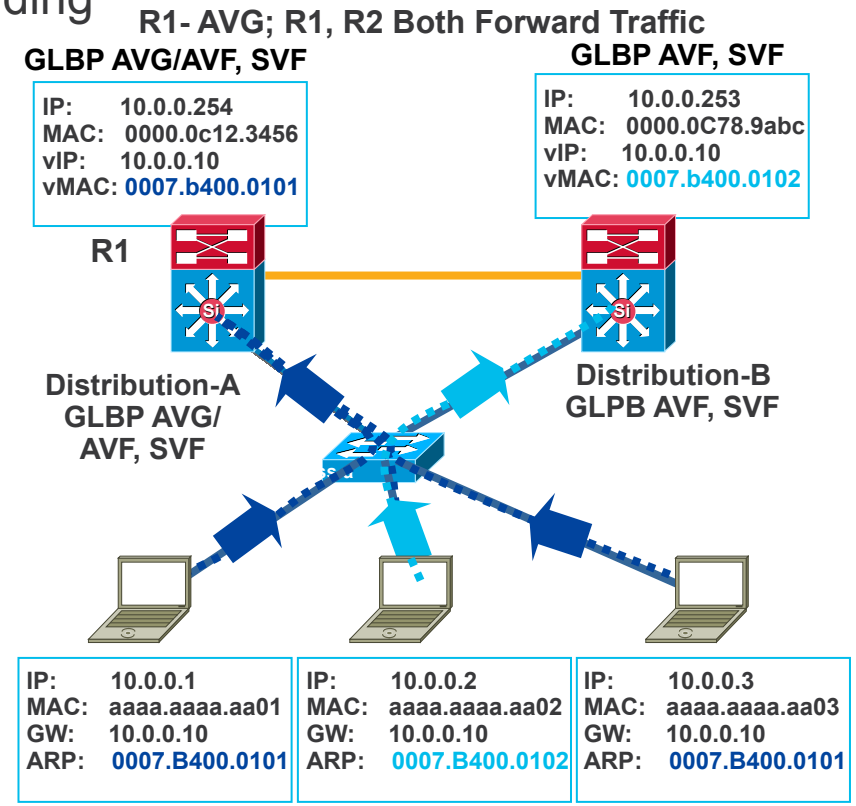
# First Hop Redundancy with GLBP

## Cisco Designed, Load Sharing, Patent Pending

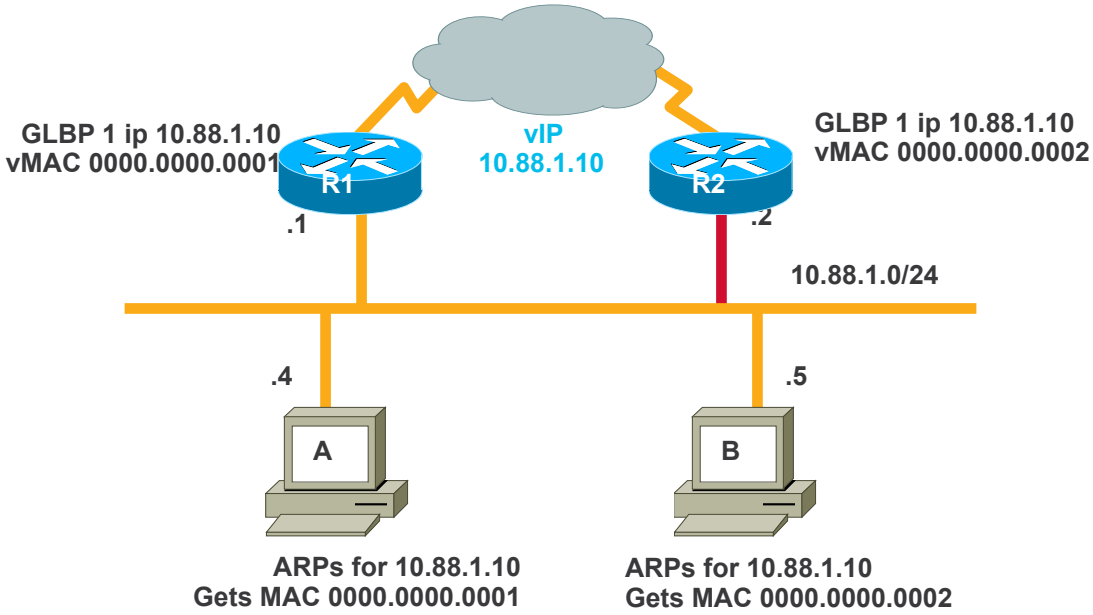
- All the benefits of HSRP plus load balancing of default gateway → utilises all available bandwidth
- A group of routers function as one virtual router by sharing one virtual IP address but using multiple virtual MAC addresses for traffic forwarding
- Allows traffic from a single common subnet to go through multiple redundant gateways using a single virtual IP address



# First Hop Redundancy with Load Balancing

## Cisco Gateway Load Balancing Protocol (GLBP)

- Each member of a GLBP redundancy group owns a unique virtual MAC address for a common IP address/default gateway
- When end-stations ARP for the common IP address/default gateway they are given a load-balanced virtual MAC address
- Host A and host B send traffic to different GLBP peers but have the same default gateway



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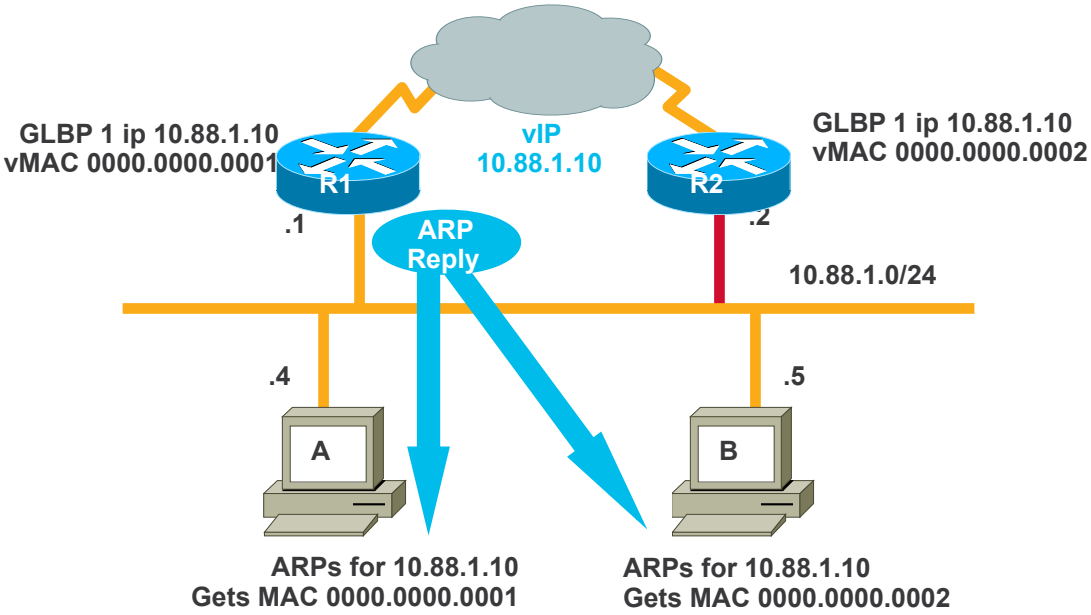

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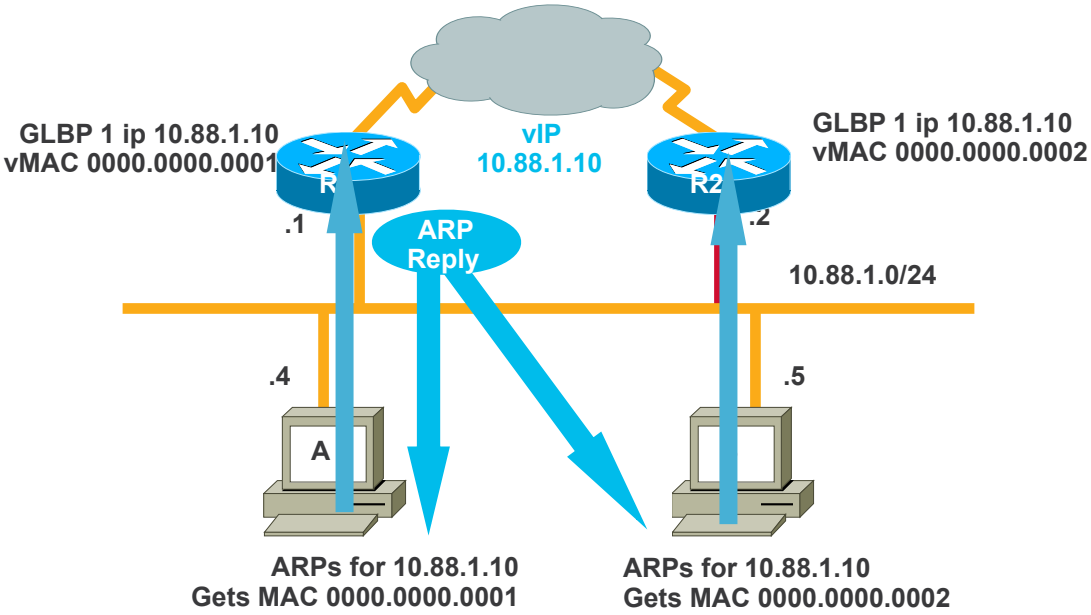
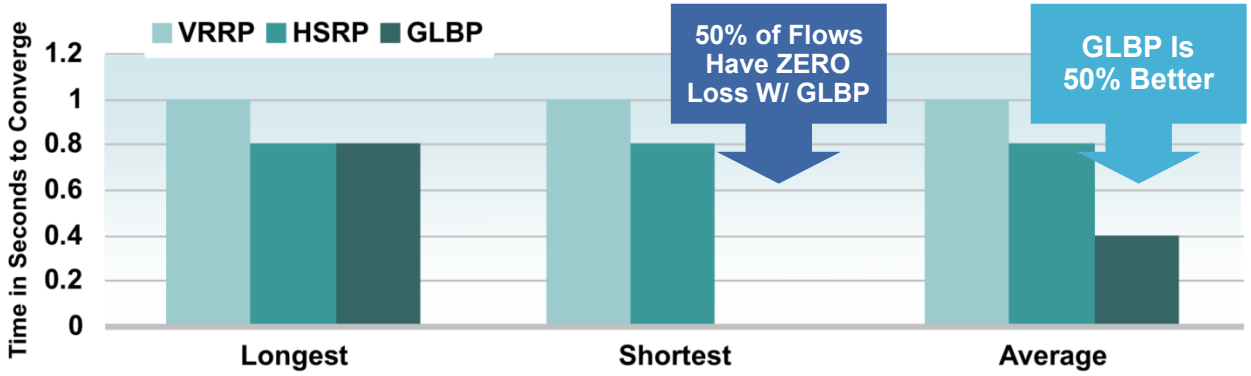


# Optimising Convergence: VRRP, HSRP, GLBP

## Mean, Max, and Min—Are There Differences?

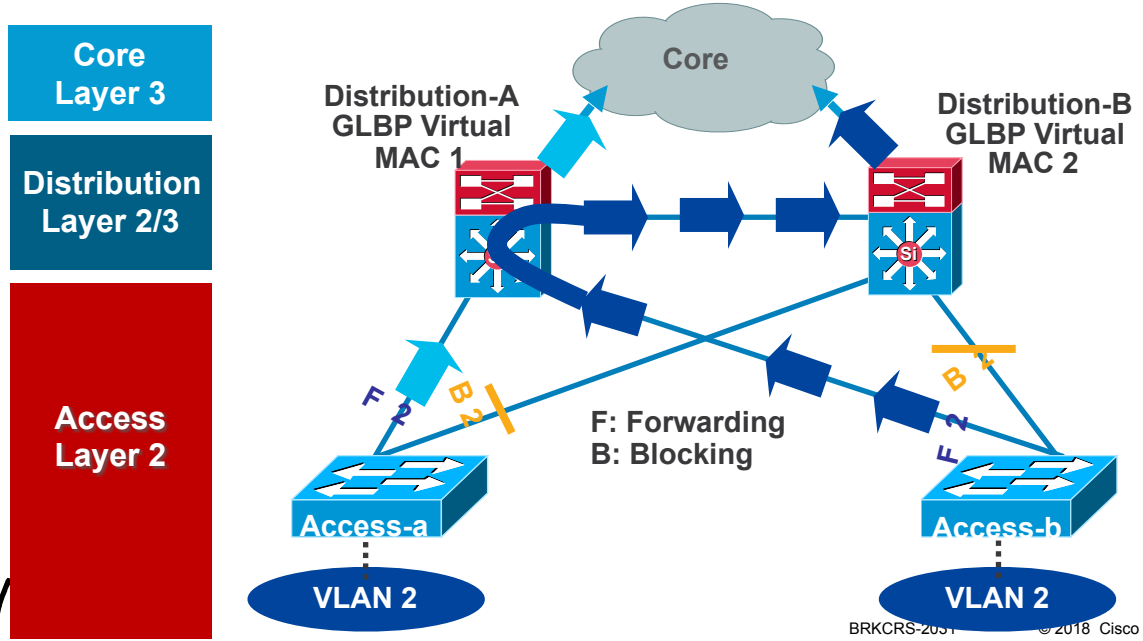
- VRRP not tested with sub-second timers and all flows go through a common VRRP peer; mean, max, and min are equal
- HSRP has sub-second timers; however all flows go through same HSRP peer so there is no difference between mean, max, and min
- GLBP has sub-second timers and distributes the load amongst the GLBP peers; so 50% of the clients are not affected by an uplink failure



# If You Span VLANS, Tuning Required

## By Default, Half the Traffic Will Take a Two-Hop L2 Path

- Both distribution switches act as default gateway
- Blocked uplink caused traffic to take less than optimal path



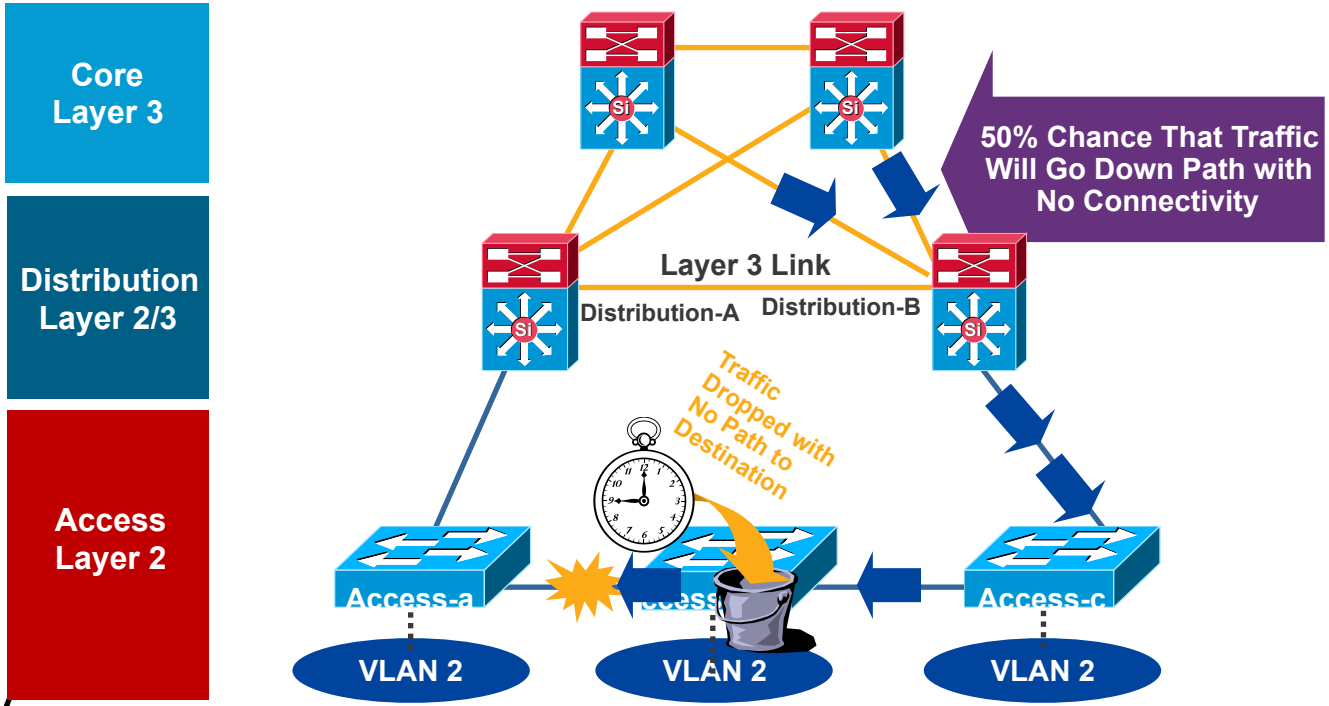
# Agenda

- Multilayer Campus Design Principles
- Foundation Services
- Campus Design Best Practices
- QoS Considerations
- Security Considerations
- Putting It All Together
- Summary

# Daisy Chaining Access Layer Switches

## Avoid Potential Black Holes

**Return Path Traffic Has a 50/50 Chance of Being 'Black Holed'**



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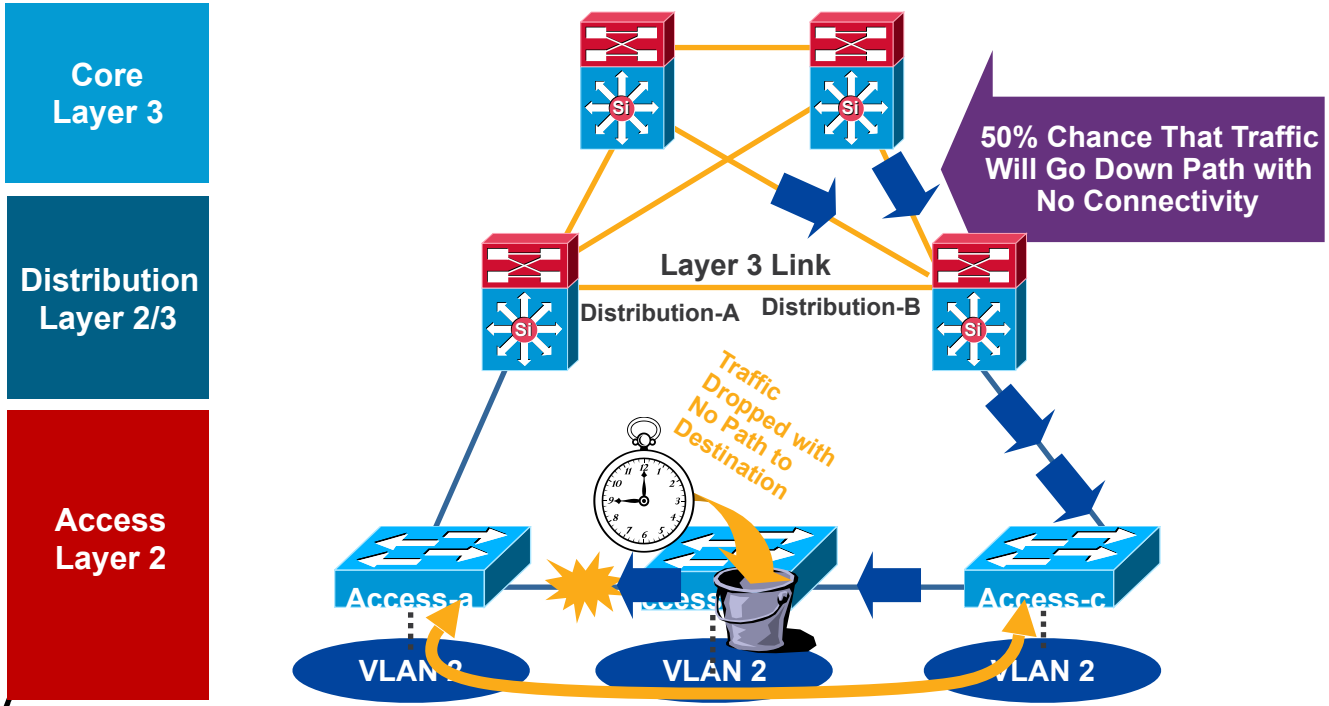
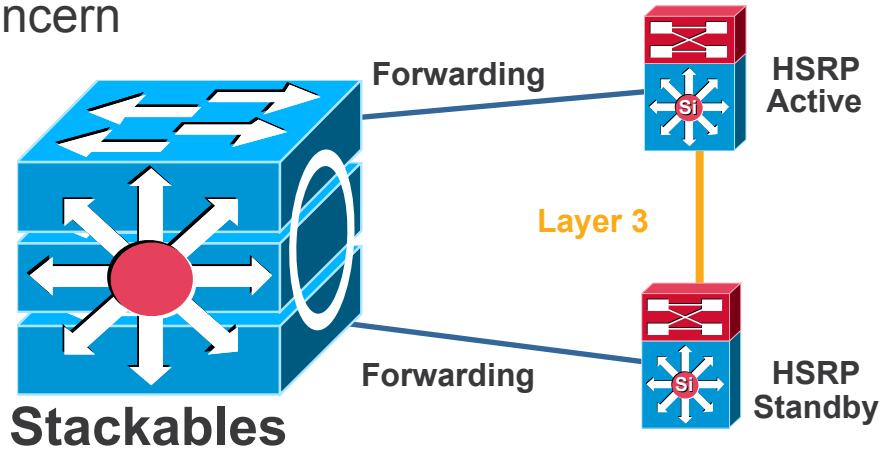


# Daisy Chaining Access Layer Switches

## New Technology Addresses Old Problems

- Stackwise/Stackwise-Plus technology eliminates the concern
  - Loopback links not required
  - No longer forced to have L2 link in distribution
- If you use modular (chassis-based) switches, these problems are not a concern



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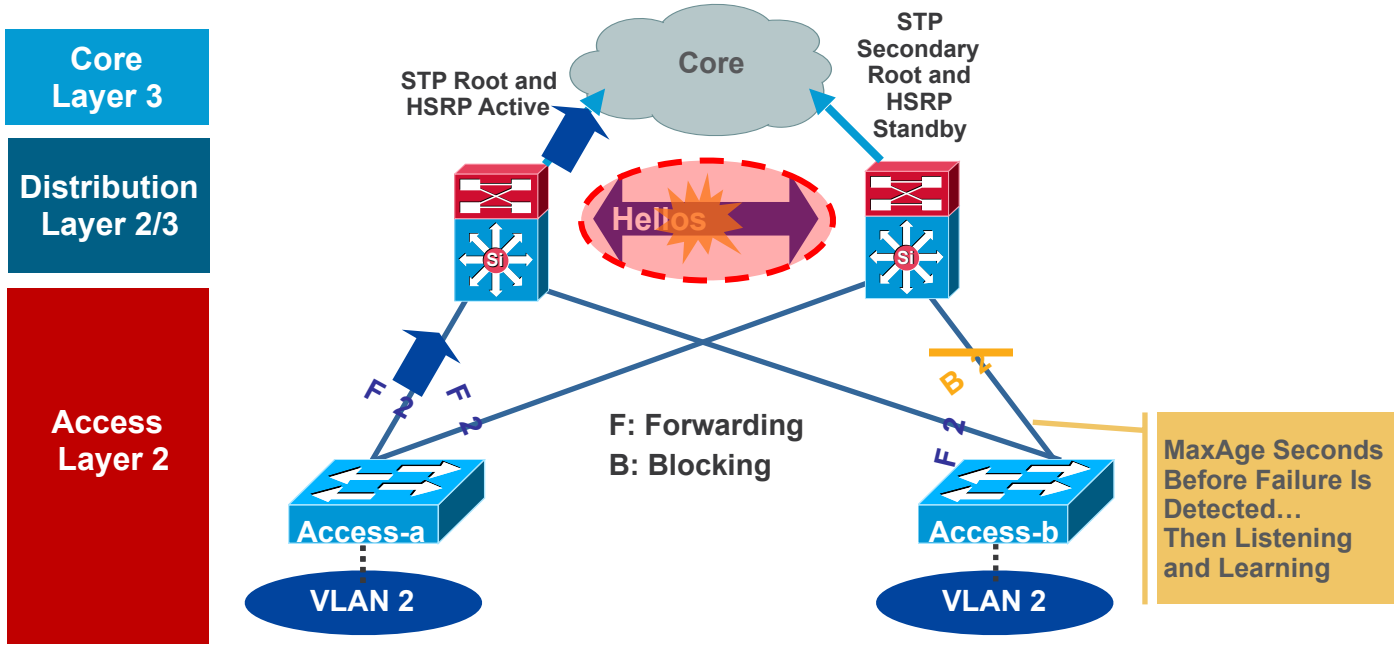
## Black Holes and Multiple Transitions …




- Blocking link on access-b will take 50 seconds to move to forwarding → traffic black hole until HSRP goes active on standby HSRP peer
- After MaxAge expires (or backbone fast or Rapid PVST+) converges HSRP preempt causes another transition
- Access-b used as transit for access-a's traffic

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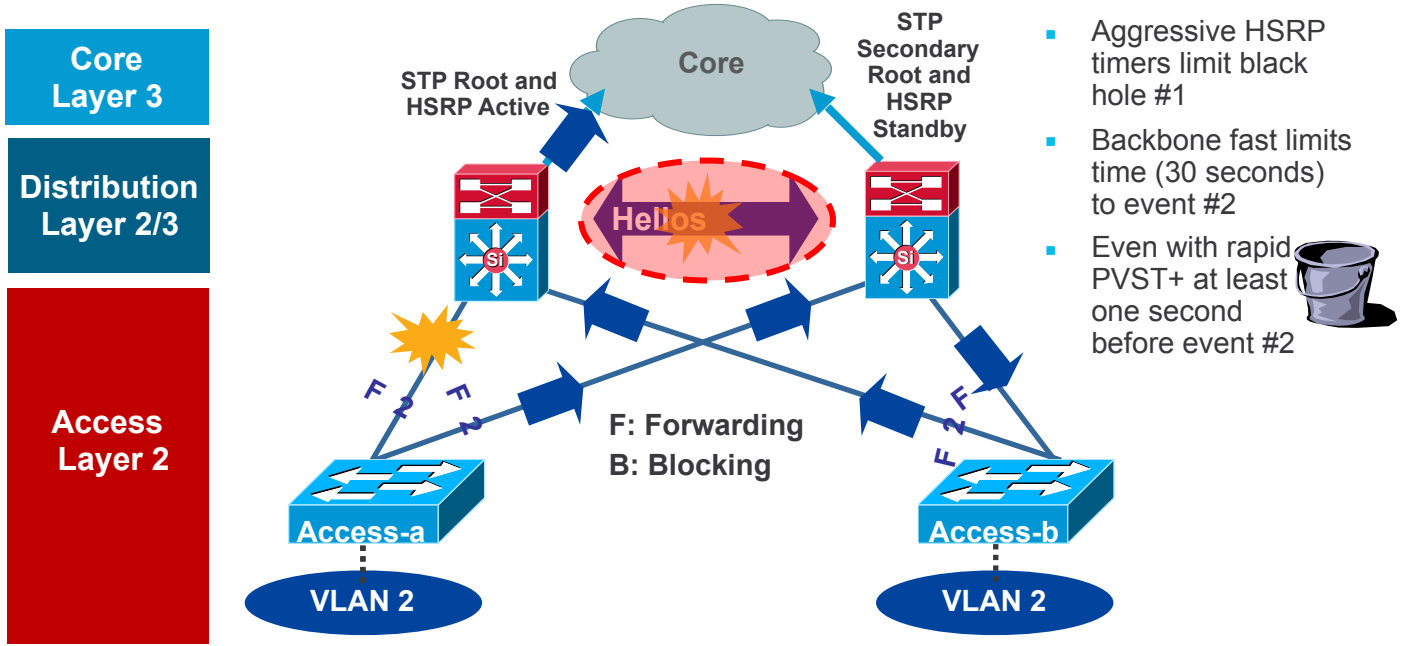


- Aggressive HSRP timers limit black hole #1
- Backbone fast limits time (30 seconds) to event #2
- Even with rapid PVST+ at least one second before event #2

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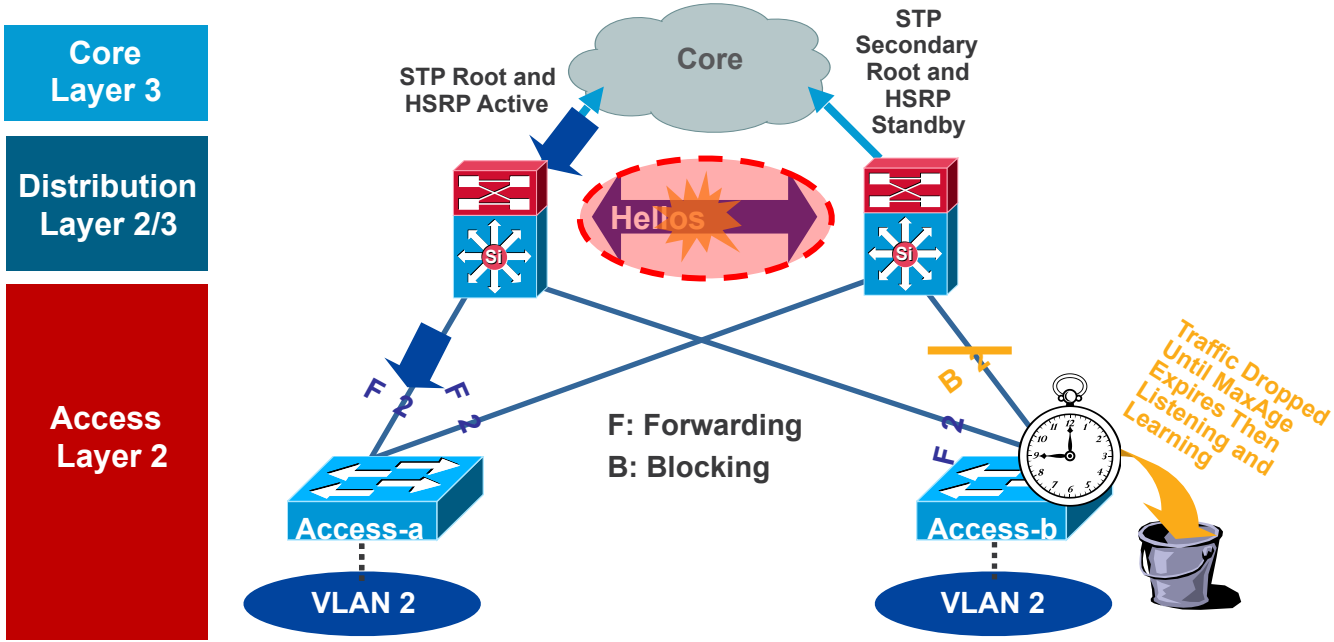


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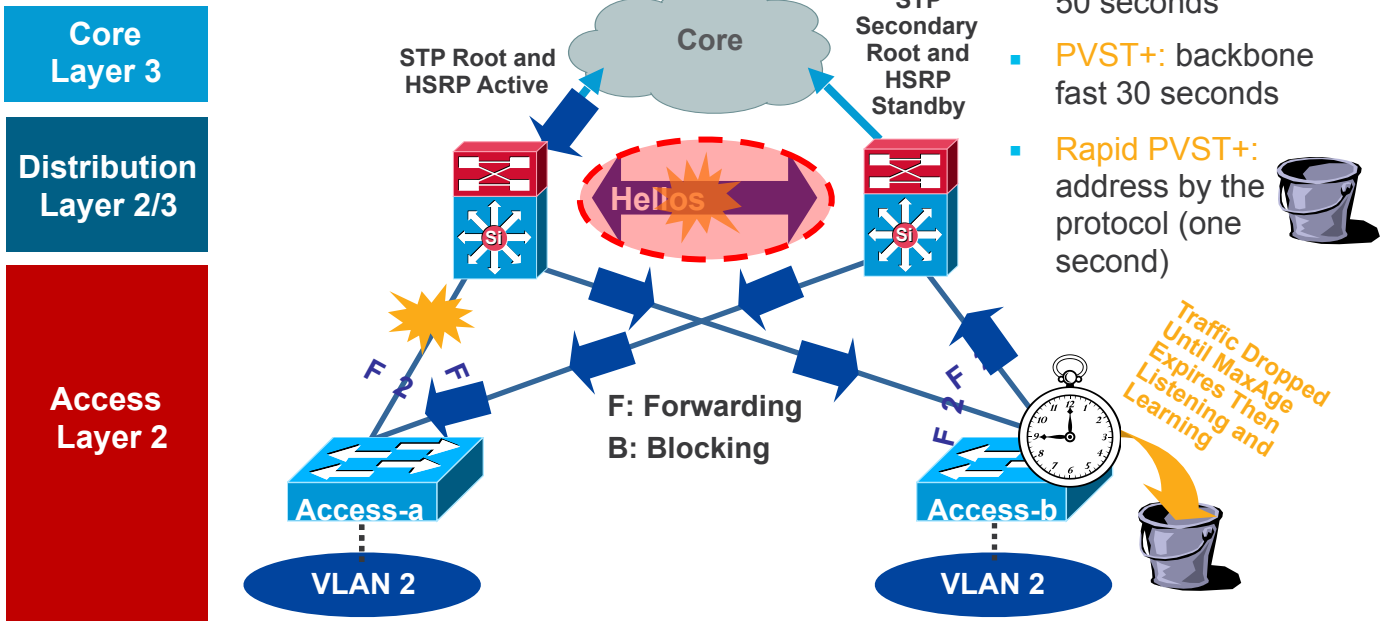


- 802.1d: up to 50 seconds
- PVST+: backbone fast 30 seconds
- Rapid PVST+: address by the protocol (one second)

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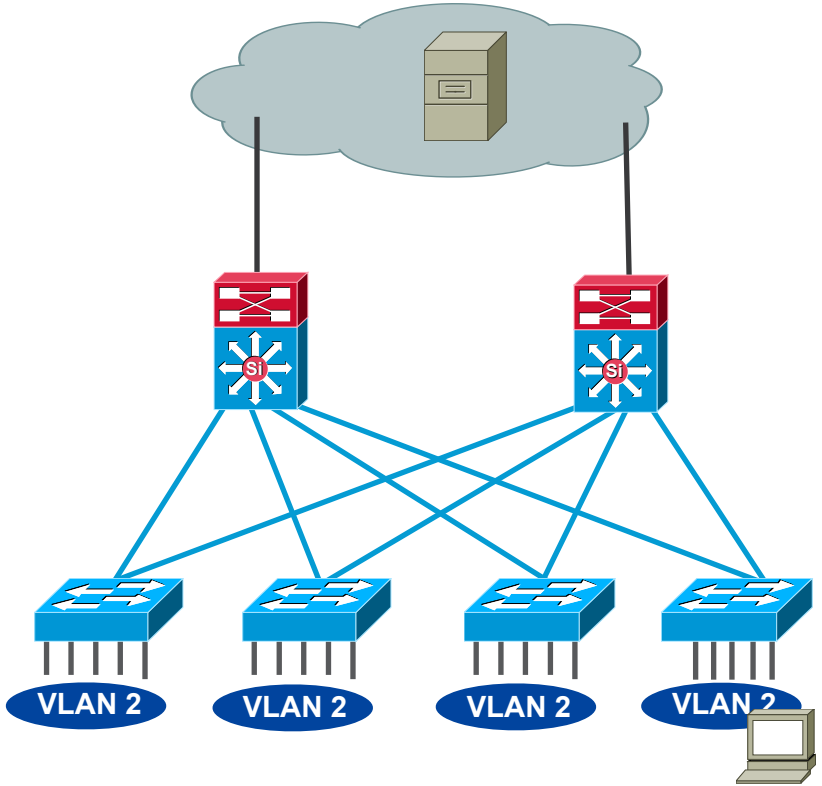
# Asymmetric Routing (Unicast Flooding)

Affects redundant topologies with shared L2 access

- One path upstream and two paths downstream
- CAM table entry ages out on standby HSRP
- Without a CAM entry packet is flooded to all ports in the VLAN



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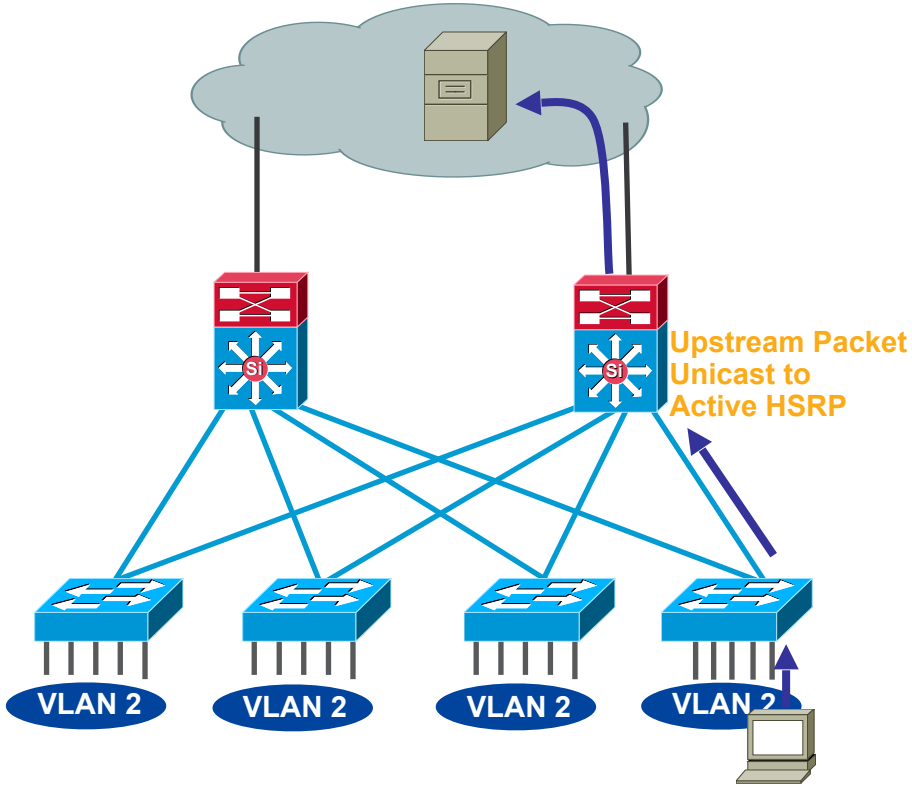

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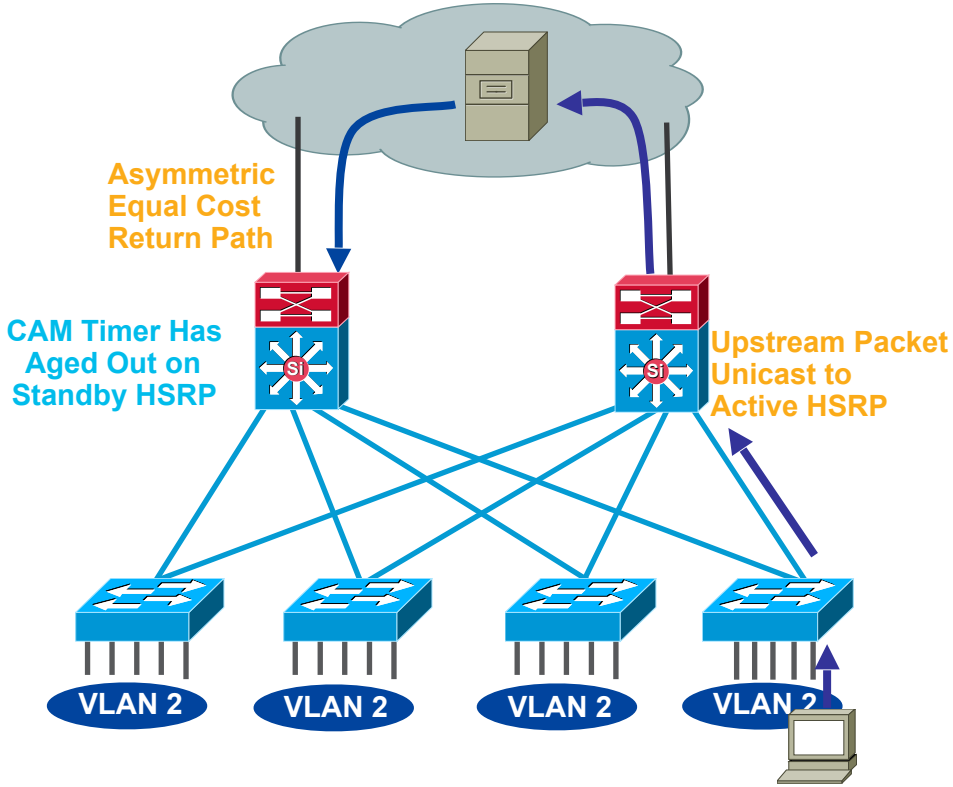
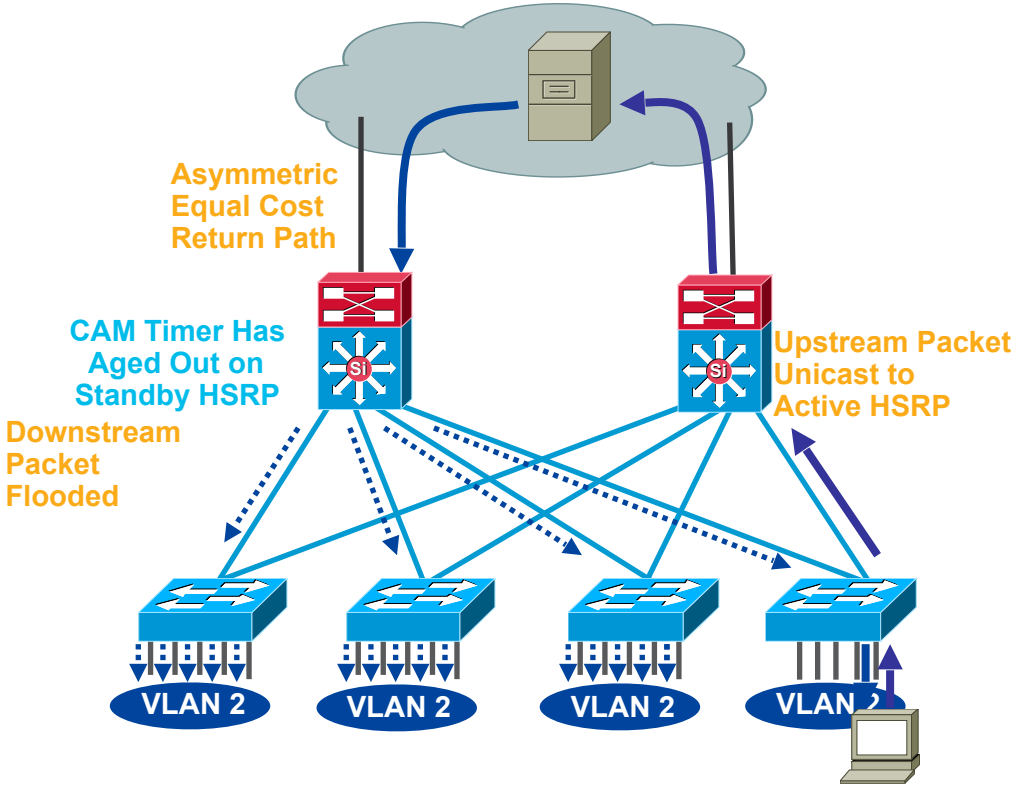


# Asymmetric Routing (Unicast Flooding)

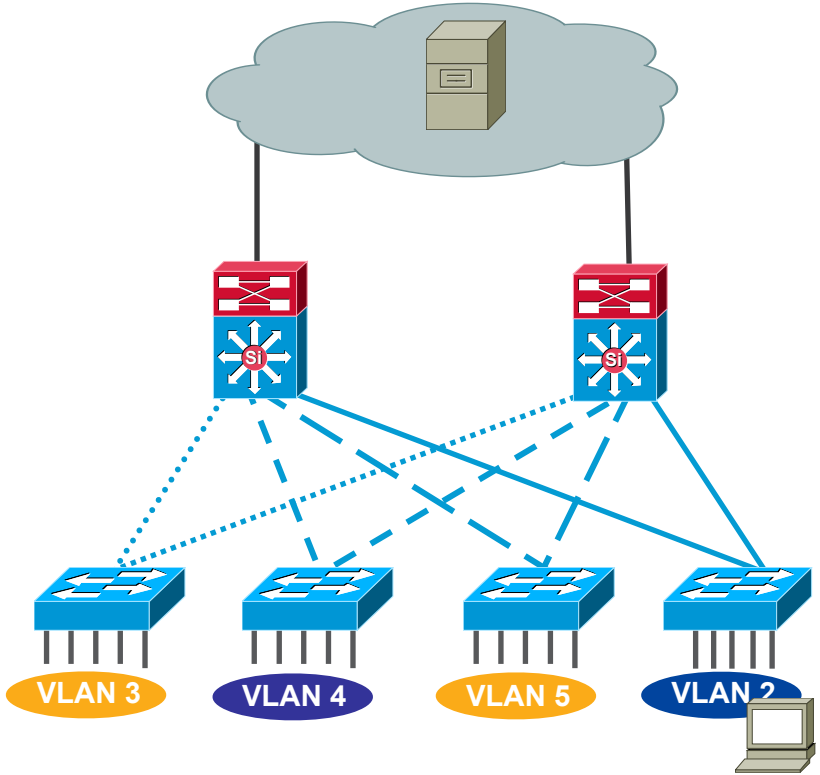
Affects redundant topologies with shared L2 access

- One path upstream and two paths downstream
- CAM table entry ages out on standby HSRP
- Without a CAM entry packet is flooded to all ports in the VLAN



# Best Practices Prevent Unicast Flooding

- Assign one unique data and voice VLAN to each access switch
- Traffic is now only flooded down one trunk
- Access switch unicasts correctly; no flooding to all ports
- If you have to:
  - Tune ARP and CAM aging timers; CAM timer exceeds ARP timer
  - Bias routing metrics to remove equal cost routes



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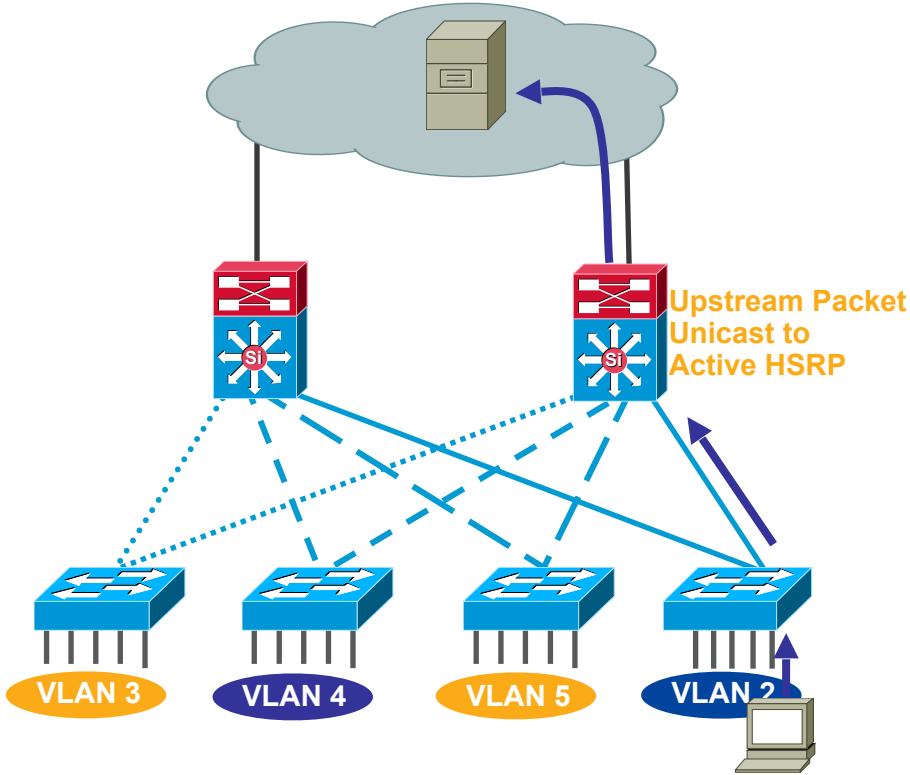

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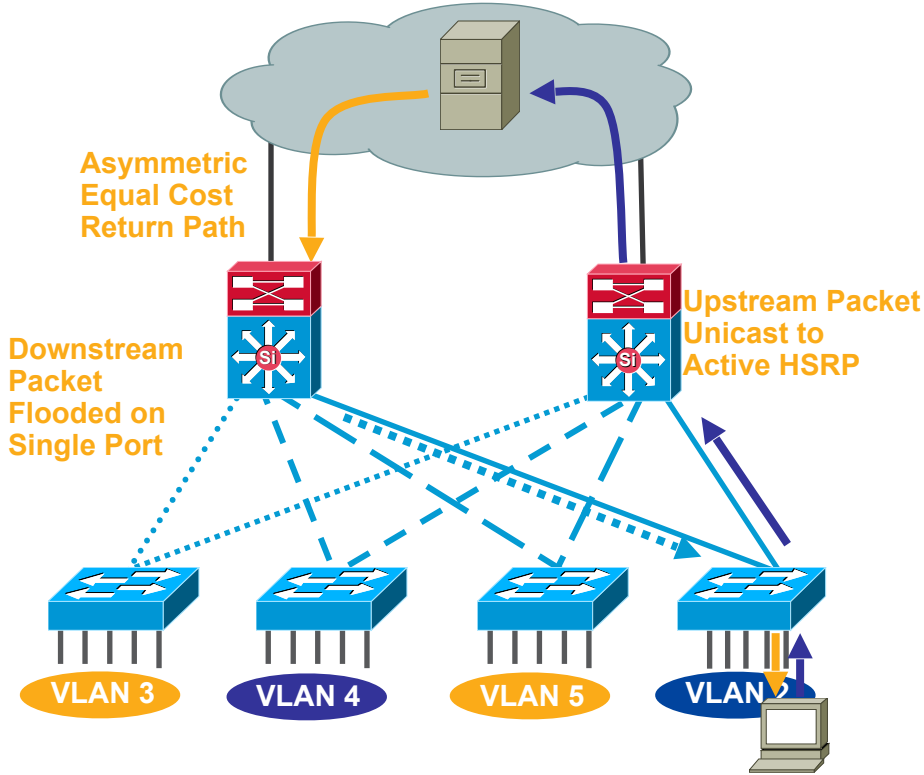
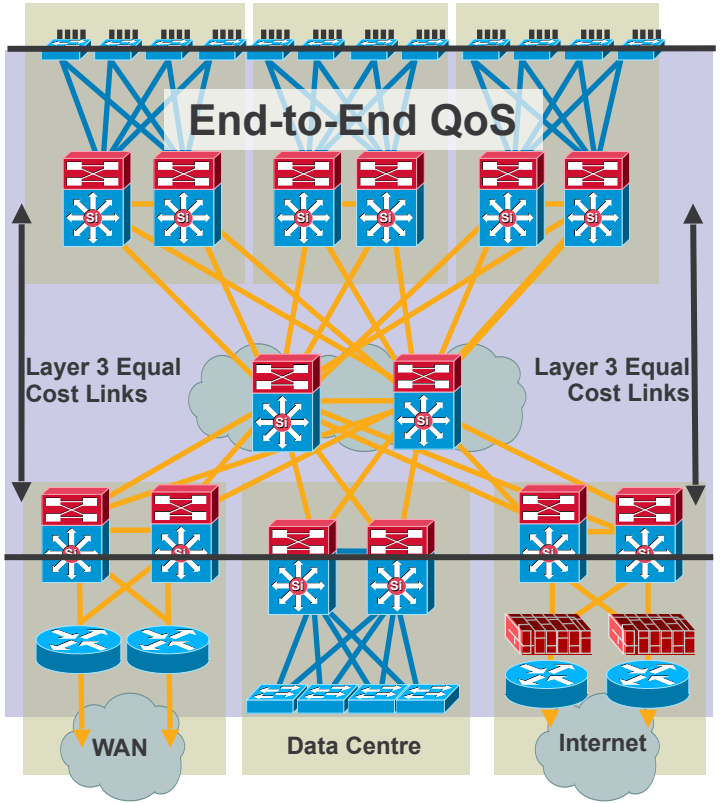


# Agenda

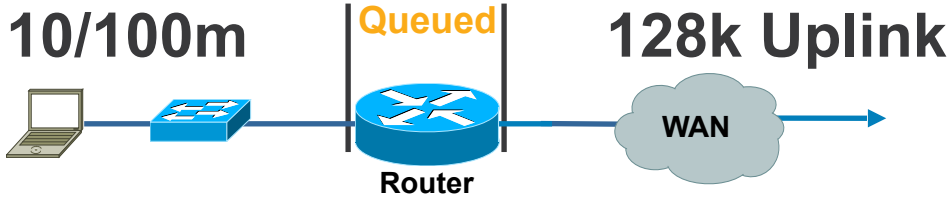
- Multilayer Campus Design Principles
- Foundation Services
- Campus Design Best Practices
- QoS Considerations
- Security Considerations
- Putting It All Together
- Summary

# Best Practices - Quality of Service

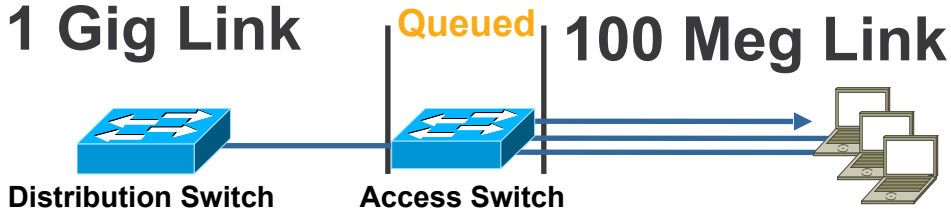
- Must be deployed end-to-end to be effective; all layers play different but equal roles
- Ensure that mission-critical applications are not impacted by link or transmit queue congestion
- Aggregation and rate transition points must enforce QoS policies
- Multiple queues with configurable admission criteria and scheduling are required



# Transmit Queue Congestion

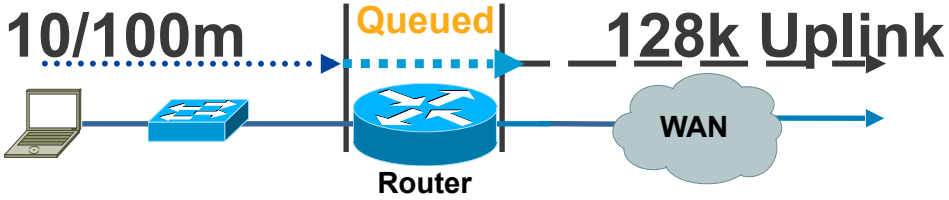



100 Meg in 128 Kb/S out—Packets Serialise in Faster than They Serialise Out
Packets Queued as They Wait to Serialise out Slower Link




1 Gig In 100 Meg out—Packets Serialise in Faster than They Serialise Out
Packets Queued as They Wait to Serialise out Slower Link

# Transmit Queue Congestion

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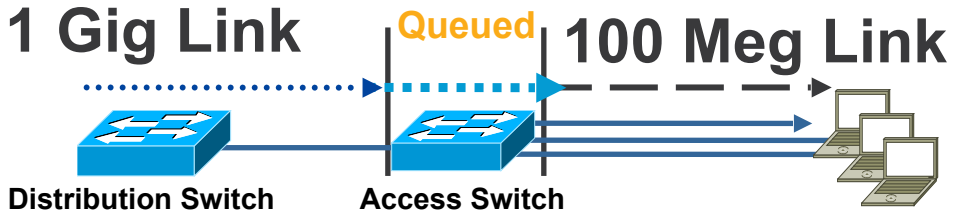


1 Gig In 100 Meg out—Packets Serialise in Faster than They Serialise Out
Packets Queued as They Wait to Serialise out Slower Link

# Auto QoS VoIP—Making It Easy …

## Configures QoS for VoIP on Campus Switches

```
Access-Switch(config-if)#auto qos voip ?
cisco-phone      Trust the QoS marking of Cisco IP Phone
cisco-softphone  Trust the QoS marking of Cisco IP SoftPhone
trust            Trust the DSCP/CoS marking

Access-Switch(config-if)#auto qos voip cisco-phone
Access-Switch(config-if)#exit
```

```
!
interface FastEthernet1/0/21
srr-queue bandwidth share 10 10 60 20
srr-queue bandwidth shape  10   0   0   0
mls qos trust device cisco-phone
mls qos trust cos
auto qos voip cisco-phone
end
```

# New:  DNA-C QoS Automation with EasyQoS

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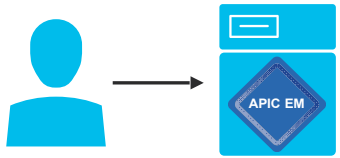
Network Operators express high-level business-intent to APIC-EM EasyQoS



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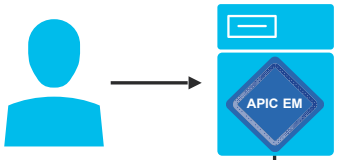
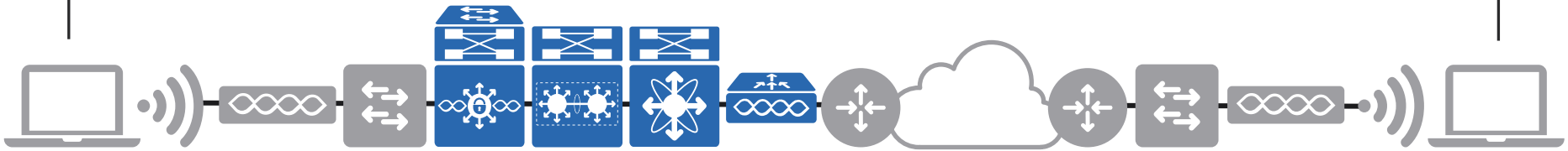


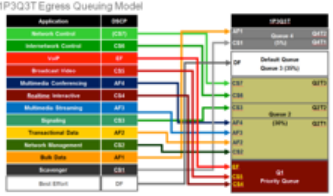

Southbound APIs translate business-intent to platform-specific configurations

**STATIC QoS**



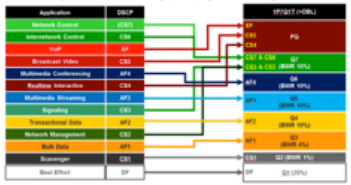
Catalyst 2960-X

1P3Q3T Egress Queuing Model



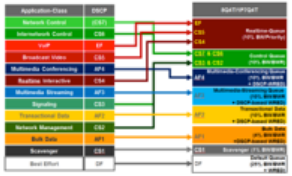
Catalyst 4500

1P7Q1T+Dynamic Buffer Limiting (DBL) Egress Queuing Model



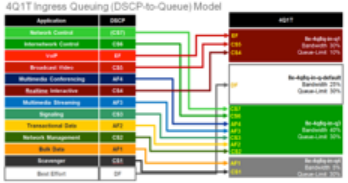
Cisco Catalyst 6500/6800

8Q4T Ingress & 1P7Q4T Egress Queuing Models (6908-10GE)



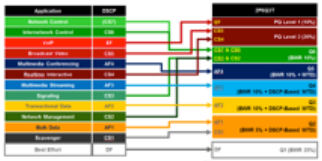
Cisco Nexus 7700 (F3)

4Q1T Ingress Queuing (DSCP-to-Queue) Model



Catalyst 3650/3850

2P6Q3T with Weighted Tail Drop (WTD) Wired Port Egress Queuing Model



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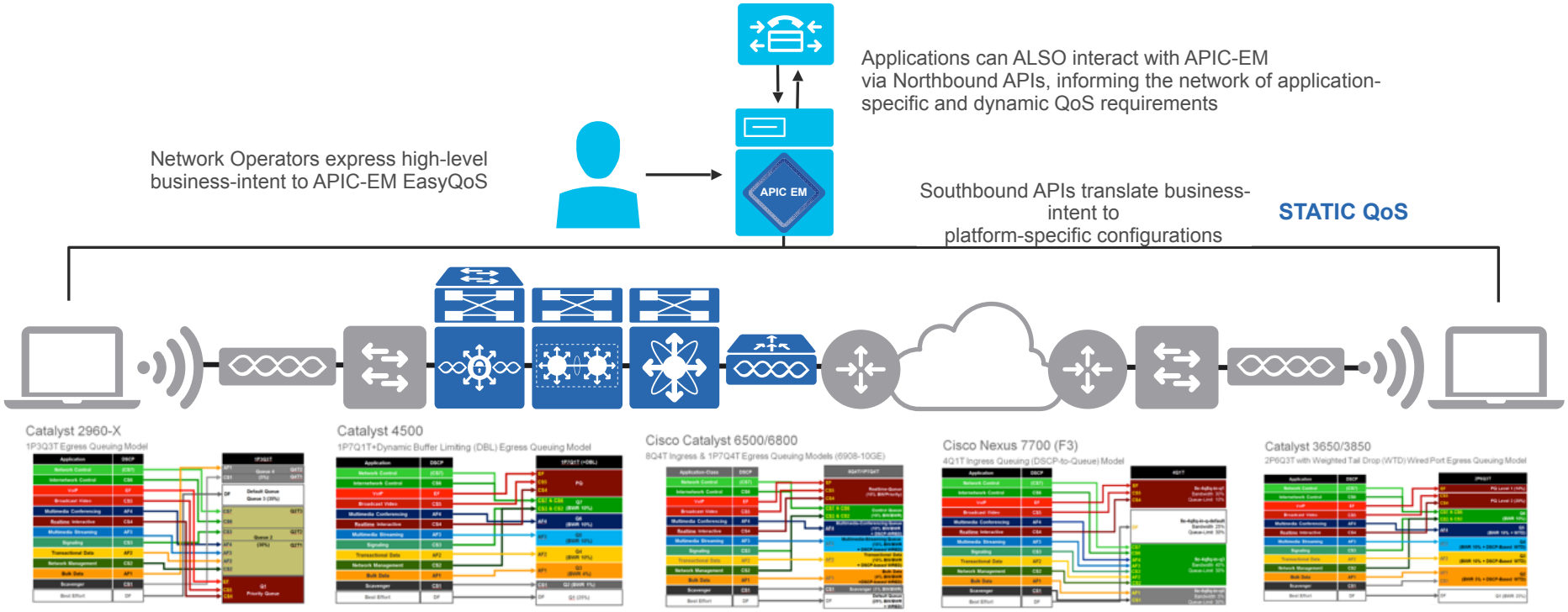

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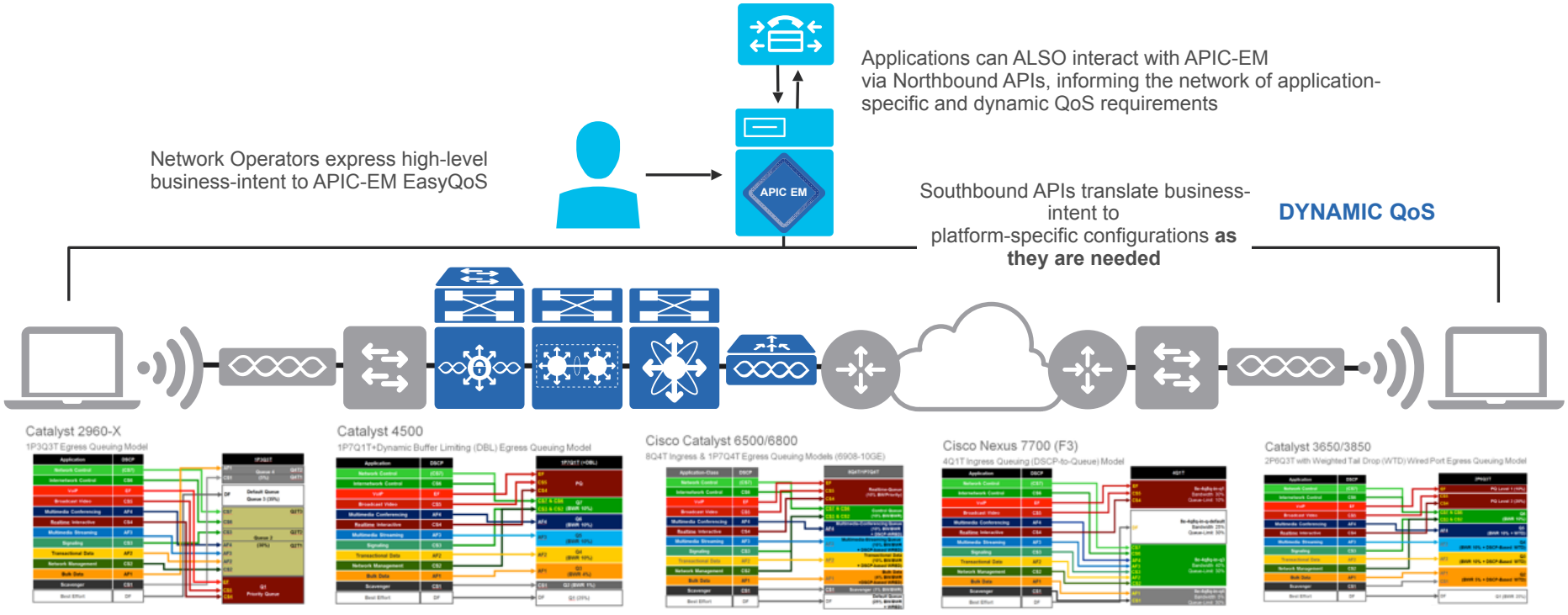

# Agenda

- Multilayer Campus Design Principles
- Foundation Services
- Campus Design Best Practices
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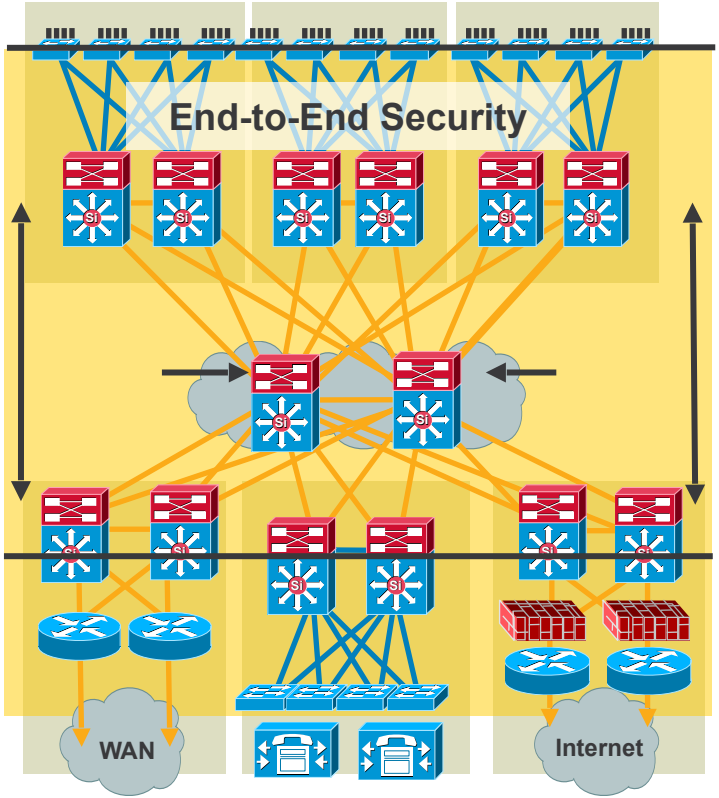
# Best Practices - Campus Security

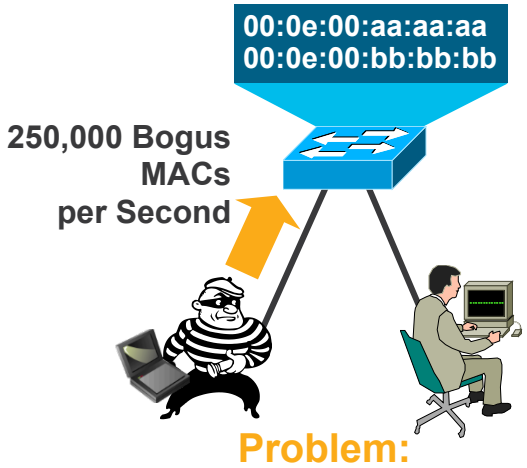
- CISF
  - Dynamic port security
  - DHCP snooping,
  - Dynamic ARP inspection
  - IP source guard




For More Details, See BRKSEC-2002 Session, Understanding and Preventing Layer 2 Attacks

# Securing Layer 2 from Surveillance Attacks

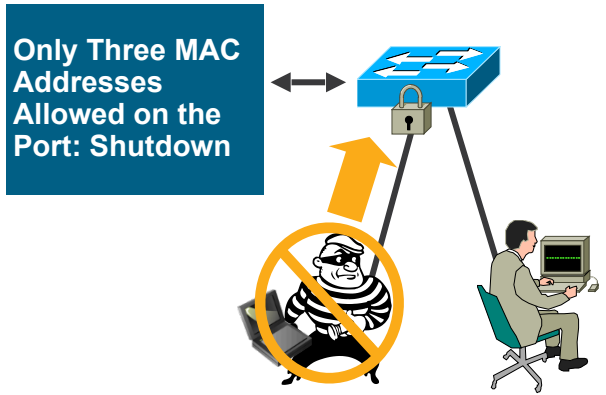
## Cutting Off MAC-Based Attacks




**Problem:**

Script Kiddie Hacking Tools Enable Attackers Flood Switch CAM Tables with Bogus Macs; Turning the VLAN into a Hub and Eliminating Privacy

Switch CAM Table Limit Is Finite Number of Mac Addresses



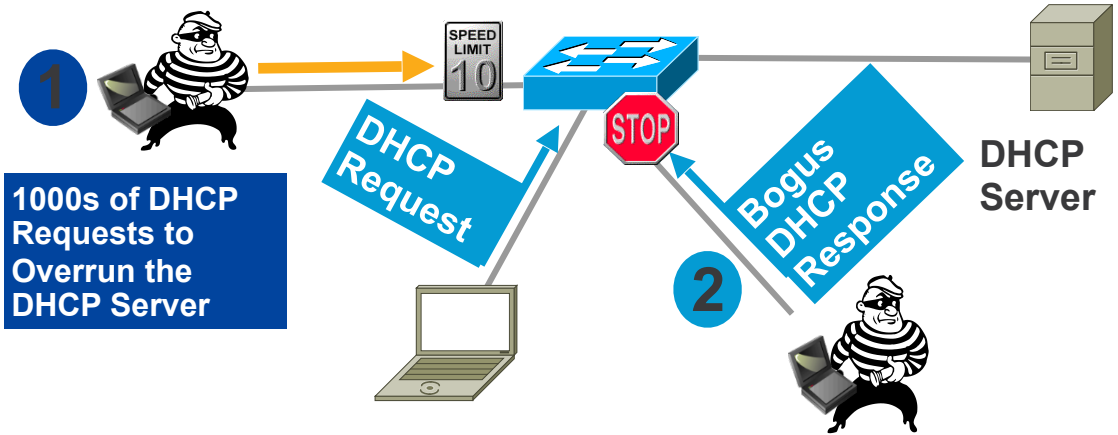

**Solution:**

Port Security Limits MAC Flooding Attack and Locks Down Port and Sends an SNMP Trap

```
switchport port-security
switchport port-security maximum 100
switchport port-security violation restrict
switchport port-security aging time 2
switchport port-security aging type inactivity
```

# DHCP Snooping

## Protection Against Rogue/Malicious DHCP Server




- DHCP requests (discover) and responses (offer) tracked
- Rate-limit requests on trusted interfaces; limits DoS attacks on DHCP server
- Deny responses (offers) on non trusted interfaces; stop malicious or errant DHCP server

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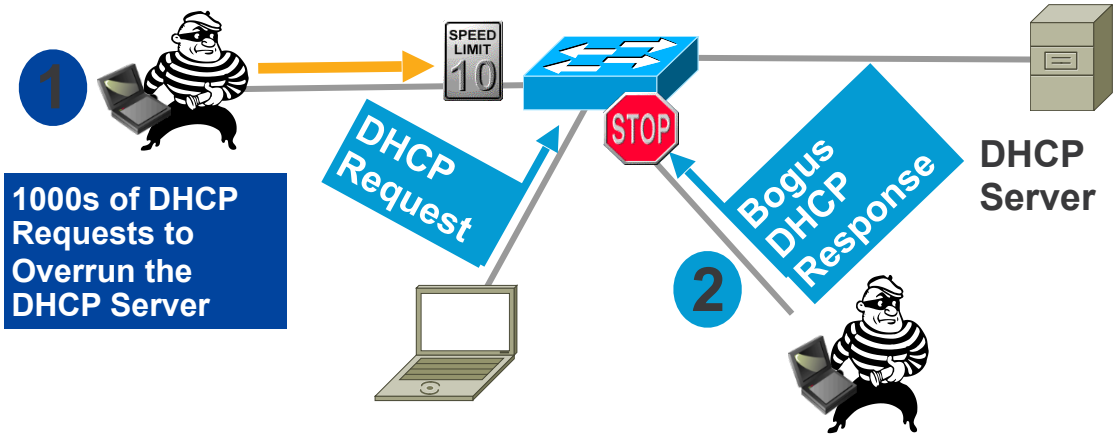


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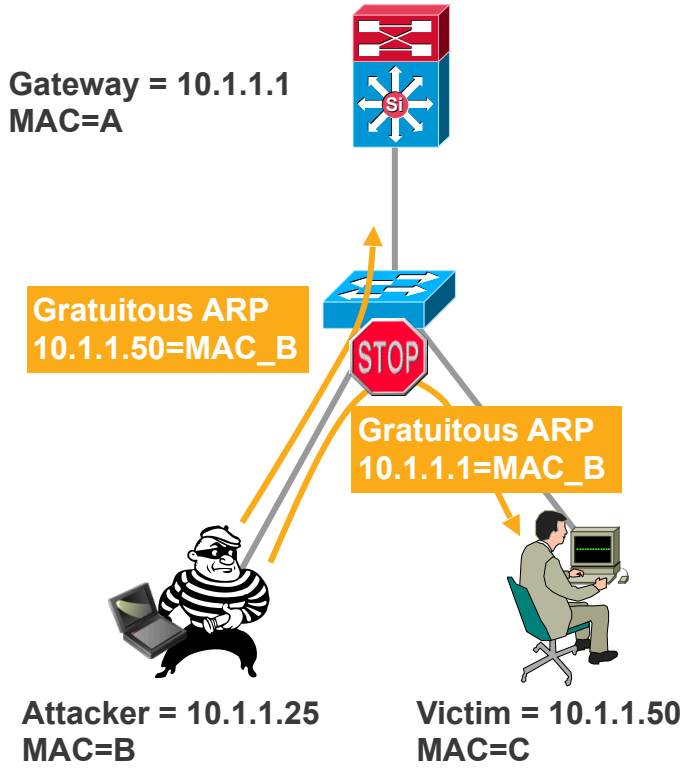
# Securing Layer 2 from Surveillance Attacks

## Protection Against ARP Poisoning

- Dynamic ARP inspection protects against ARP poisoning (ettercap, dsnif, arpspoof)
- Uses the DHCP snooping binding table
- Tracks MAC to IP from DHCP transactions
- Rate-limits ARP requests from client ports; stop port scanning
- Drop bogus gratuitous ARPs; stop ARP poisoning/MIM attacks



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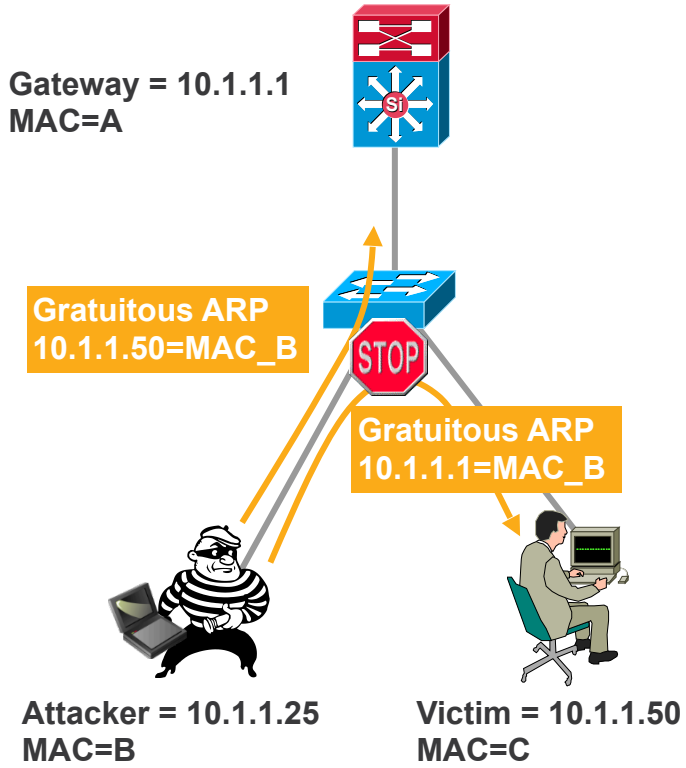
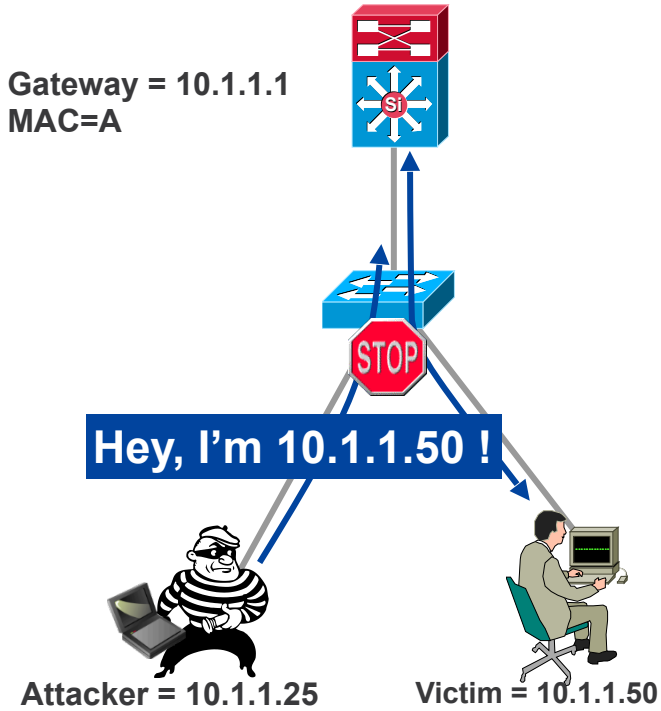


# IP Source Guard

## Protection Against Spoofed IP Addresses

- IP source guard protects against spoofed IP addresses
- Uses the DHCP snooping binding table
- Tracks IP address to port associations
- Dynamically programs port ACL to drop traffic not originating from IP address assigned via DHCP



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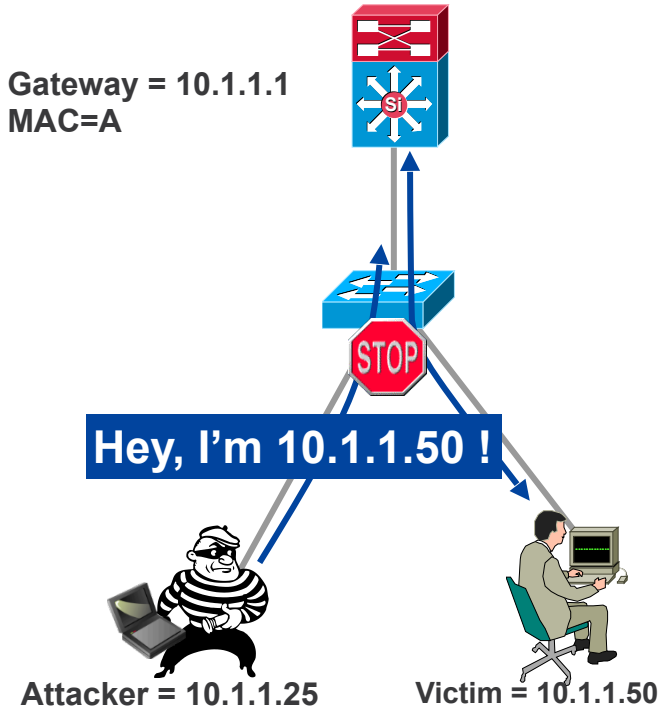
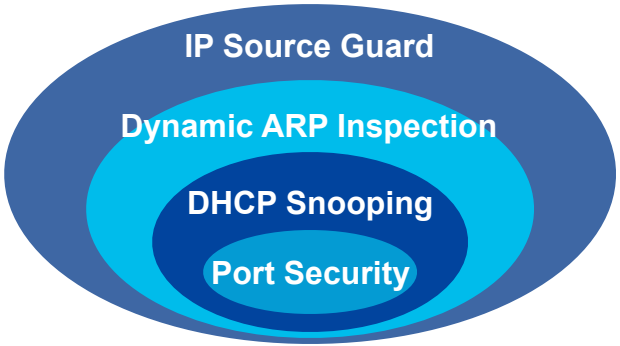


# Catalyst Integrated Security Features

## Summary Cisco IOS




- Port security prevents MAC flooding attacks
- DHCP snooping prevents client attack on the switch and server
- Dynamic ARP Inspection adds security to ARP using DHCP snooping table
- IP source guard adds security to IP source address using DHCP snooping table

```
ip dhcp snooping
ip dhcp snooping vlan 2-10
ip arp inspection vlan 2-10
!
interface fa3/1
switchport port-security
switchport port-security max 3
switchport port-security violation
restrict
switchport port-security aging time 2
switchport port-security aging type
inactivity
ip arp inspection limit rate 100
ip dhcp snooping limit rate 100
ip verify source vlandhcp-snooping
!
Interface gigabit1/1
ip dhcp snooping trust
ip arp inspection trust
```

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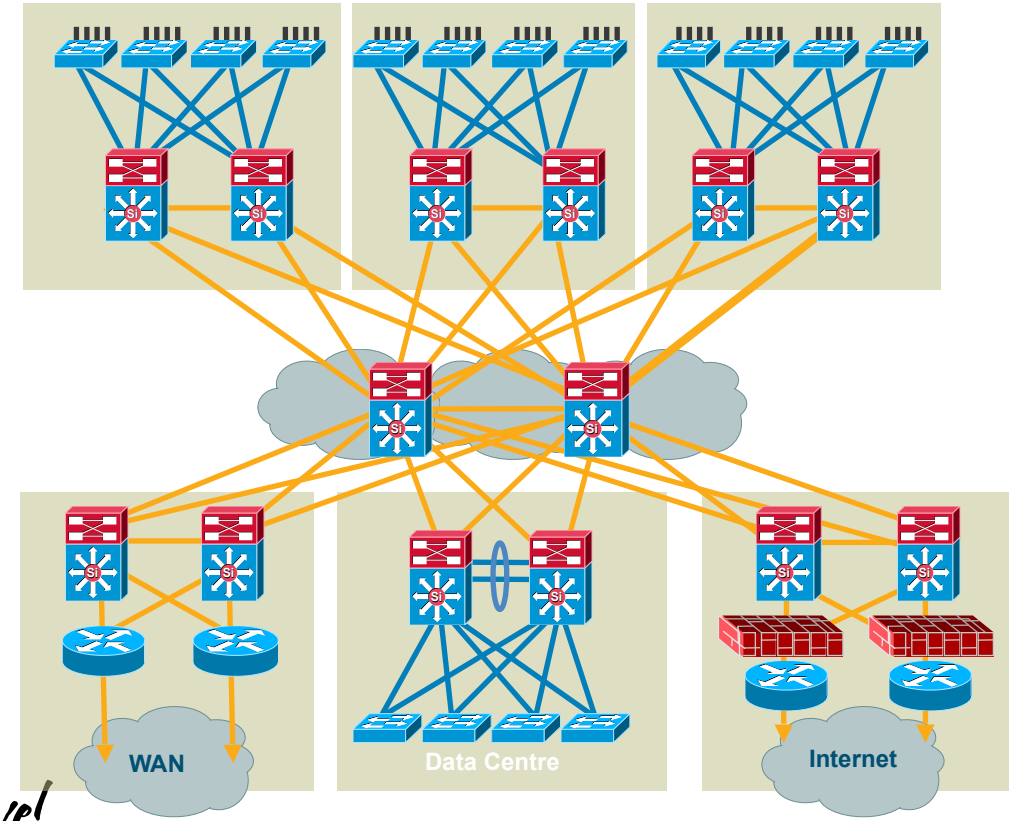
# Hierarchical Campus




Access

Distribution

Core

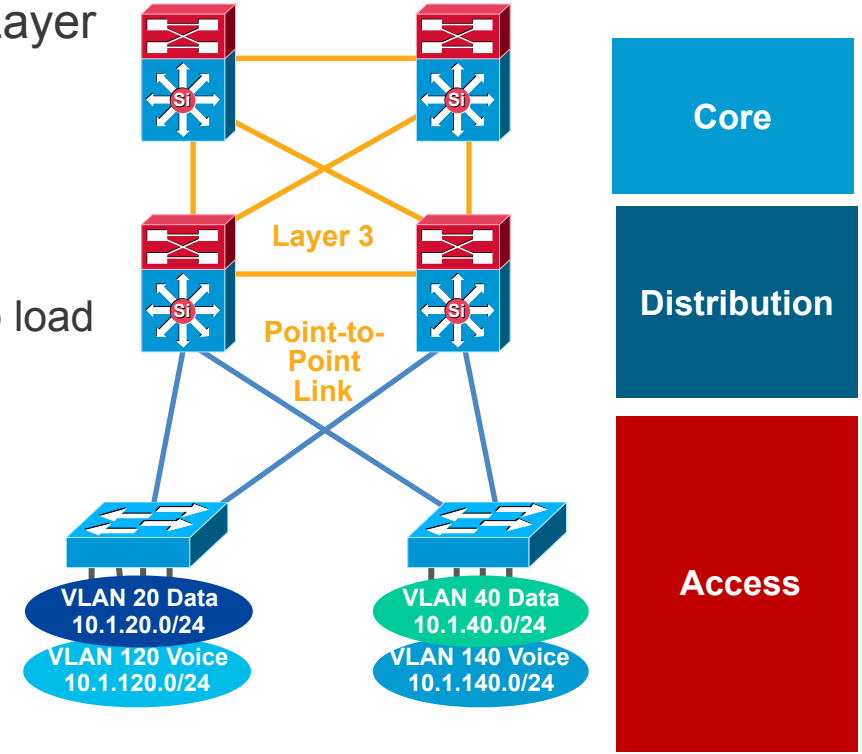
Distribution

Access

# Layer 3 Distribution Interconnection

## Layer 2 Access—No VLANs Span Access Layer

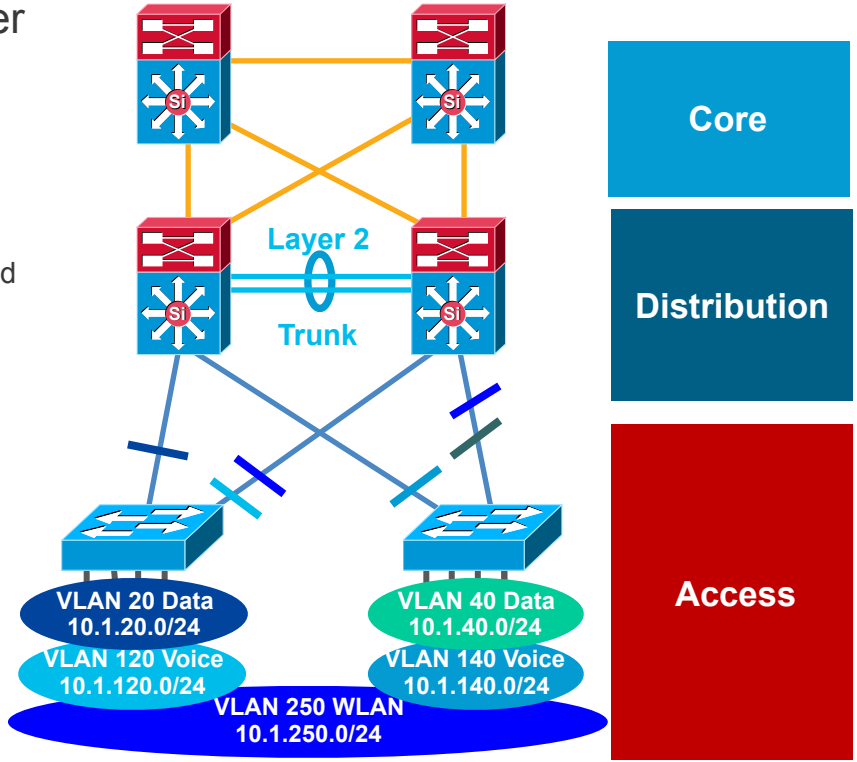
- Tune CEF load balancing
- Summarise routes towards core
- Limit redundant IGP peering
- STP Root and HSRP primary tuning or GLBP to load balance on uplinks
- Set trunk mode on/no-negotiate
- Disable Ether Channel unless needed
- Set port host on access layer ports:
  - Disable trunking
    Disable Ether Channel
    Enable PortFast
- RootGuard or BPDU-Guard
- Use security features



# Layer 2 Distribution Interconnection

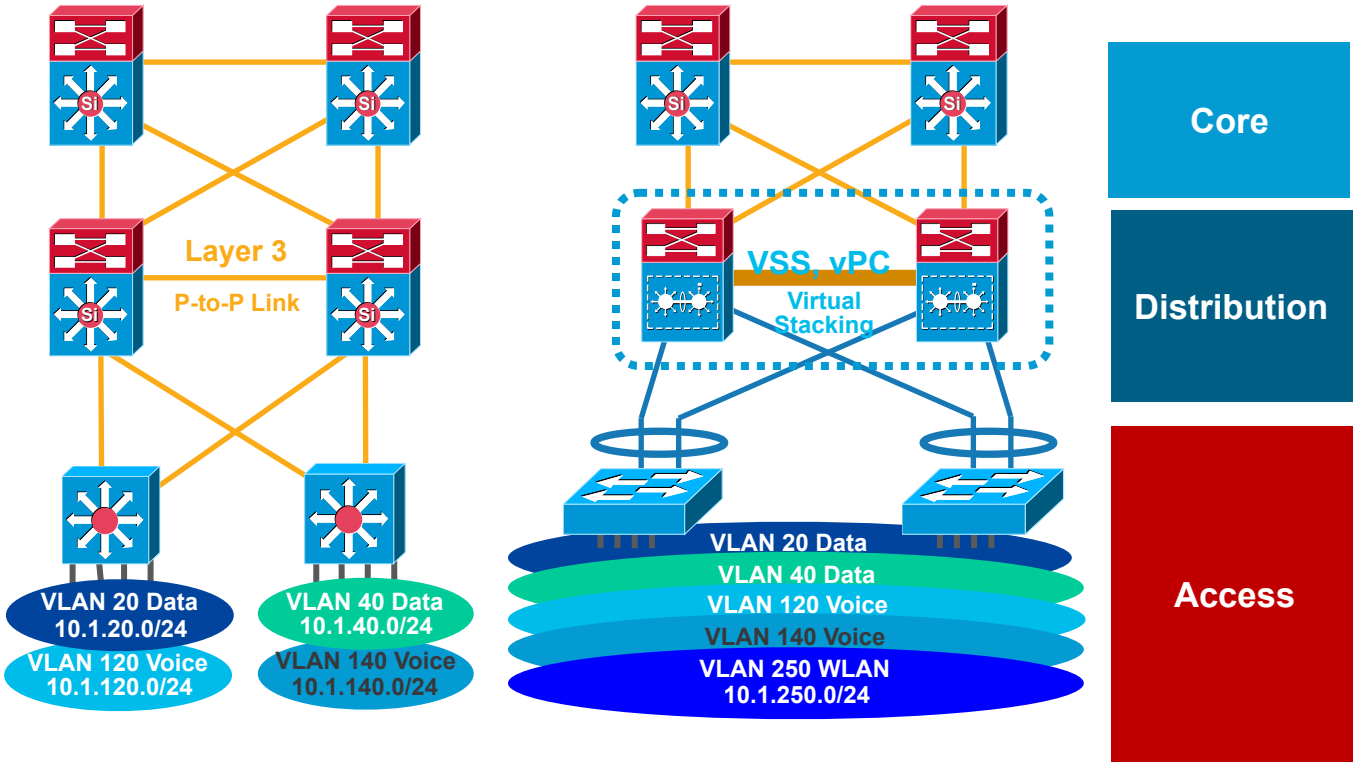
## Layer 2 Access - Some VLANs Span Access Layer

- Tune CEF load balancing
- Summarise routes towards core
- Limit redundant IGP peering
- STP Root and HSRP primary or GLBP and STP port cost tuning to load balance on uplinks
- Set trunk mode on/no-negotiate
- Disable Ether Channel unless needed
- RootGuard on downlinks
- LoopGuard on uplinks
- Set port host on access Layer ports:
  - Disable trunking
    Disable Ether Channel
    Enable PortFast
- RootGuard or BPDU-Guard
- Use security features



# Routed Access and Virtual Switching System

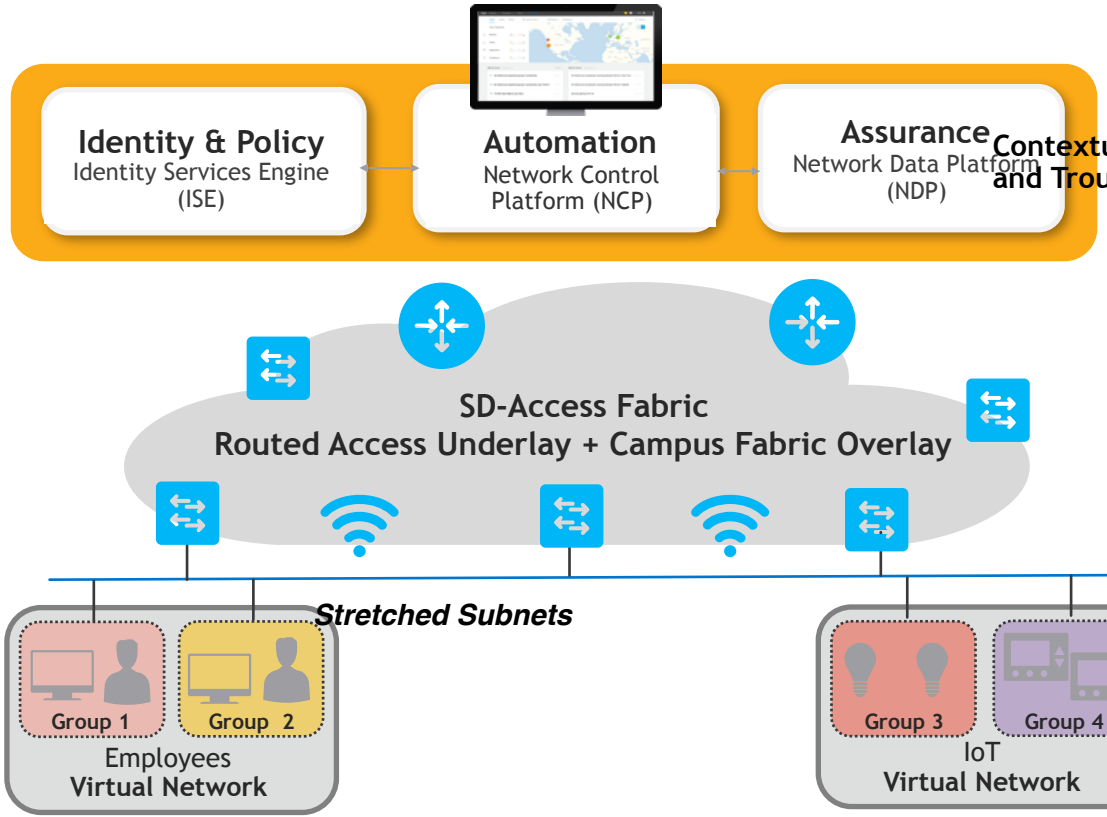
## Evolutions of and Improvements to Existing Designs



# Deploy DNA-C & SD-Access

## Architecture for the Digital Enterprise

**Policy Mobility with no Topology Dependence**



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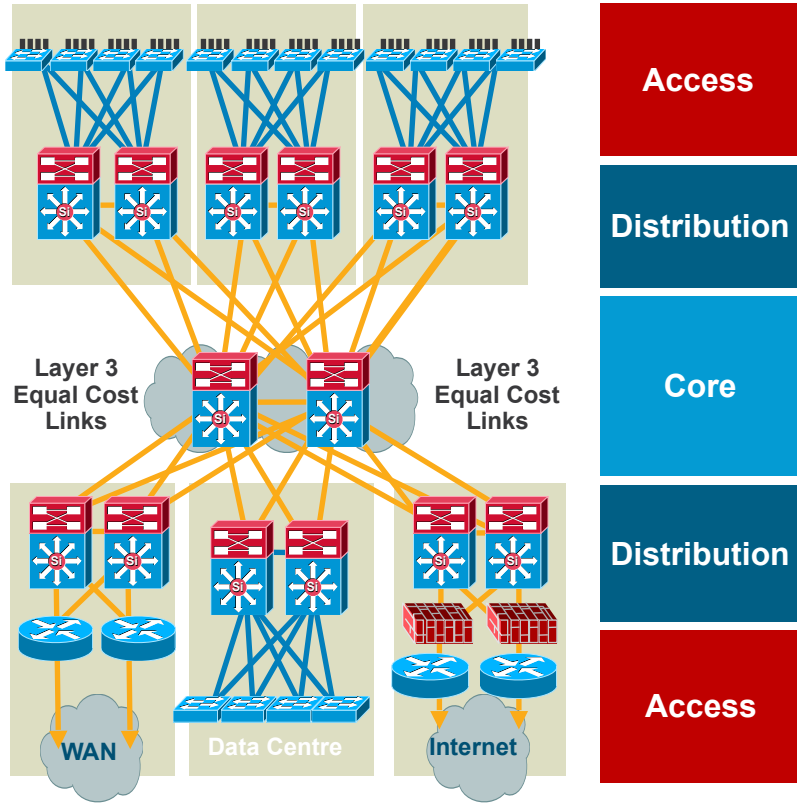
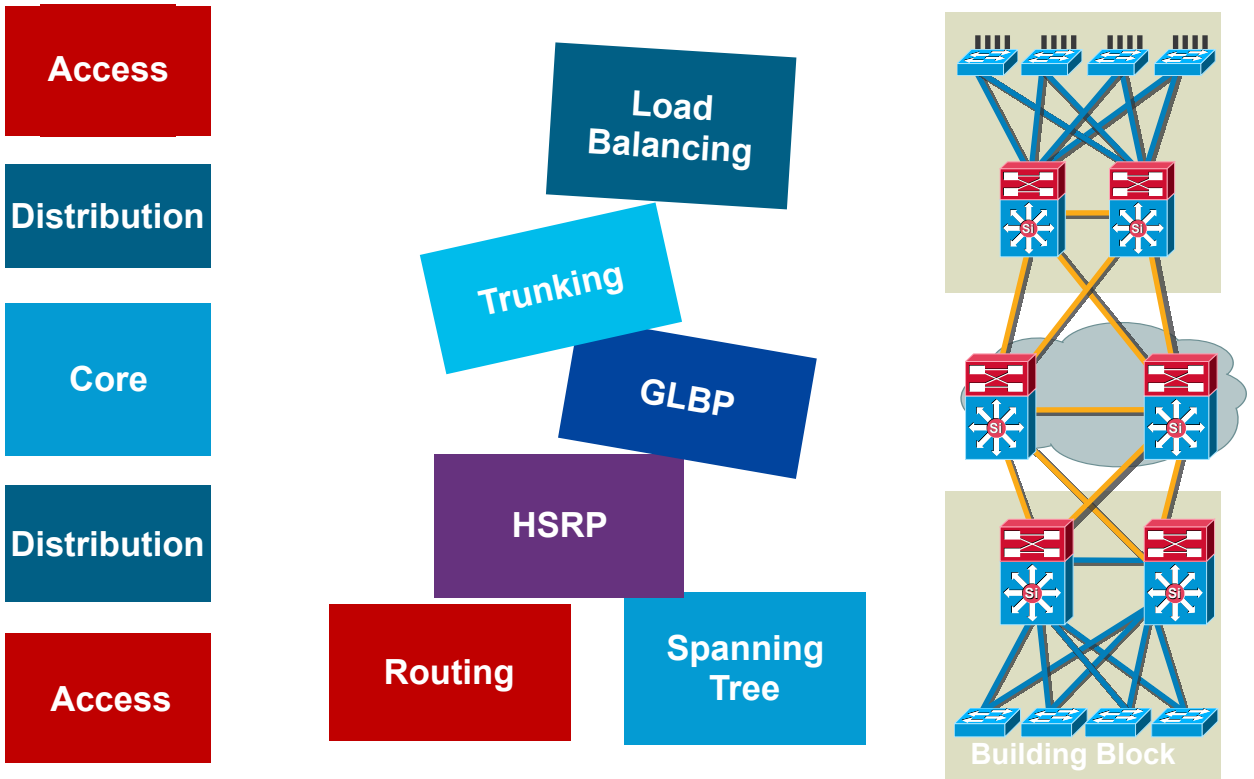
# Summary

- Offers hierarchy—each layer has specific role
- Modular topology—building blocks
- Easy to grow, understand, and troubleshoot
- Creates small fault domains— clear demarcations and isolation
- Promotes load balancing and redundancy
- Promotes deterministic traffic patterns
- Incorporates balance of both Layer 2 and Layer 3 technology, leveraging the strength of both
- Utilises Layer 3 routing for load balancing, fast convergence, scalability, and control

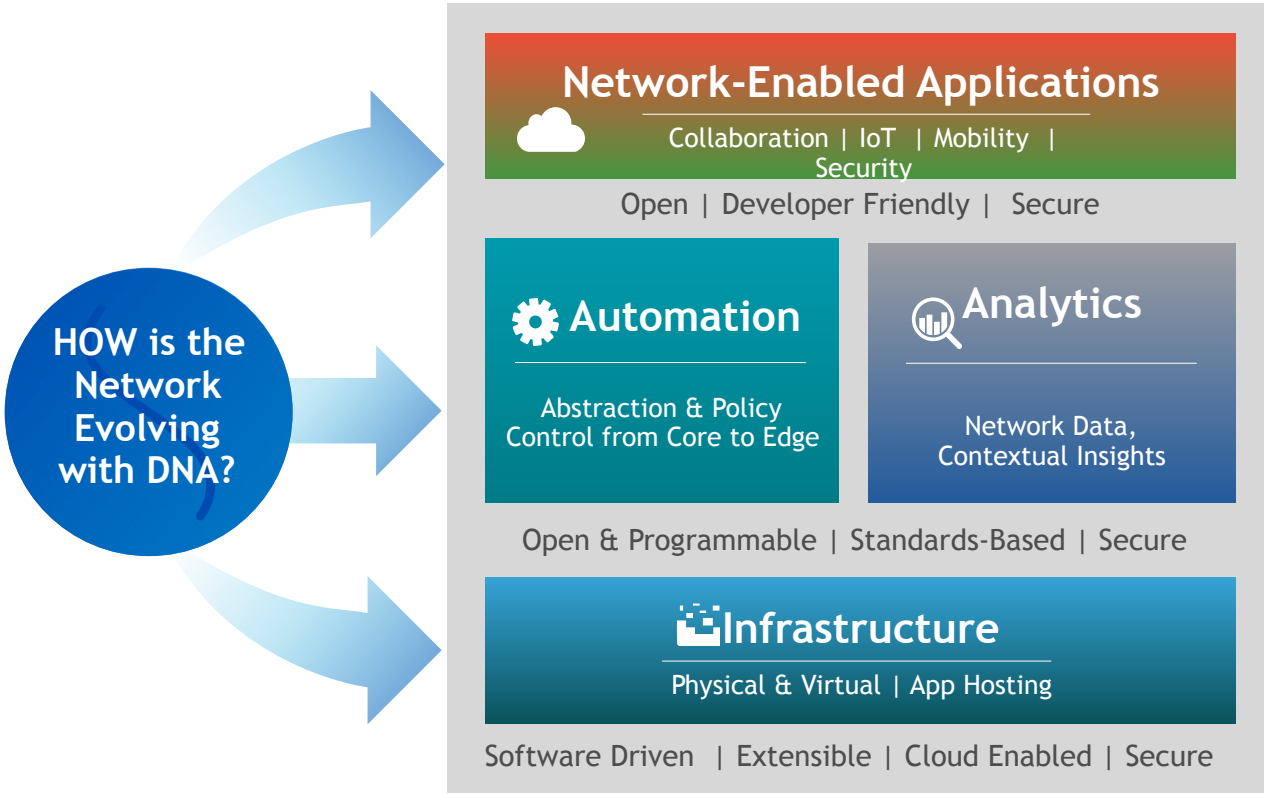


# Hierarchical Network Design

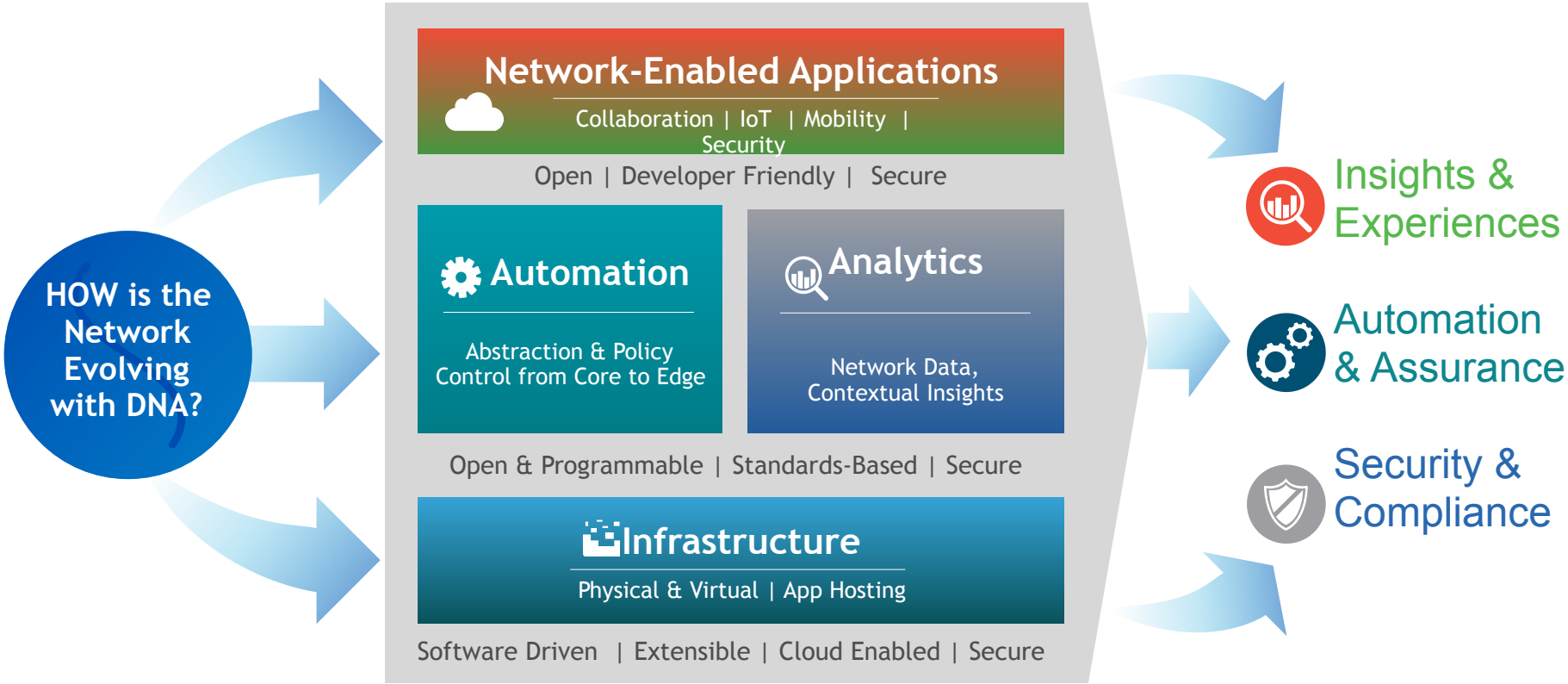
## Without a Rock Solid Foundation the Rest Doesn't Matter



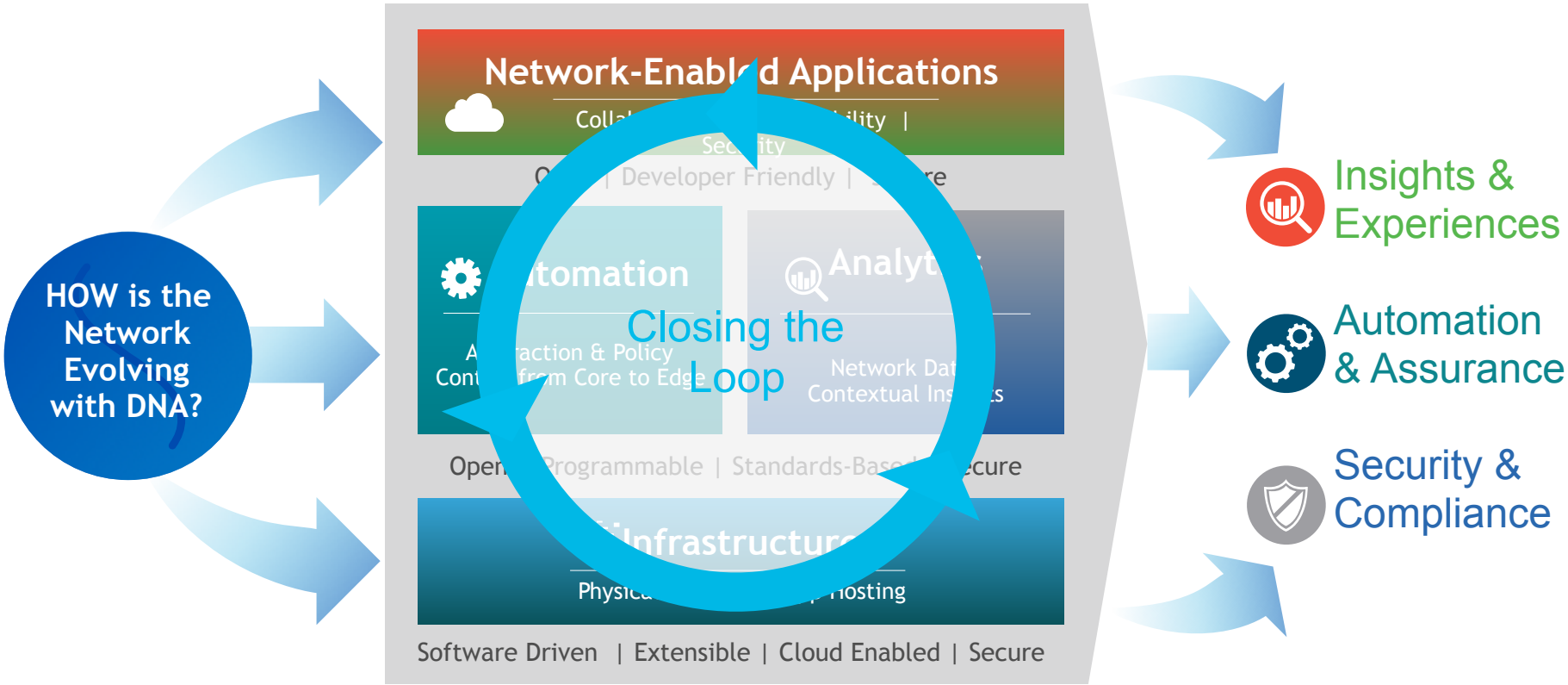
# Cisco Digital Network Architecture



# Cisco Digital Network Architecture



# Cisco Digital Network Architecture



# Q & A

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