Chapter 4

Enterprise and Campus Network Design

Overview

- An emerging enterprise should be
  - efficient
  - highly available
  - scalable
  - manageable

- It includes descriptions of various topologies, routing protocols, configuration guidelines, and other considerations relevant to the design of highly available and reliable campus networks.

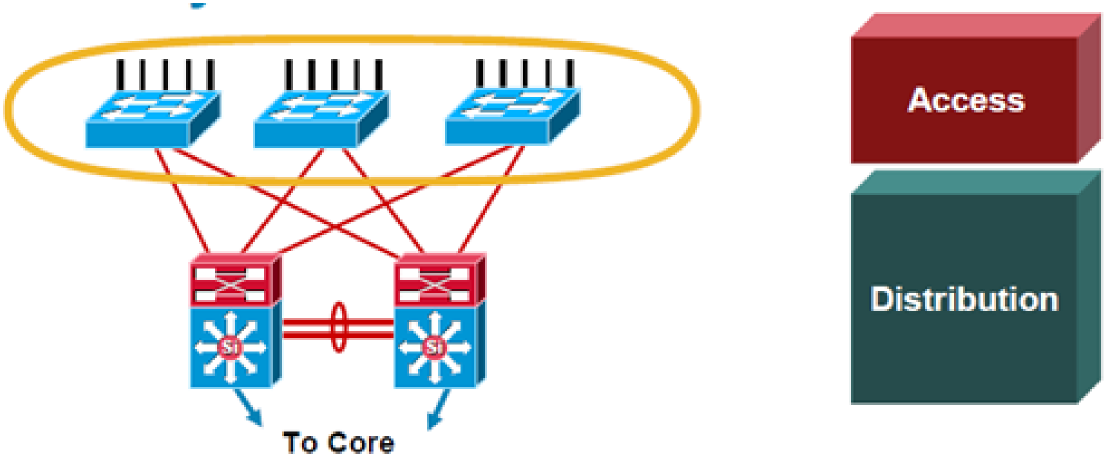
High Availability in the Enterprise Campus

- Hierarchical network model
  - supports designing a highly available modular topology using scalable building blocks that allow the network to meet evolving business needs.
- It makes the network easy to **scale**, **understand**, and **troubleshoot** by promoting deterministic traffic patterns.
- **Objectives:**
  1. Describe the layers of the enterprise campus architecture
  2. Discuss high availability options in the enterprise campus

Enterprise Campus Infrastructure

Note Three layers: access layer, distribution layer, and core layer.

- The **access layer** is the point of entry into the network for end devices.



- Provides access and aggregation for users in a feature-rich environment
- Provides high availability through software attributes and redundancy
- Supports convergence for voice, wireless, and data
- Provides security services to help control network access
- Offers QoS services including traffic classification and queuing
- Supports IP multicast traffic for efficient network use

Access Layer

- Aggregates end users and provides uplinks to the distribution layer.

- The access layer can be a feature-rich environment:
  - **High availability**
  - **Convergence:** Supports inline **power over Ethernet (PoE)** for IP telephony and wireless access points, allowing customers to converge voice onto their data network and providing roaming WLAN access for users.
  - **Security:** Provides services for additional security against unauthorized access to the network.

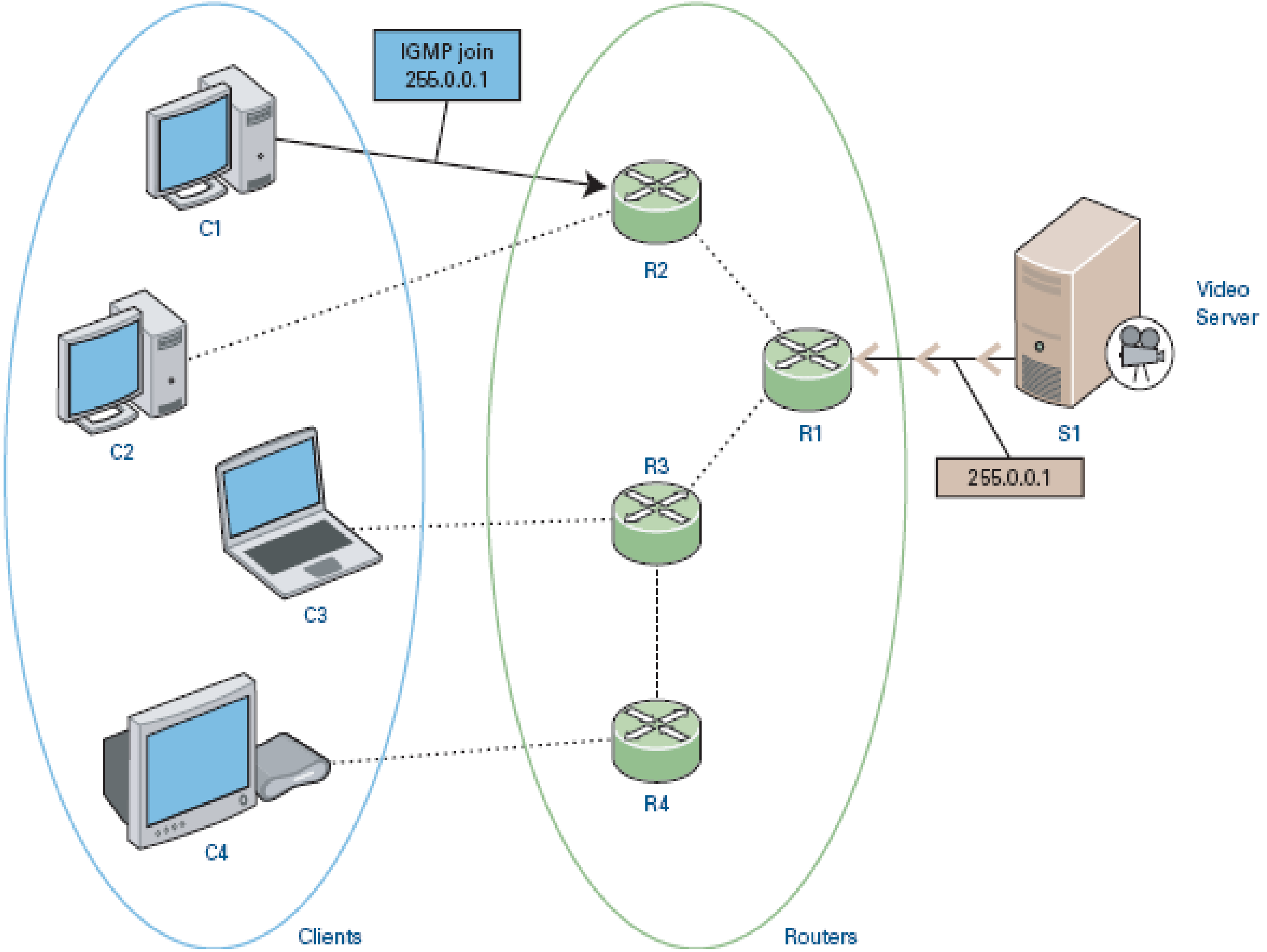
Access Layer

- **Quality of Service (QoS):** Allows prioritization of mission-critical network traffic using traffic classification and queuing as close to the ingress of the network as possible

- **IP multicast:** Supports efficient network and bandwidth management using software features such as Internet Group Management Protocol (IGMP) snooping.

IGMP Basics

Step 1



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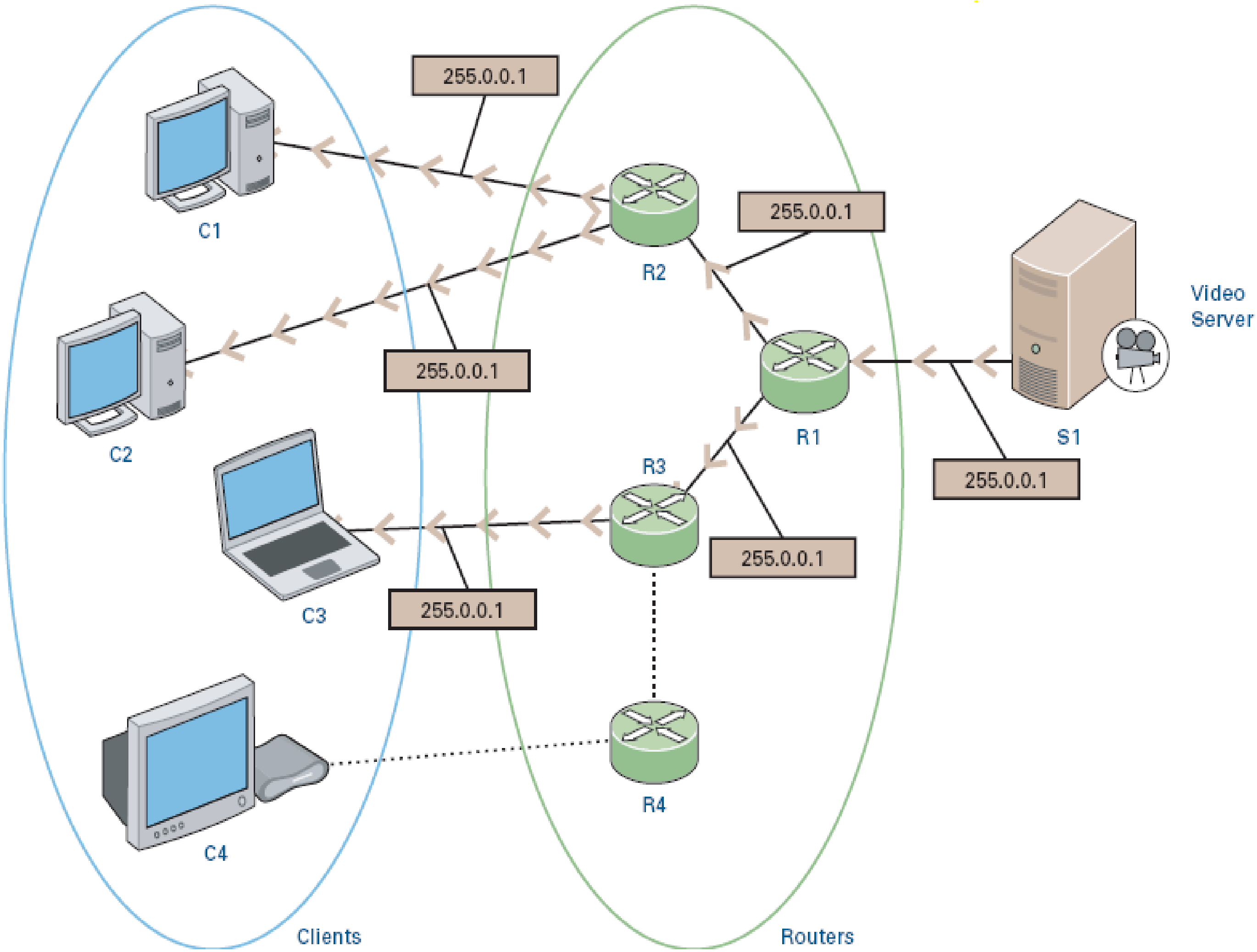
IGMP Basics

Step 2



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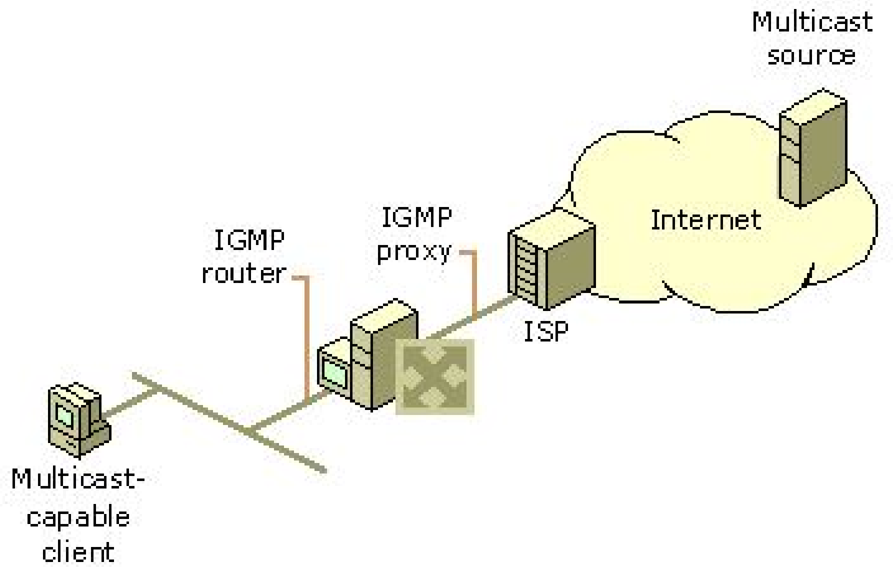
IGMP Versions

- IGMP v1
  - Membership query
  - Membership report
- IGMP v2
  - Membership query
  - V2 Membership report *(Fast Leave)*
  - Leave group
  - V1 Membership report
- IGMP v3
  - Membership query
  - V3 Membership report *(Explicit Host Tracking)*
  - V3 Leave group
  - V2 Membership report
  - V2 Leave group
  - V1 Membership report

Definitions

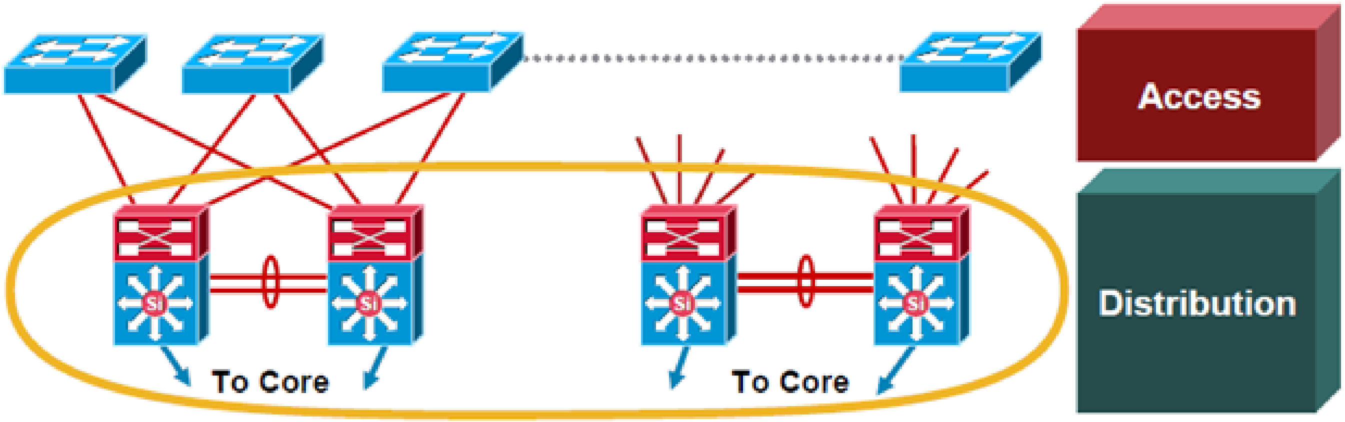
- IGMP Proxy
  - Terminates LAN side IGMP
  - Initiates IGMP on WAN side
  - Port-based bridge group



- IGMP Snooping
  - Layer 2 switch uses Layer 3 IP header for intelligent forwarding
  - No traffic is send on ports were no IGMP is required

Distribution Layer

- Aggregates nodes and uplinks from the access layer and provides policy-based connectivity.
- Availability, load balancing, QoS and provisioning are the important considerations at this layer.



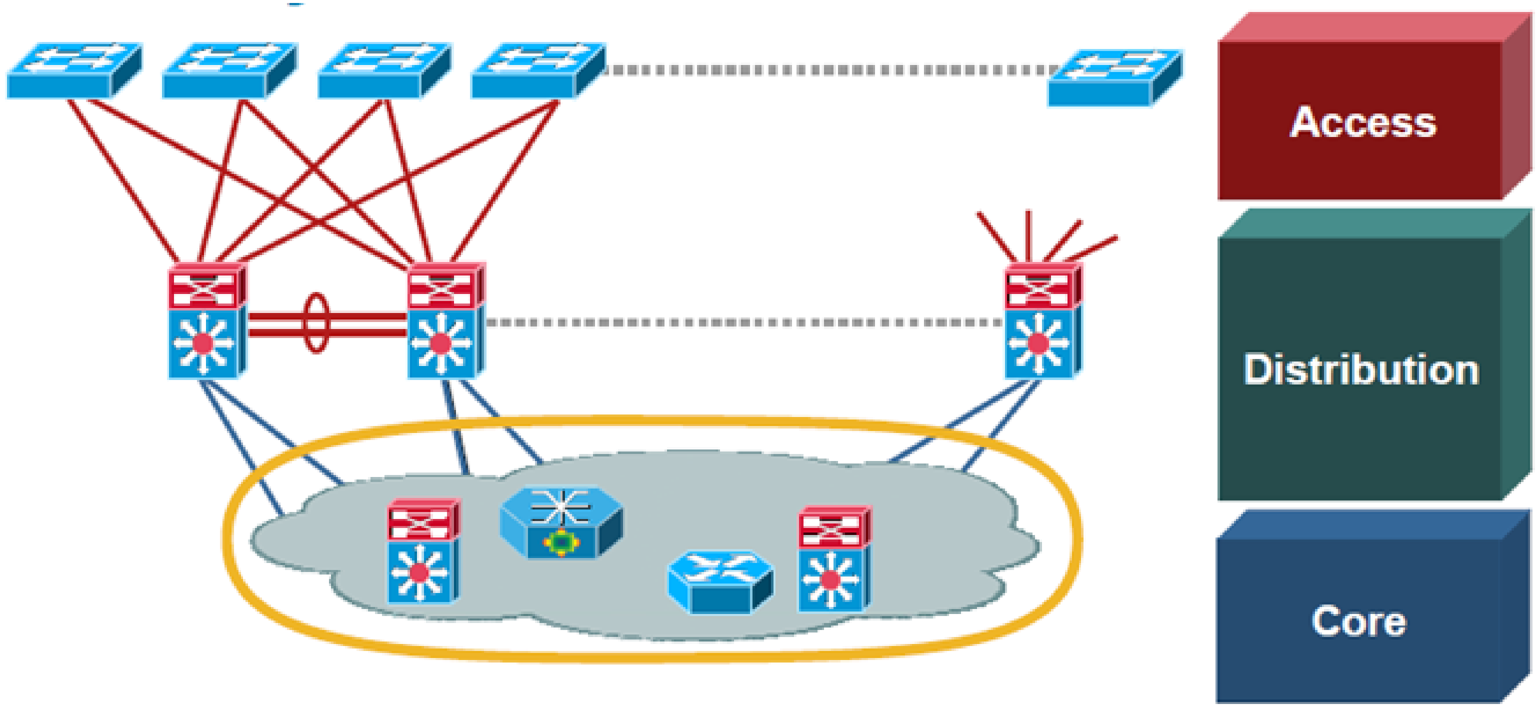
- Aggregates access nodes and uplinks
- Provides redundant connections and devices for high availability
- Offers routing services such as summarization, redistribution, and default gateways
- Implements policies including filtering, security, and QoS mechanisms
- Segments workgroups and isolates problems

Distribution Layer

- The distribution layer is the place where
  - **routing** and **packet manipulation** are performed
  - is a routing boundary between the access and core layers
- To further improve routing protocol performance, the distribution layer summarizes routes from the access layer.
- It uses a combination of Layer 2 and multilayer switching to segment workgroups and isolate network problems, preventing them from impacting the core layer.

Core Layer

- Provides scalability, high availability, and fast convergence to the network.



- High-speed backbone and aggregation point for the enterprise
- Provides reliability through redundancy and fast convergence
- Separate core layer helps in scalability during future growth

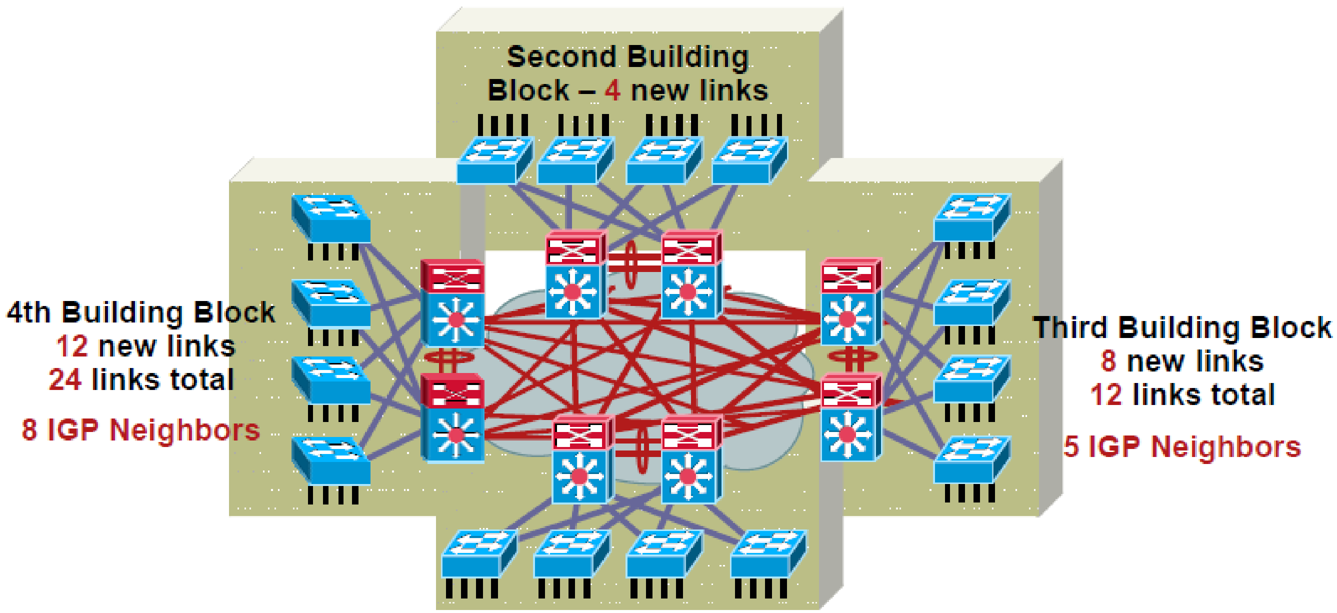
Core Layer

- It is the **backbone** and is the aggregation point the other layers and modules.
- A high-speed, Layer 3 switching environment utilizing hardware-accelerated services.
- The core devices must be able to implement
  - scalable protocols
  - alternate paths
  - load balancing

Is a Core Layer Needed?

- The core and distribution layer functions can be combined at the distribution layer for a smaller campus.

Is a Core Layer Needed?



Benefits of a campus core:

- Distribution layer switches are connected hierarchically
- Less physical cabling is required
- Less routing complexity is imposed

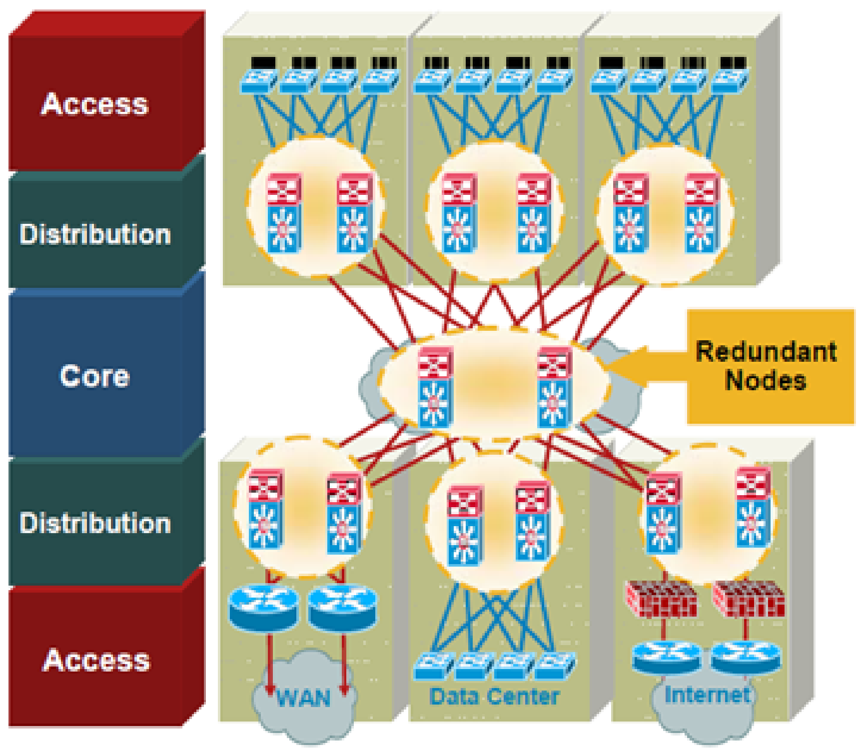
Is a Core Layer Needed?

- The distribution layer switches will need to be **fully meshed**.
- This design is difficult to scale, and increases the cabling requirements as new building distribution switch need full-mesh connectivity to all the distribution switches.
- The routing complexity of a full mesh design increases as new neighbors are added.
  - four additional links for full mesh connectivity to the first module.
  - require 8 additional links to support connections to all the distribution switches, or a total of 12 links

Implement Optimal Redundancy

- High availability is concerned with **minimizing link and node failures** and **optimizing recovery times** to minimize convergence and downtime.
- Access switches should have redundant connections to redundant distribution switches.

- Core and distribution have redundant switches and links
- Access has redundant links
- Network bandwidth and capacity can withstand single switch or link failure
- 120–200ms to converge around most events

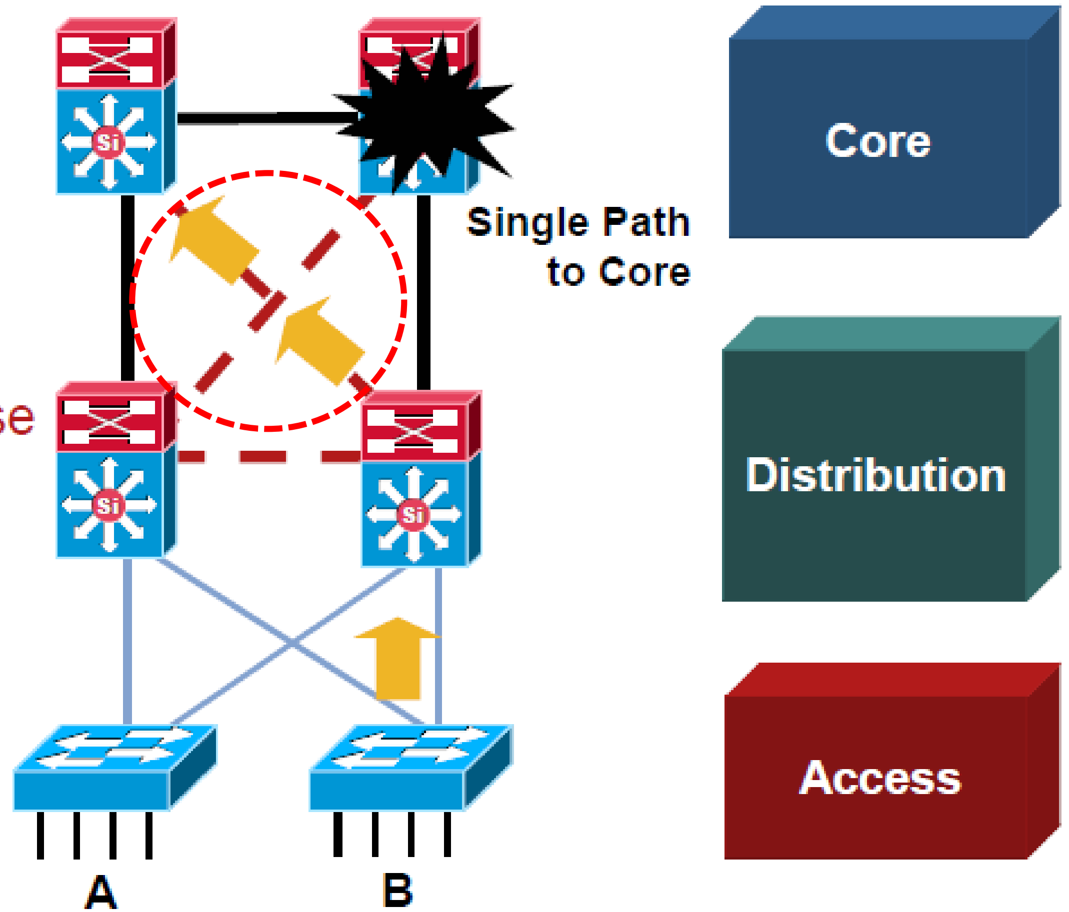


Implement Optimal Redundancy

- The core and distribution layers are built with redundant switches and fully meshed links to provide maximum redundancy and optimal convergence.
- Access switches should have redundant connections to redundant distribution switches.
- In a fully redundant topology, redundant supervisors with nonstop forwarding (NSF) and stateful switchover (SSO) may cause longer convergence time than single supervisors.
  - NSF/SSO are designed to maintain link up/Layer 3 up state during a convergence event.

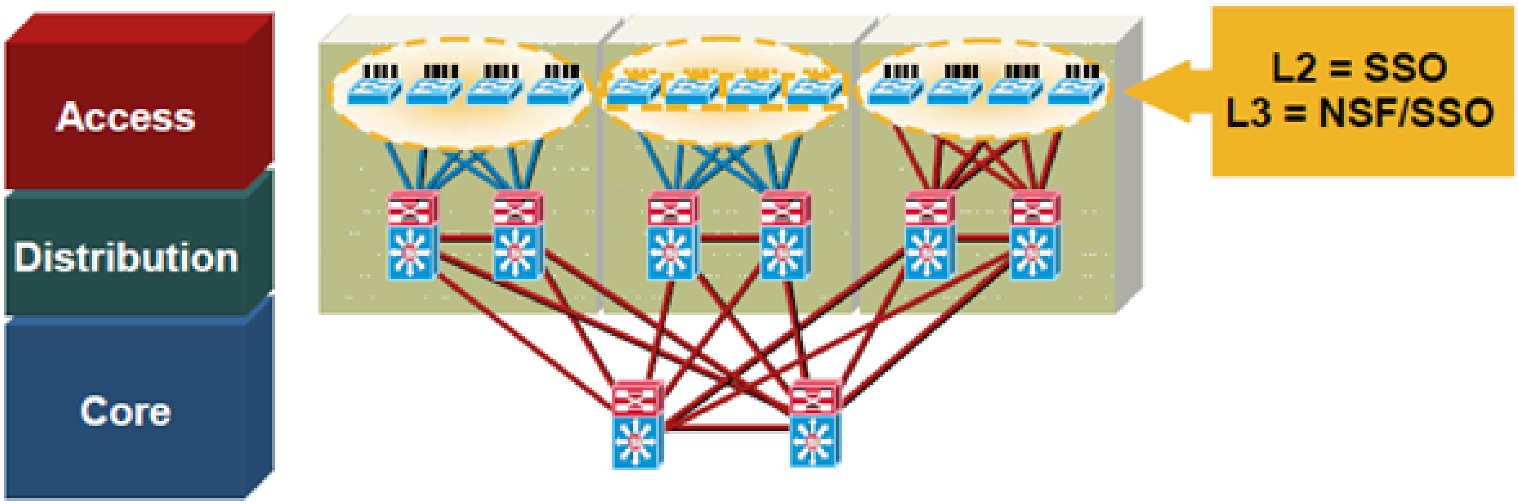
Provide Alternate Paths

- With single path to core, one failure causes traffic to be dropped.
- A redundant link to the core resolves this issue.
- Recommend practice: Use a redundant link to core with a Layer 3 link between distribution switches.



Avoid Single Points of Failure

- Nonstop forwarding with stateful switchover (NSF/SSO) and redundant supervisors have the most impact in the campus in the access layer.

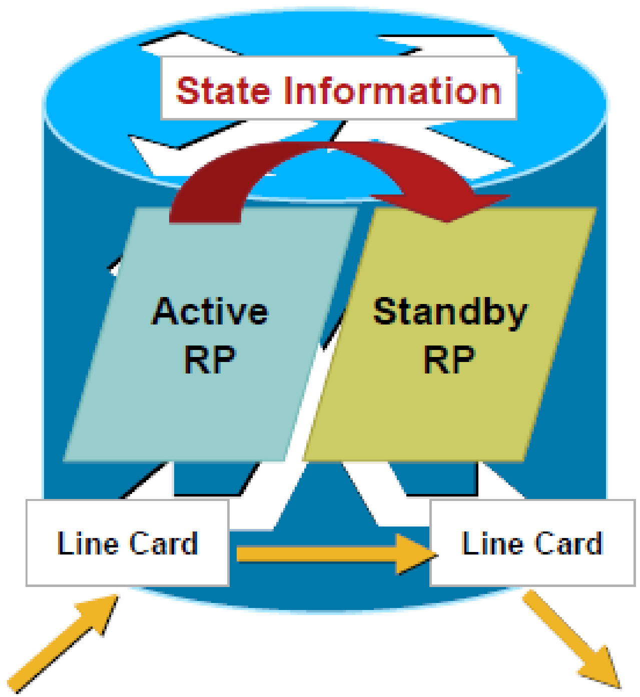


- The access layer is candidate for supervisor redundancy
- L2 access layer SSO
- L3 access layer SSO and NSF
- Reduces network outage to 1 to 3 seconds

Cisco Solutions

- NSF/SSO is a supervisor redundancy mechanism in Cisco IOS Software that allows extremely fast supervisor switchover at Layers 2 to 4.

- The standby Route Processor (RP) takes control of the router after a hardware or software fault on the Active RP.
- SSO allows the standby RP to take immediate control an maintain connectivity protocols.
- NSF continues to forward packets until route convergence is complete.



NSF/SSO

- SSO allows the standby Route Processor (RP) to takes control of the device after a hardware or software fault on the Active RP.
  - SSO synchronizes startup configuration, startup variables, and running configuration as well as dynamic runtime data including Layer 2 protocol state for trunks and ports, hardware Layer 2 and Layer 3 tables (MAC, FIB(forwarding information base), adjacency table) as well as ACL and QoS tables.
- NSF is a Layer 3 function that works with SSO to minimize the amount of time a network is unavailable to its users following a switchover.
  - Continue forwarding IP packets following a RP switchover.

Layer 2 Design Recommendations

Objectives

- To develop designs to support Layer 2 high availability and optimum convergence.
  - Describe how to support supporting tree convergence in the enterprise campus
  - Discuss how to harden Layer 2 for STP predictability
  - Describe recommended practices for Layer 2 trunks
  - Describe recommended practices for UDLD (unidirectional link detection) configuration
  - Describe recommended practices for EtherChannel

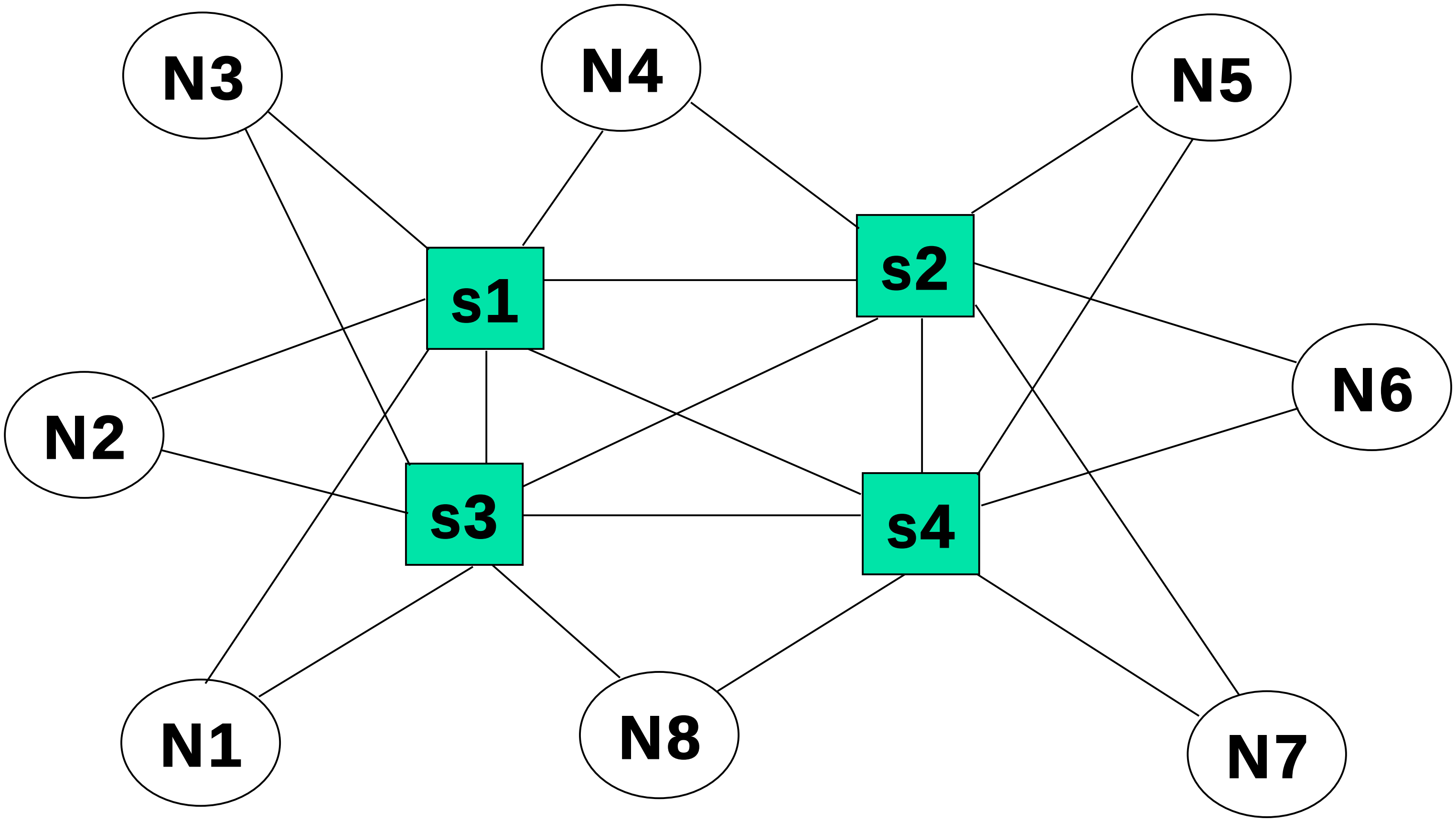
Spanning Tree

- There are several reasons you may need to implement **Spanning Tree Protocol (STP)** :
  - When a VLAN spans access layer switches in order to support business applications.
  - To support data center applications on server farms.
  - To protect against “user side” loops.
    - STP lets the network deterministically block interfaces and provides a loop-free topology in a network with redundant links.

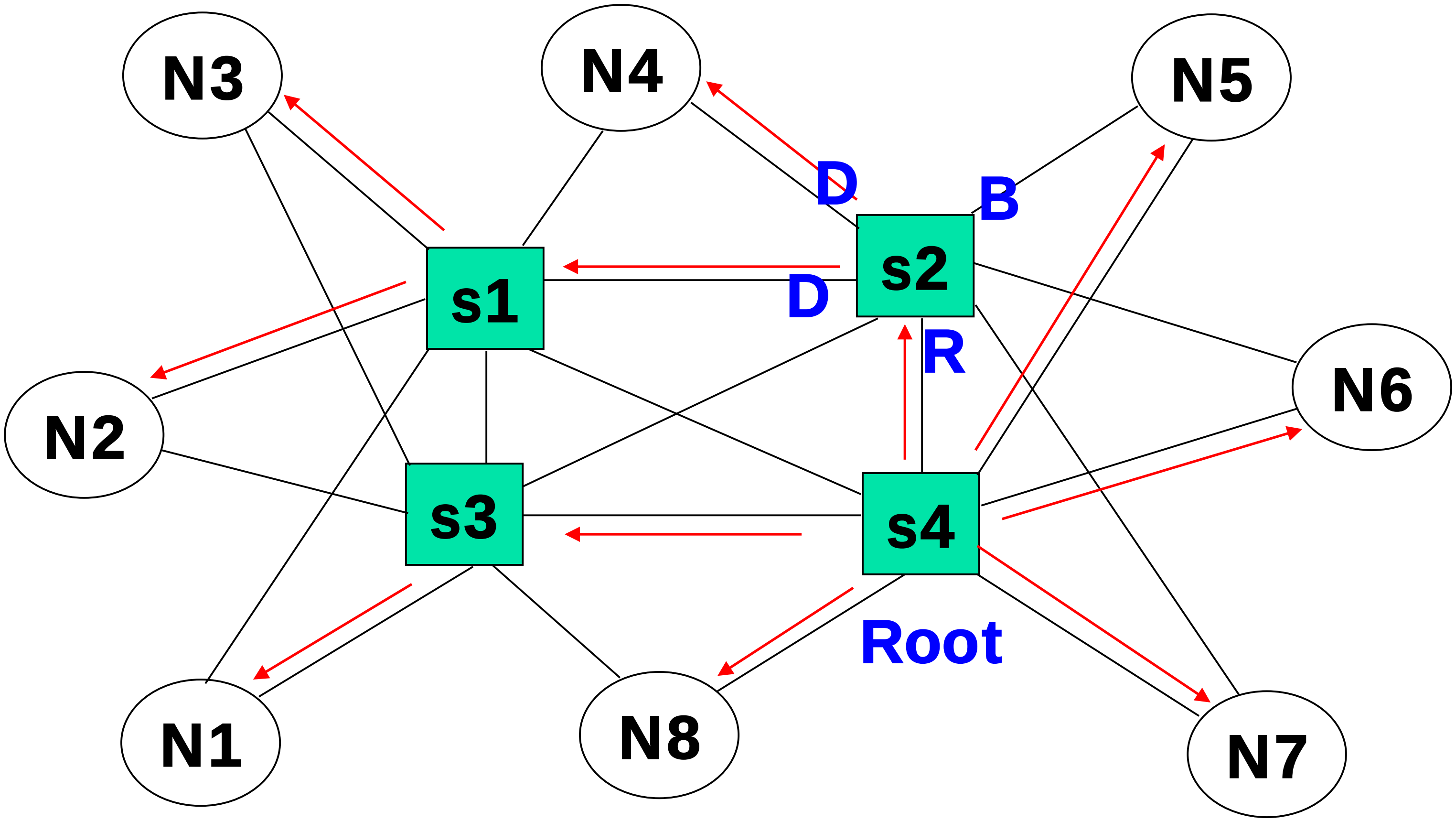
Spanning Tree

- Drawback:
  - Not all physical links are used in a network
  - No load-sensitive dynamic routing
  - Fail-over latency is high (> 5 seconds)

Spanning Tree Topology



Spanning Tree Topology



IEEE 802.1D: STP

- A distributed spanning tree construction algorithm
- Bridge Protocol Data Unit (BPDU): root ID, cost (link data rate), sender ID
- Port state: Root, Designated, Blocked and Disabled
- Port operating mode:
  - Blocked: receiving BPDU
  - Listening: receiving/processing BPDU
  - Learning: receiving/processing BPDU, and learning
  - Forwarding: receiving/processing BPDU, learning, and forwarding
- Slow convergence: 30 seconds
  - Everyone agrees on a common SPT
  - Everyone knows that everyone agrees on a common SPT, and turn a port from blocked to forwarding

STP (1)

- The Spanning-Tree Protocol establishes a root node, called the root bridge
  - STP constructs a topology that has one path to reach every node in a network.
  - The resulting tree originates from the root bridge
  - Redundant links that are not the parts of the shortest path tree are blocked.
    - Data frames received on the blocked port are dropped.
- Because certain paths are blocked, a loop free topology is possible.

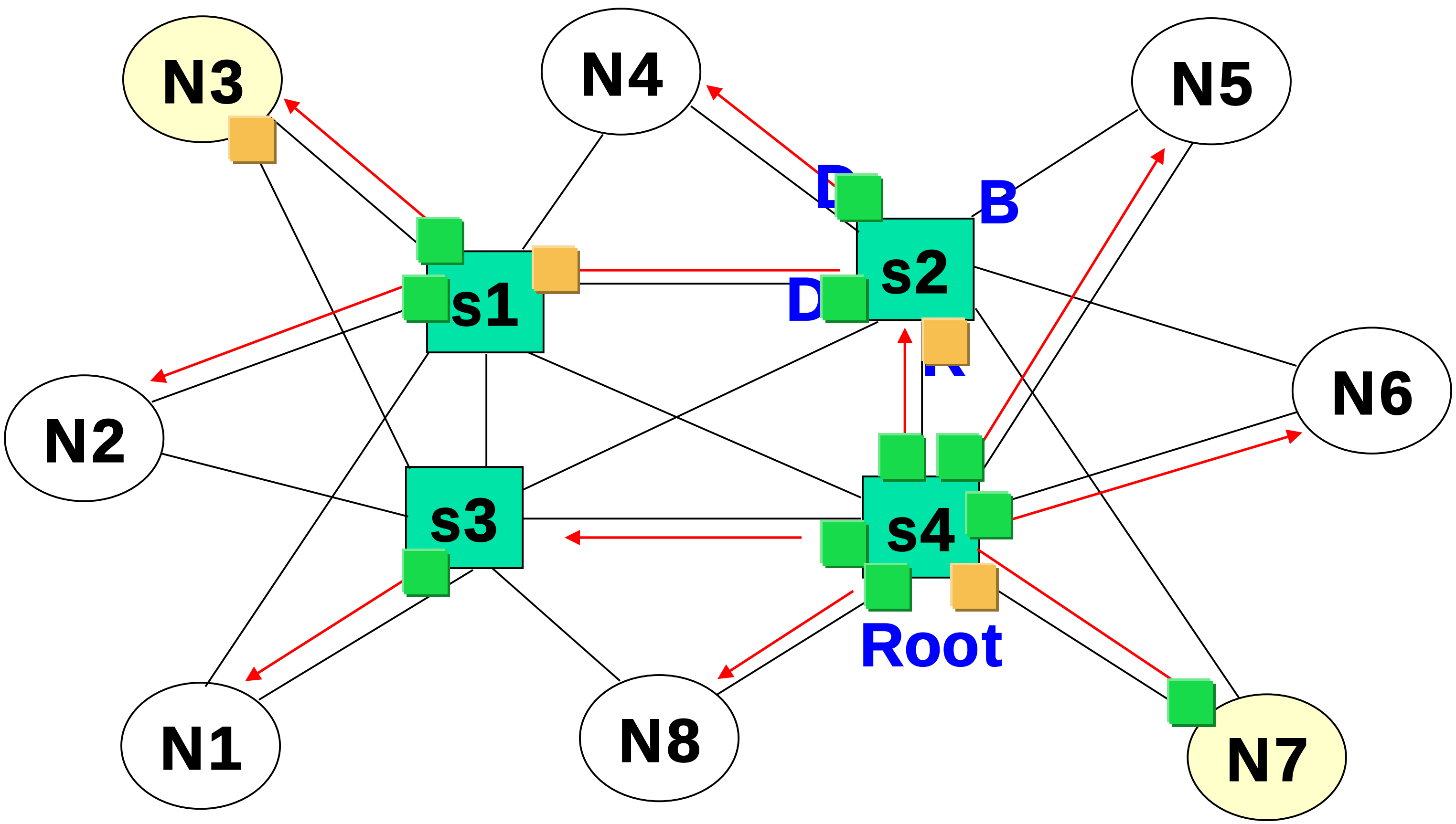
STP (2)

- There are several varieties of STP:
  - STP is the original 802.1D version to provide a loop-free topology in a network with redundant links.
  - Common Spanning Tree (CST) assumes one spanning-tree instance for the entire bridged network, regardless of the number of VLANs.
  - Rapid STP (RSTP), or 802.1w, is an evolution of STP providing for <u>faster convergence</u> of STP.

Broadcast and Source Learning

- Switch broadcasts a packet when its forwarding state does not exist
- Source learning: When receiving the packet, bind its source address with the port via which it comes in
- Example: N7 sends a packet to N3
  - N7 sends a broadcast-based ARP query for N3
    - Establishing forwarding state for N7 in the spanning tree
  - N3 responds with a unicast-based ARP response
    - Establish forwarding state for N3 in the spanning tree

Broadcast and Source Learning



Spanning-Tree Operation

- When the network has stabilized, it has **converged** and there is one spanning tree per network
- For every switched network the following elements exist:
  - One root bridge per network
  - One root port per non root bridge
  - One designated port per segment
  - Unused, non-designated ports
- Root ports and designated ports **forward** data traffic.
- Non-designated ports **discard** data traffic
  - These ports are called blocking or discarding ports

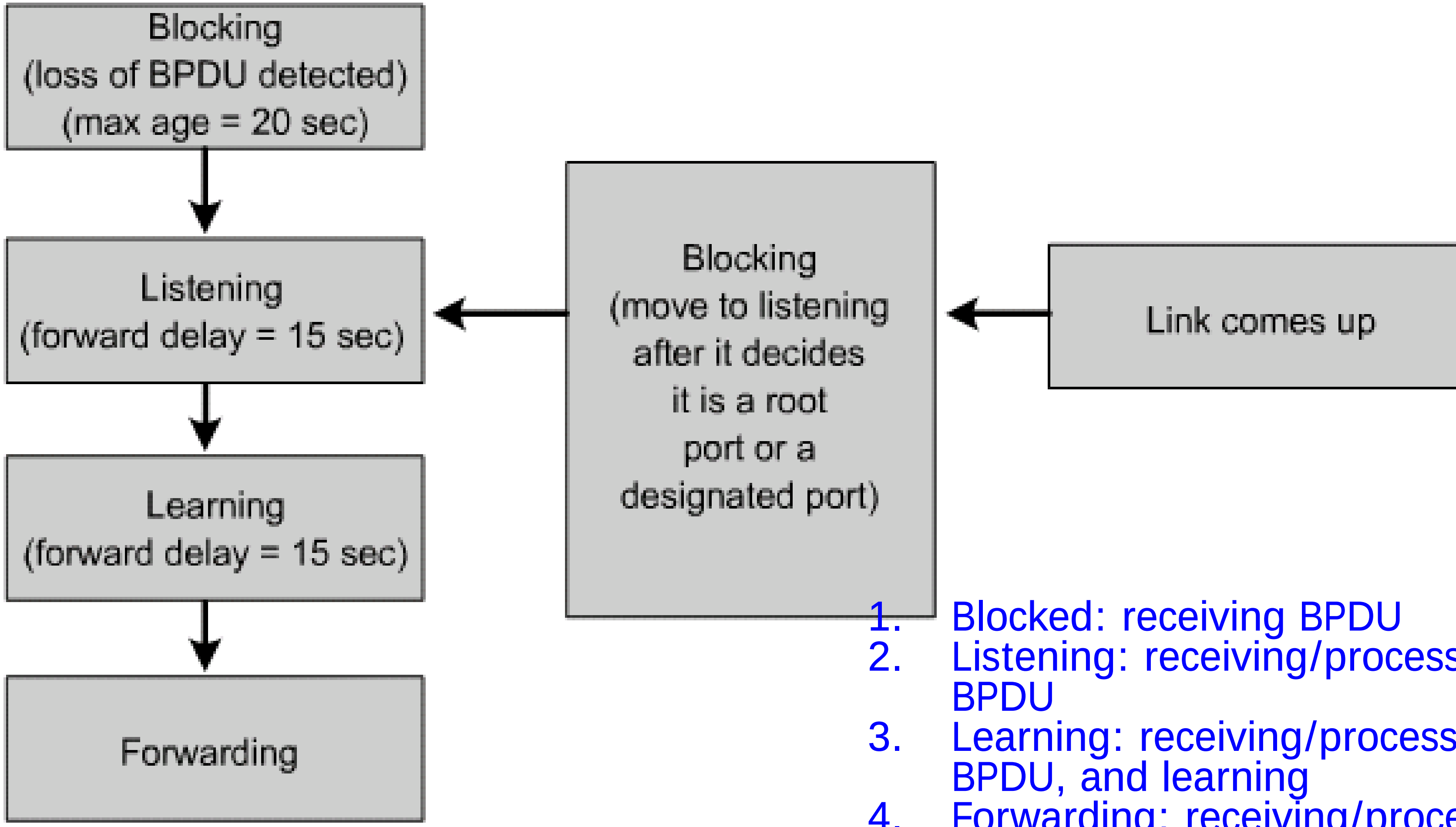
Selecting the Root Bridge

- The first decision that all switches in the network make, is to identify the root bridge using the spanning-tree algorithm
  - the bridge with **the smallest Bridge ID (BID)** value will be the root bridge.
- BPDUs are sent out with the Bridge ID (BID).
  - The BID consists of a bridge priority (that defaults to 32768) and the switch base MAC address
  - All switches send the BPDU
  - Default BPDUs are sent every **two** seconds

Selecting the Root Bridge Cont'd

- When a switch first starts up, it assumes it is the root switch and sends "inferior" BPDUs.
  - These BPDUs contain the bridge priority and switch MAC address in both the root and sender BID
- As a switch receives a BPDU with a lower root BID it replaces that in the subsequent BPDUs it sends out
- A network administrator can influence the decision by setting the switch priority to a smaller value than the default (Using smaller BID)
  - Should only be implemented when the traffic flow on the network is well understood

Four Stages of Spanning-Tree Port States



1. Blocked: receiving BPDU
2. Listening: receiving/processing BPDU
3. Learning: receiving/processing BPDU, and learning
4. Forwarding: receiving/processing BPDU, learning, and forwarding

• *A port can also be in a* ***disabled state*** *which occurs when an administrator shuts down the port or the port fails.*

Four Stages of Spanning-Tree Port States

- **Blocking State**
  - Ports can only receive BPDUs
  - Data frames are discarded and no addresses can be learned
  - It may take up to 20 seconds to change from this state
- **Listening State**
  - Switches determine if there are any other paths to the root bridge
  - The path that is not the least cost path to the root bridge goes back to the blocked state
  - BPDUs are still processed.
  - User data is **not** being forwarded and MAC addresses are not being learned
  - The listening period is called the forward delay and lasts for 15 seconds

Four Stages of Spanning-Tree Port States

- **Learning State**
  - User data is not forwarded, but MAC addresses are learned from any traffic that is seen
  - The learning state lasts for 15 seconds and is also called the forward delay
  - BPDUs are still processed
- **Forwarding state**
  - User data is forwarded and MAC addresses continue to be learned
  - BPDUs are still processed
- **Disabled State** (Fifth State)
  - Can occur when an administrator shuts down the port or the port fails

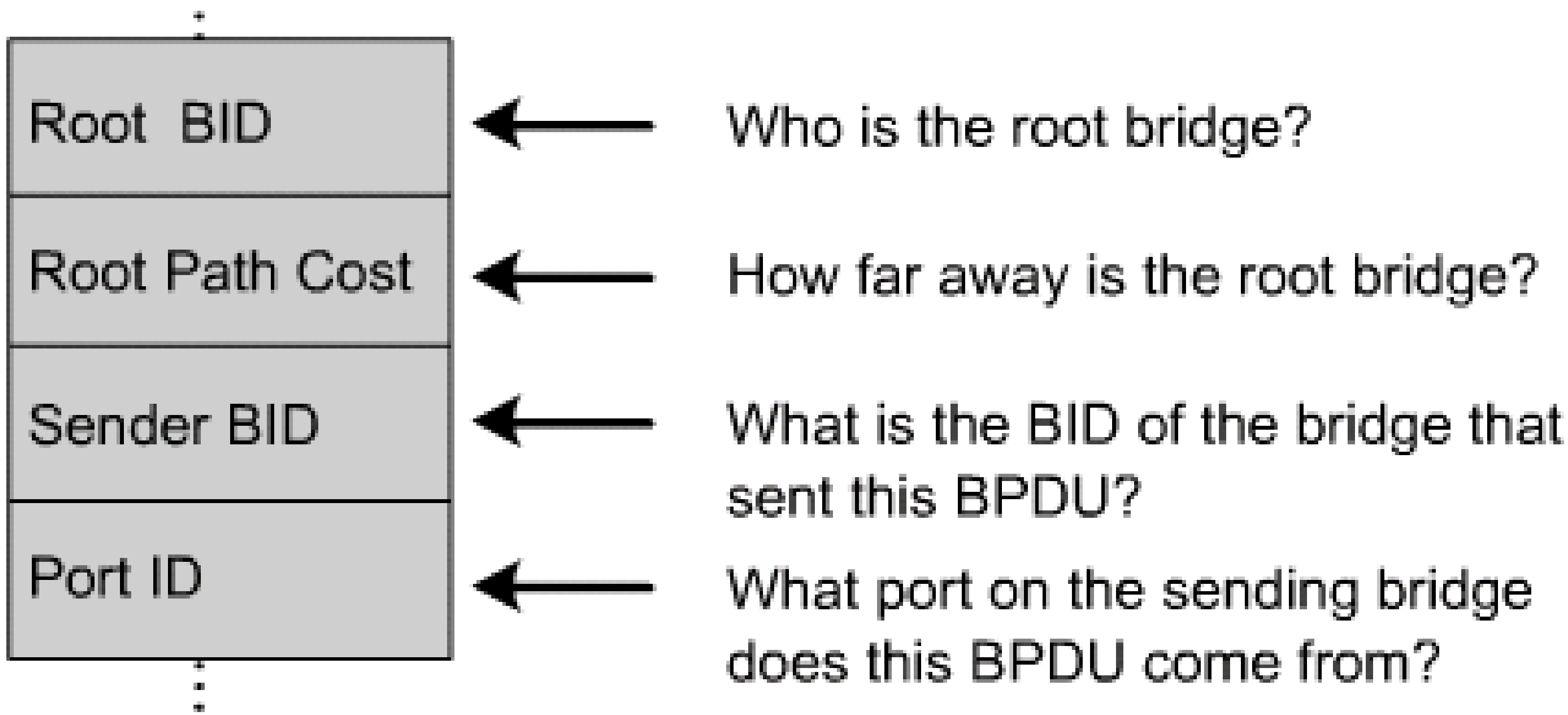
Spanning-Tree Recalculation

- A switched internetwork has converged when all the switch and bridge ports are in either the *forwarding or blocked state*
  - Forwarding ports send and receive data traffic and BPDUs
  - Blocked ports will only receive BPDUs
- When the network topology changes, switches and bridges recompute the Spanning Tree causing a disruption of user traffic.
- Convergence on a new spanning-tree topology using the IEEE 802.1D standard can take up to 30 seconds

Bridge Protocol Data Units (BPDUs)

- The STP requires network devices to exchange messages to form a loop-free logical topology.
- These messages are called Bridge Protocol Data Units (BPDUs)
  - Links that will cause a loop is set to a blocking state to solve the problem.
  - BPDUs continue to be received on blocked ports
    - if an active path or device fails, a new spanning tree can be calculated

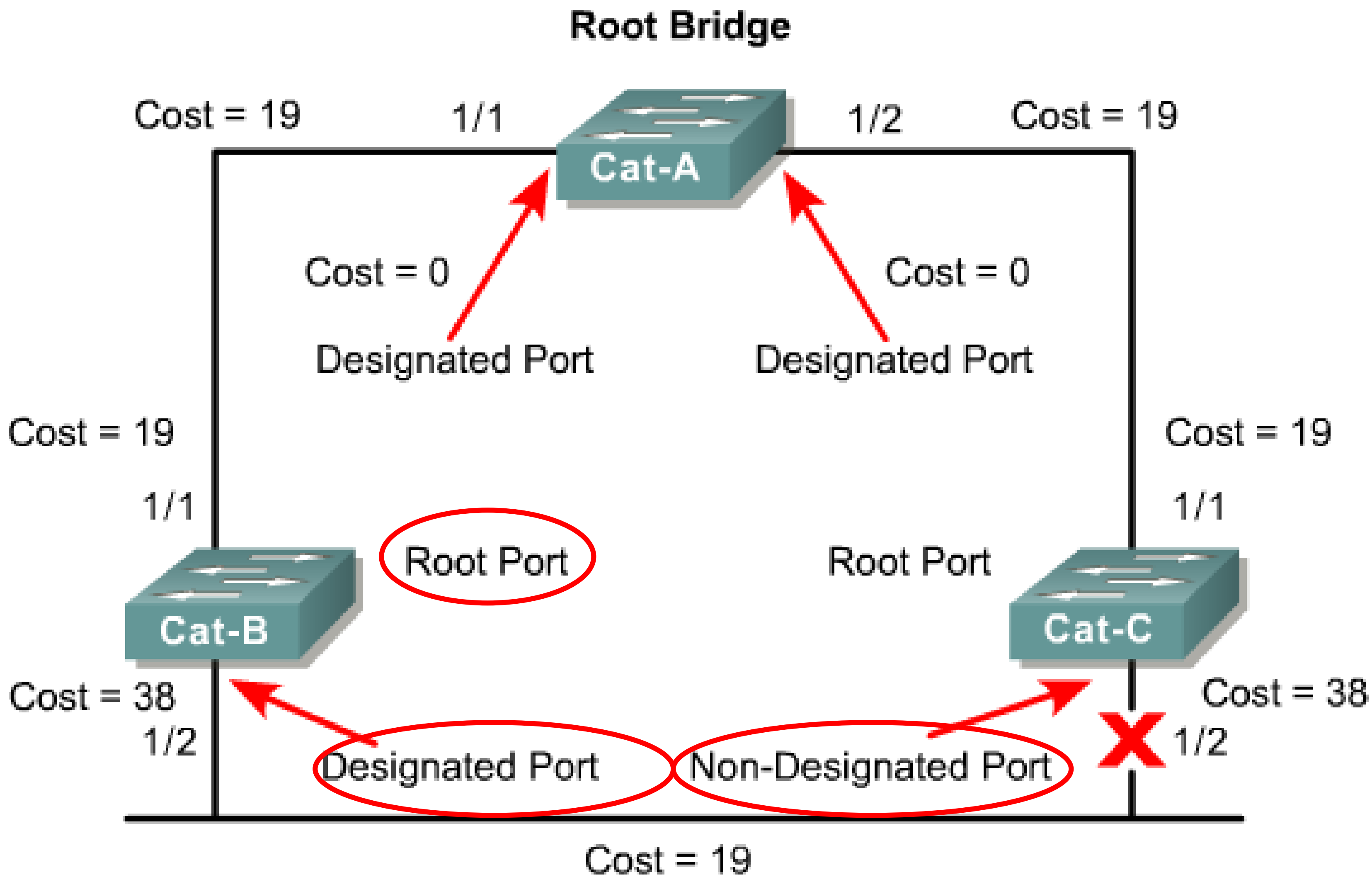
Information Contained in BPDUs



BPDUs

- BPDUs help switches do the following:
  1. Select a single switch that will act as the **root** of the spanning tree
  2. Calculate the shortest path from the root bridge to others
  3. Designate one of the switches as the closest one to the root, for each LAN segment. This bridge is called the "designated switch"
     - The designated switch handles all communication from that LAN towards the root bridge.
  4. Choose one of its ports as a root port (if it is a non-root switch)
     - This is the interface that gives the best path to root switch.
  5. Select ports that are part of the spanning tree, called designated ports
  6. Non-designated ports are blocked

Root Ports, Designated Ports, & Non-Designated Ports



Summary

- The configuration BPDU contains enough info. so that bridges can do the following:
  1) Elect a single bridge to be **Root Bridge**
  2) Calculate the distance of the shortest path from the Root Bridge to others
  3) Elect a **Designated Bridge** for each LAN segment, which is the bridge in the LAN segment closest to the Root Bridge, to forward packets from LAN segment toward the Root Bridge.
  4) Choose the port, called the **root port**, that gives the best path from themselves to the Root Bridge.
  5) Select ports to be included in the spanning tree.
     - These include only root ports and designated ports.

CISCO STP Instructions

- **PortFast*:** Causes a Layer 2 LAN interface configured as an access port to enter the forwarding state immediately, bypassing the listening and learning states. (從 Blocked state or Disabled state 直接到 Forwarding state)
  - Use PortFast only when connecting a single end station to a Layer 2 access port.

- **UplinkFast:** Provides three to five seconds convergence after a direct link failure and achieves load balancing between redundant Layer 2 links using uplink groups. (可以在有link故障的情況下改善 STP 的收斂時間)

CISCO STP Instructions

- **BackboneFast:** Cuts convergence time by max_age for indirect failure. (是在某條沒有直接連到該交換器的link故障時, 用來加快收斂的速度)
  - BackboneFast is initiated when a root port or blocked port on a network device receives inferior BPDUs from its designated bridge.
- **LoopGuard*:** helps prevent bridging loops that could occur because of a unidirectional link failure on a point-to-point link.
- **RootGuard*:** Secures root on a specific switch by preventing external switches from becoming root.
- **BPDUGuard*:** When enabled on a port, BPDU Guard shuts down a port that receives a BPDU.

Layer 2 Hardening

Place the root where you want it

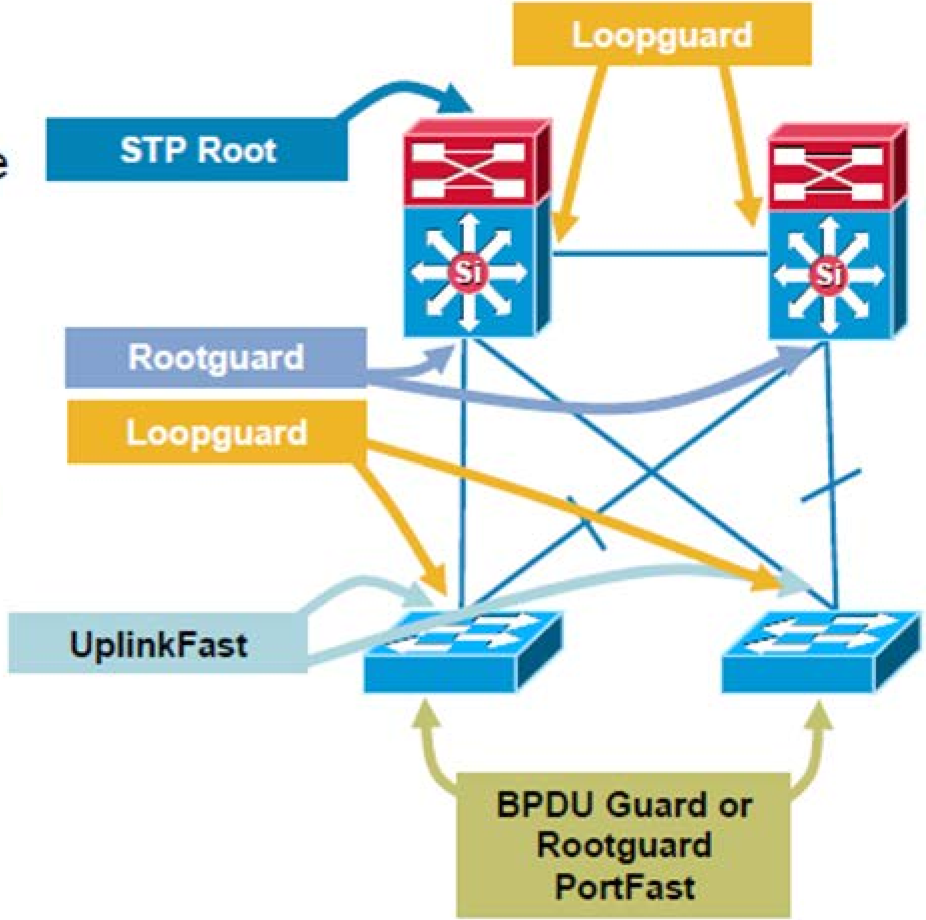
- Root Primary/Secondary Macro

The root bridge should stay where you put it

- RootGuard
- LoopGuard
- UplinkFast
- UDLD

Only end station traffic should be seen on an edge port

- BPDUGuard
- RootGuard
- PortFast
- port-security



Unidirectional Link Detection Protocol (UDLD)

Layer 2 Hardening

- **Loop guard** is implemented on the Layer 2 ports between distribution switches, and on the uplink ports from the access switches to the distribution switches.

- **Root guard** is configured on the distribution switch ports facing the access switches.

- **UplinkFast** is implemented on the uplink ports from the access switches to the distribution switches.

- **BPDU guard** or **root guard** is configured on ports from the access switches to the end devices, as is PortFast.

Unidirectional Link Detection (UDLD)

- UDLD is a data link layer protocol from Cisco Systems to monitor the physical configuration of the cables and detect unidirectional links.
- UDLD complements the STP which is used to eliminate switching loops.
  - UDLD is one of two major features (UDLD and loop guard) to prevent Layer 2 loops.
  - Unidirectional Link failure can cause " traffic blackholing" and loop in the topology.
  - In order to detect the unidirectional links before the forwarding loop is created, UDLD works by exchanging protocol packets between the neighboring devices.
  - Both switch devices on the link must support UDLD and have enabled on respective ports.

UDLD

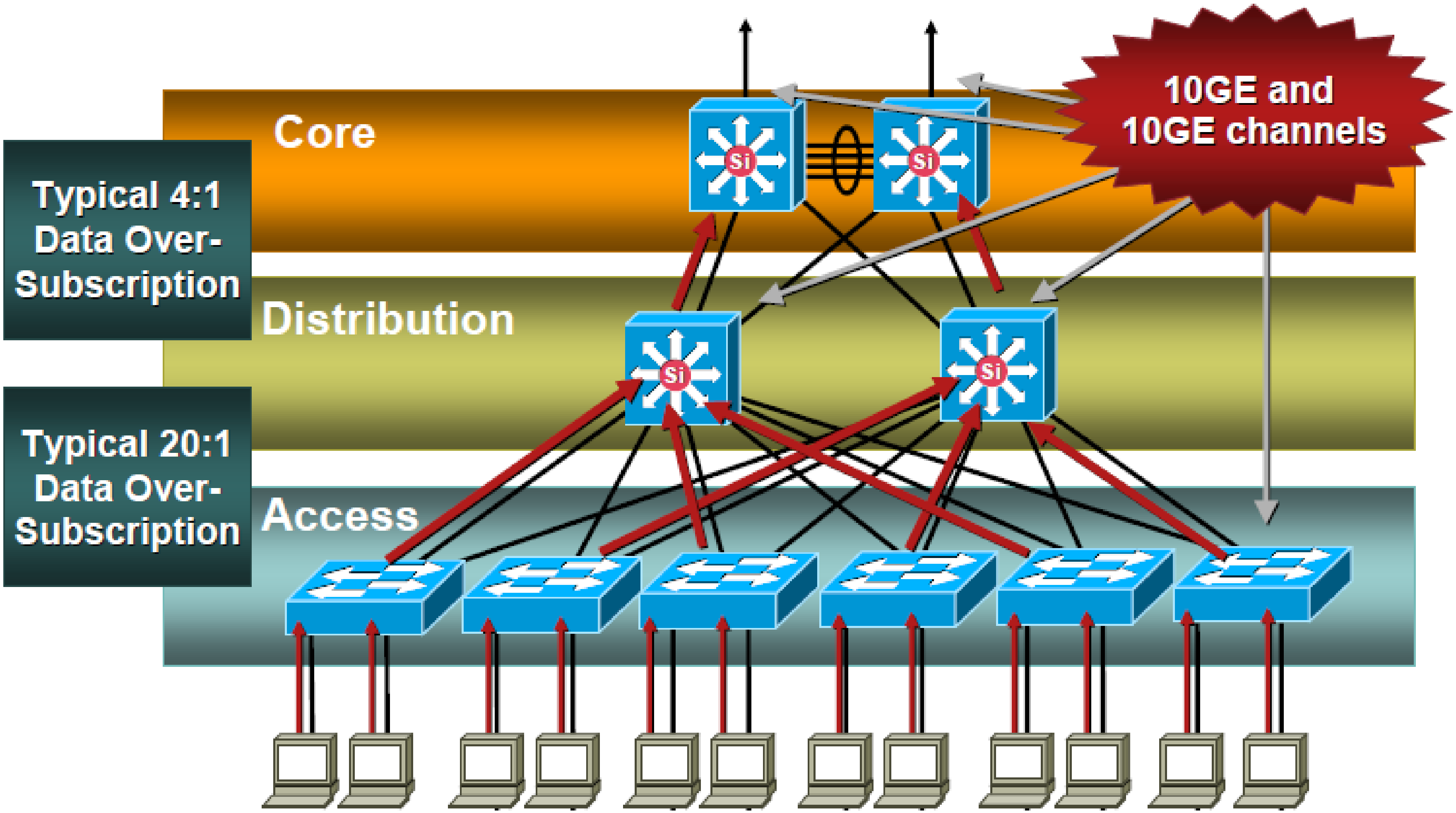
- A and B, are connected via a pair of optical fibers, one used for sending from A to B and other for sending from B to A, the link is bidirectional (two-way).
- If one of these fibers is broken, the link has become one-way or unidirectional.
- UDLD detects a broken bidirectional link (e.g. transmitted packets do not arrive at the receiver, or the fibers are connected to different ports).
- For each device and each port, a UDLD packet is sent to the port it links to.
  - The packet contains sender identity information (device and port), and expected receiver identity information (device and port).
  - Each port checks that the UDLD packets it receives contain the identifiers of his own device and port.

Layer 3 Design Recommendations

Objectives

- Describe recommendations for managing oversubscription and bandwidth
- Discuss design tradeoffs for supporting link load balancing
- Describe recommendations for routing protocol design
- Discuss recommendations for first hop redundancy protocols

Oversubscription and Bandwidth

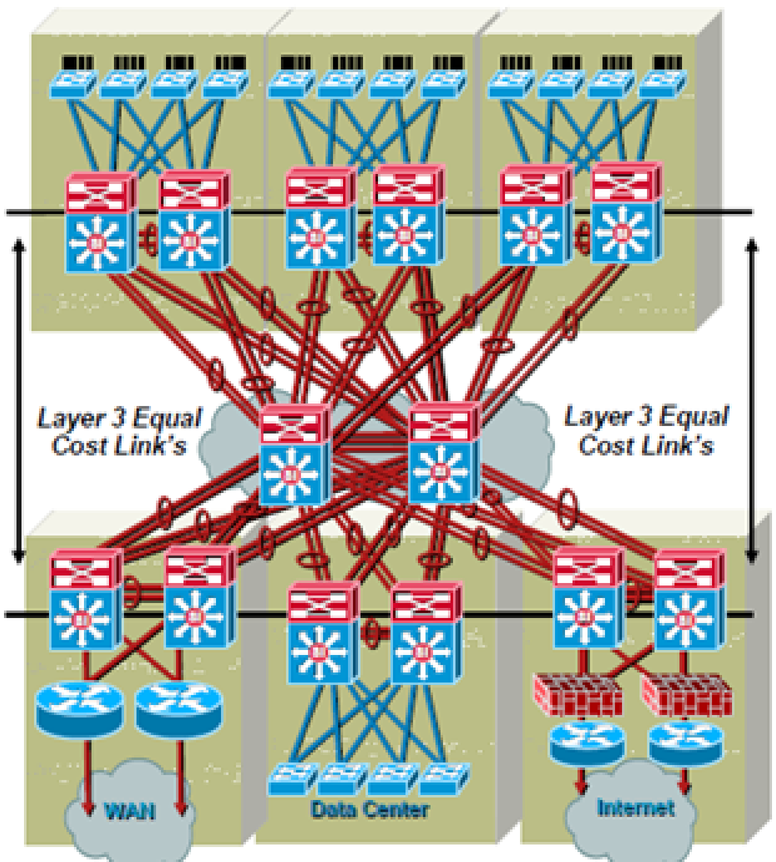


Oversubscription Ratio

- Typical campus networks are designed with **oversubscription**.
- The rule-of-thumb recommendation for data oversubscription is 20:1 for access ports on the access-to-distribution uplink.
- The recommendation is 4:1 for the distribution-to-core links.
  - Congestion may occur infrequently on the uplinks

Bandwidth Management with EtherChannel

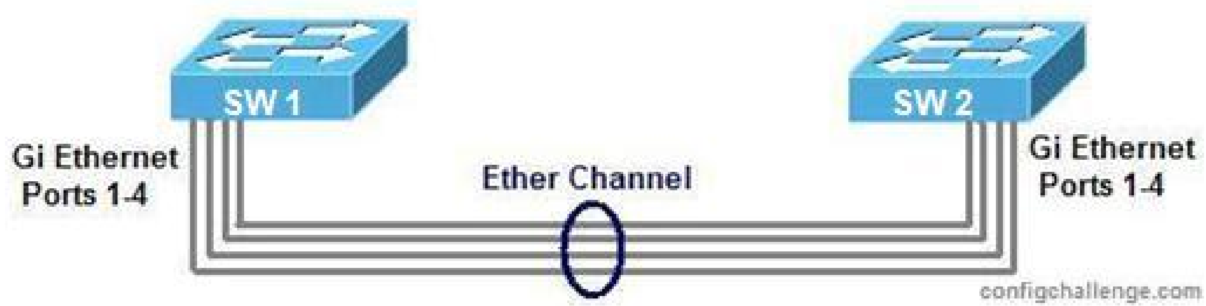
- As bandwidth from the distribution layer to the core increases, oversubscription to the access layer must be managed, and there are some design decisions to be made.
  - More links lead to more routing peer relationships and associated overhead.
  - EtherChannels reduces peers by creating single logical interface.
  - A single link failure in a bundle impacts routing protocols:
    - OSPF running on a IOS based switch will reduce link cost and re-route traffic.
    - OSPF running on a Hybrid based switch will *not* change link cost and may overload remaining links.
    - EIGRP *may not* change link cost and may overload remaining links.
  - LACP EtherChannel supports **min-links** feature.



Link Aggregation Control protocol (LACP)

EtherChannel

- **EtherChannel** is a port link aggregation technology or port-channel architecture used primarily on Cisco switches.
  - Grouping of several physical Ethernet links to create one logical Ethernet link to provide fault-tolerance and high-speed links between switches, routers and servers.
- An EtherChannel can be created from between **two and eight** active Fast, Gigabit or 10-Gigabit Ethernet ports, with an additional one to eight inactive (failover) ports which become active as the other active ports fail.



EtherChannel

- EtherChannel
  - is primarily used in the backbone network, but can also be used to connect end user machines.
  - was invented by Kalpana in the early 1990s. They were later acquired by Cisco Systems in 1994.
- In 2000 the IEEE passed 802.3ad which is an open standard version of EtherChannel.

Bandwidth Management with EtherChannel

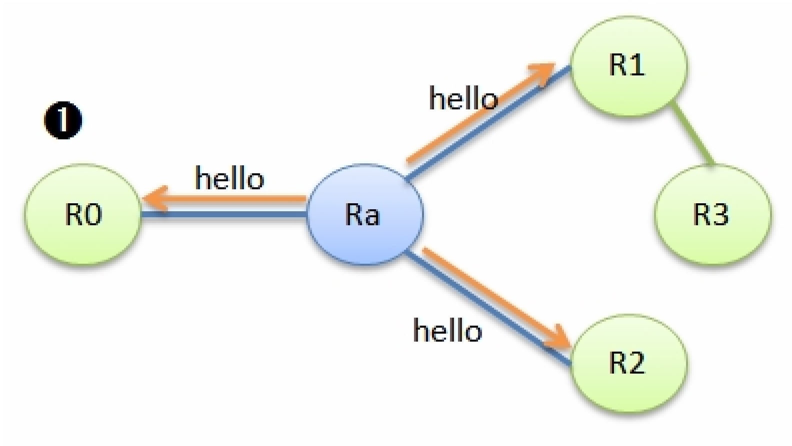
- Adding more uplinks between the distribution and core layers leads to more peer relationships with an increase in associated overhead.
- EtherChannel reduces the number of peers by creating single logical interface.
- There are some issues to consider about how routing protocols will react to single link failure:
  - Traffic is re-routed, and this design leads to a convergence event.
  - Enhanced Interior Gateway Protocol (EIGRP) may not change link cost, since the protocol looks at the end-to-end cost.

EIGRP

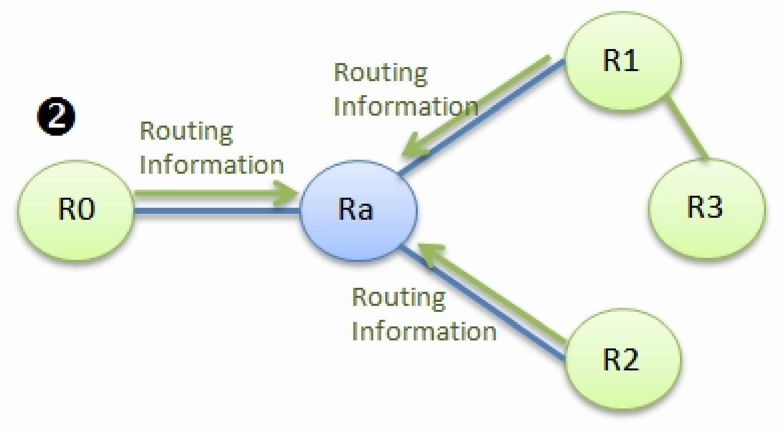
- EIGRP is an enhanced distance vector protocol, relying on the Diffused Update Algorithm (DUAL) to calculate the shortest path to a destination within a network.
- 在 EIGRP 的網路中，每一台 Router 必須維護3個表格
  - 路徑表 (Routing Table)：記錄每一個網路的最佳路徑，往此網路之最佳路徑的下一個路由器稱之為 Successor。
  - 拓樸表 (Topology Table)：記錄到目的網路的所有路徑，最佳的路徑連接的 Router 稱 successor ，次佳的稱為 feasible successor。
  - 鄰居表 (Neighbor Table)：記錄直接相接的路由器有哪些。

EIGRP Example (1)

1. Router sends Hello packet to the neighbor router(s)

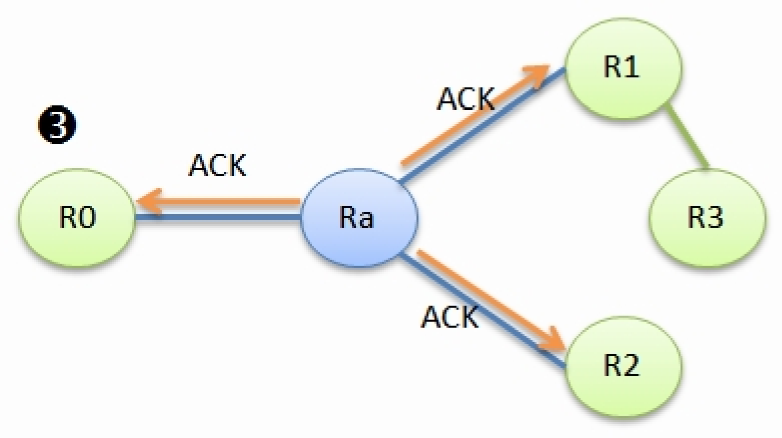


2. Neighbor router(s) send back their Routing Information(s)

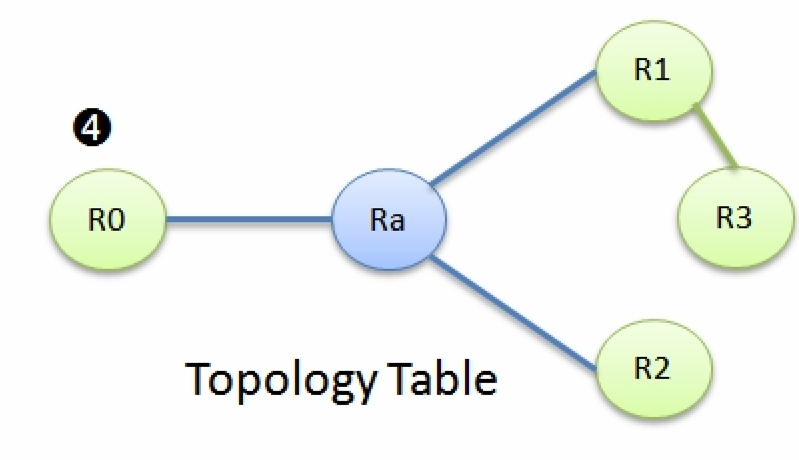


EIGRP Example (2)

3. Router receives the information and then responses ACK packet to the neighbor router(s)

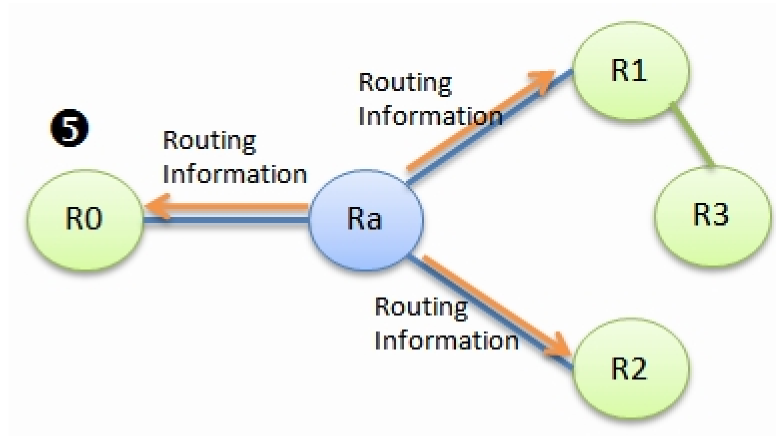


4. Router can construct the Topology Table

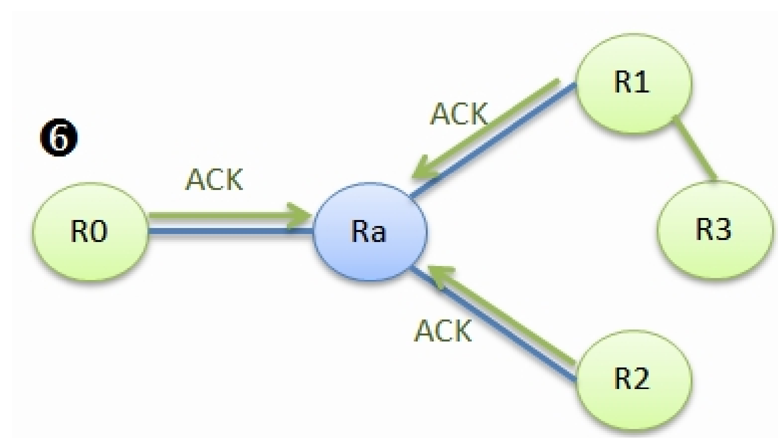


EIGRP Example (3)

5. Router transmits its Routing Information to the neighbor router(s)



6. The neighbor router(s) receives the Routing Table of Ra and then sends back ACK

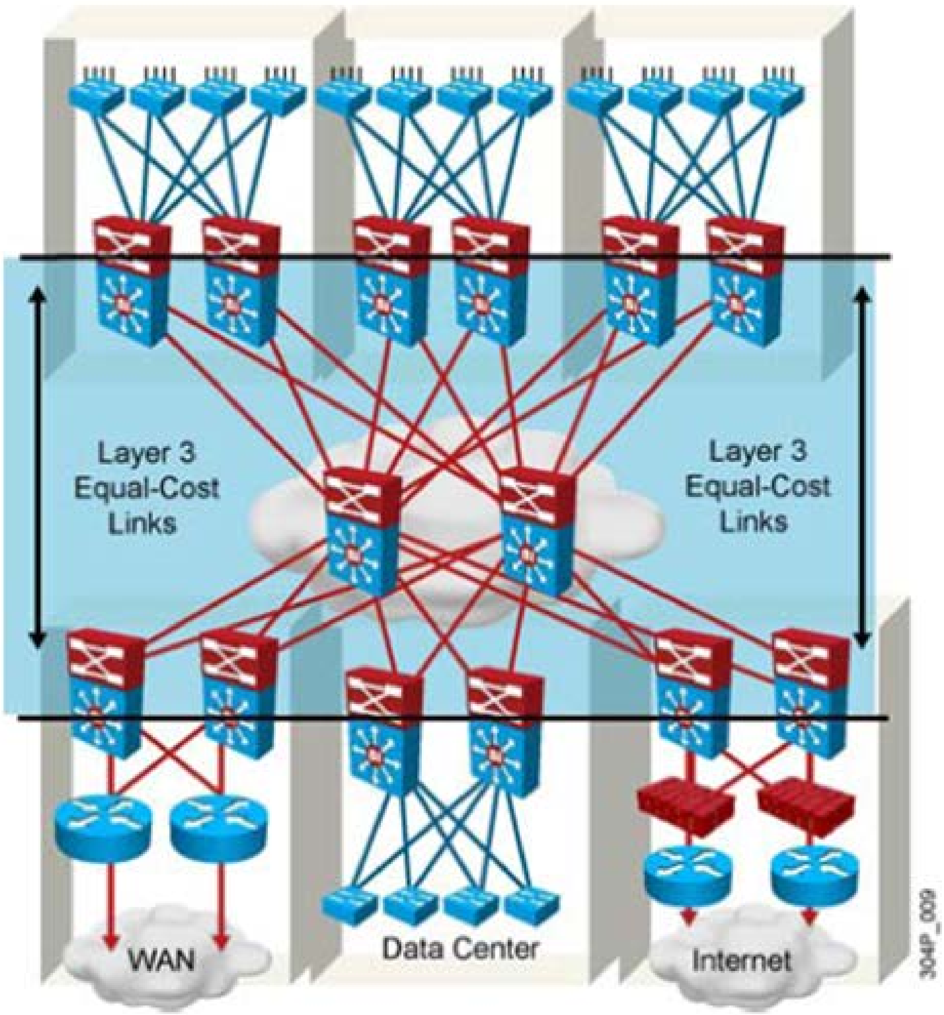


如果連結的狀態沒更動，則不會在傳送任何 Routing Table 的訊息！

10 Gigabit Interfaces

10 Gigabit Ethernet links provides increased bandwidth:

- Does not increase complexity.
- Does not affect the routing protocols ability to select best path.

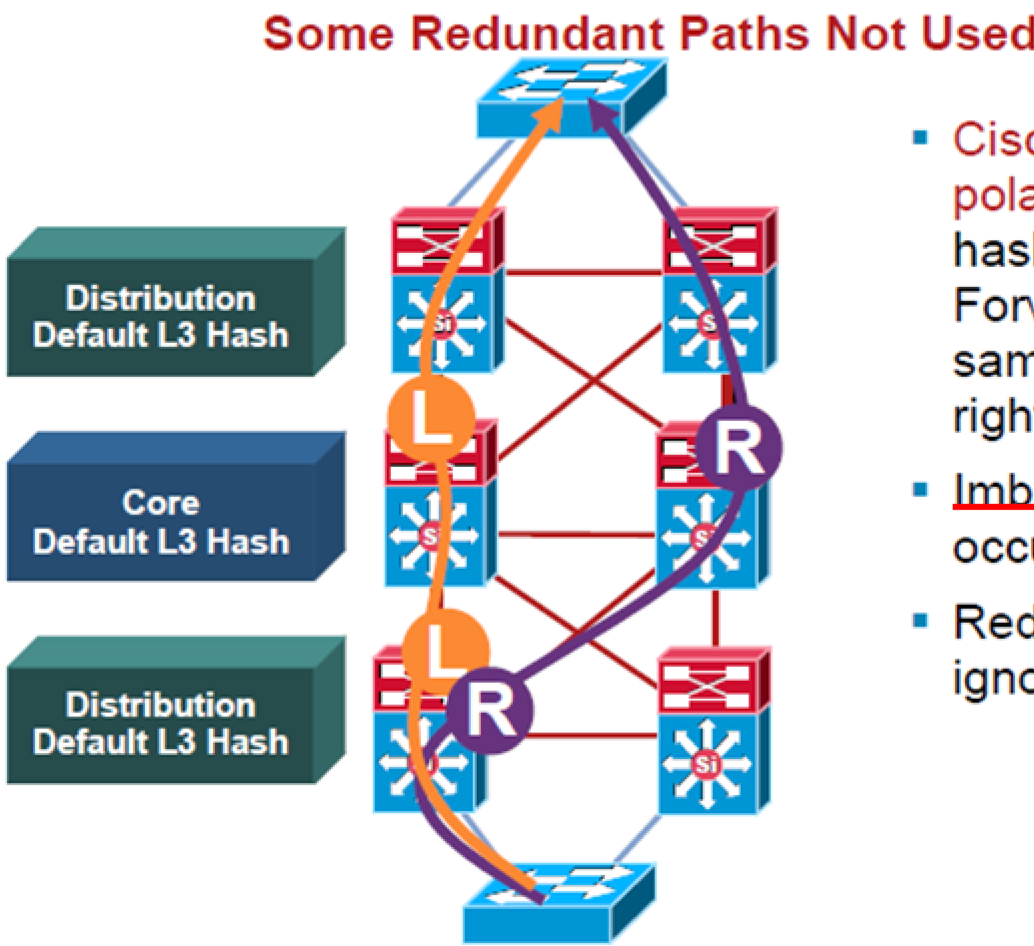


10 Gigabit Interfaces

- The 10 Gigabit Ethernet links support the increased bandwidth requirements.

- Advantage:
  - Unlike the multiple link solution, 10 Gigabit Ethernet links does not increase routing complexity.
    - The number of routing peers is not increased.
  - Unlike the EtherChannel solution, the routing protocols will have the ability to deterministically select the best path between the distribution and core layer.

Link Load Balancing



- Cisco Express Forwarding polarization: without tuning hash, Cisco Express Forwarding will select the same path left/left or right/right.
- Imbalance/overload could occur.
- Redundant paths are ignored/underutilized.

Link Load Balancing

- Many equal cost redundant paths are provided in the network topology from one access switch to the other across the distribution and core switches.

- Cisco Express Forwarding is a deterministic algorithm.
  - When packets traverse the network that all use the same input value to the Cisco Express Forwarding hash, a "go to the right" or "go to the left" decision is made for each redundant path

Link Load Balancing with EtherChannel

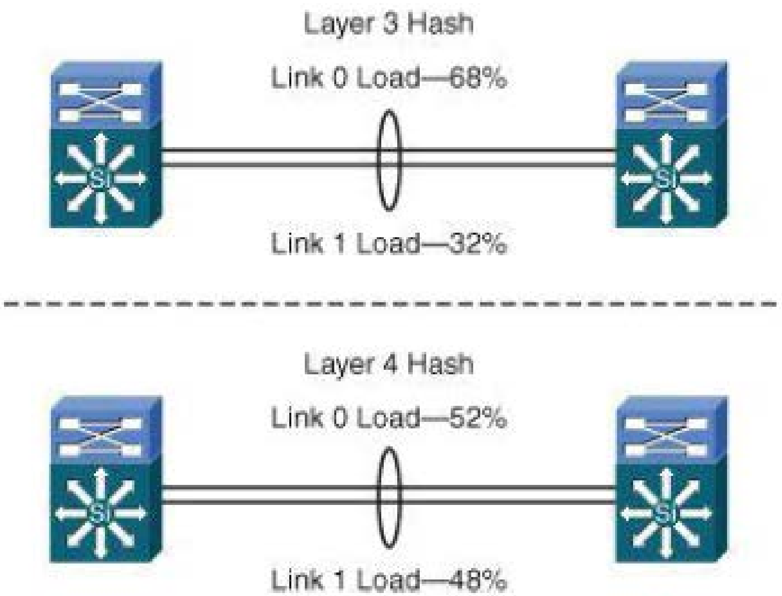
- EtherChannel allows load sharing of traffic among the links in the channel and redundancy in the event that one or more links in the channel fail.

- Tune the hashing algorithm used to select the specific EtherChannel link on which a packet is transmitted.

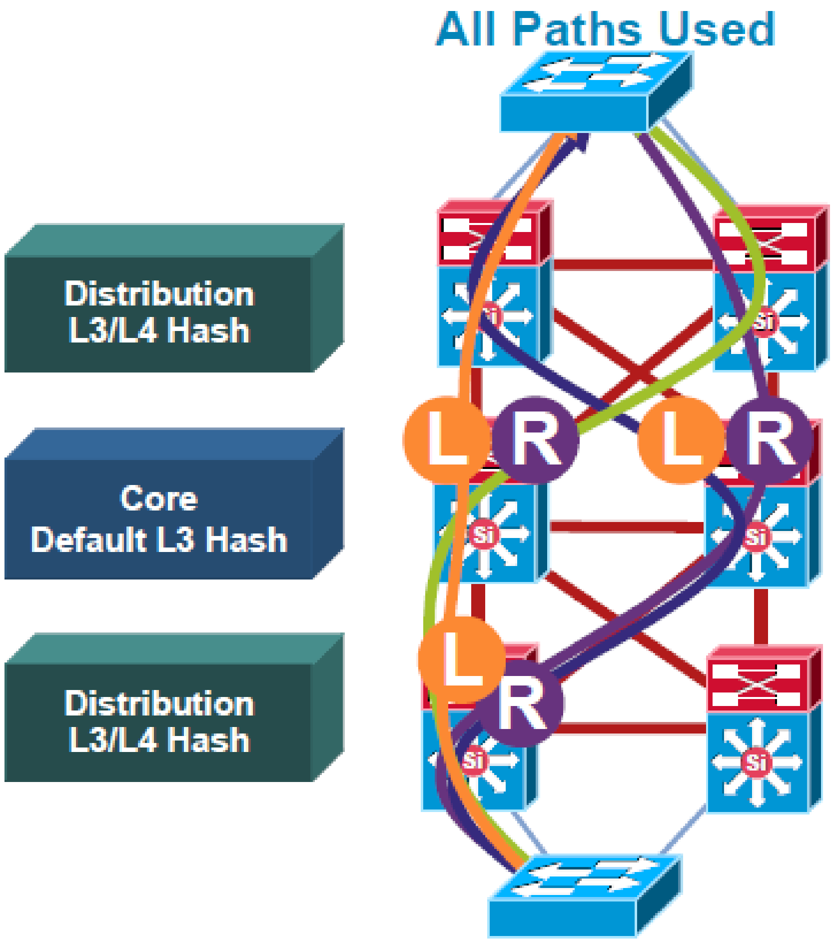
- Use the default Layer 3 source and destination information.
  - add a level of load balancing to the process by adding the Layer 4 TCP/IP port information as an input to the algorithm.

EtherChannel Load Balancing

- The default Layer 3 hash algorithm provided about one-third to two-thirds utilization.
- When the algorithm included Layer 4 information, nearly full utilization was achieved with the same topology and traffic pattern.
- To use Layer 3 plus Layer 4, load balancing uses as much information as possible for input to the EtherChannel algorithm to achieve the best or most uniform utilization of EtherChannel members.



Link Load Balancing



- The default Cisco Express Forwarding hash 'input' is Layer 3 information.
- Optional hash uses Layer 3 + Layer 4 information as 'input' to the hash derivation.
- Alternating hashes by layer will give us the best load balancing results:
  - Use default Layer 3 hash in core.
  - Use Layer 3 + Layer 4 hash in distribution layer.

```
dist2-6500(config)#mls ip cef load-sharing full
```

Link Load Balancing

- In the core layer, continue to use the default which is based on only Layer 3 information.

- In the distribution layer,
  - The default input hash value use Layer 3 information.
    - Using Layer 3 with Layer 4, the output hash value also changes.
  - Use the Layer 3 and Layer 4 information as input into the Cisco Express Forwarding hashing algorithm with the **mls ip cef load-sharing full** command

Routing Protocol Design

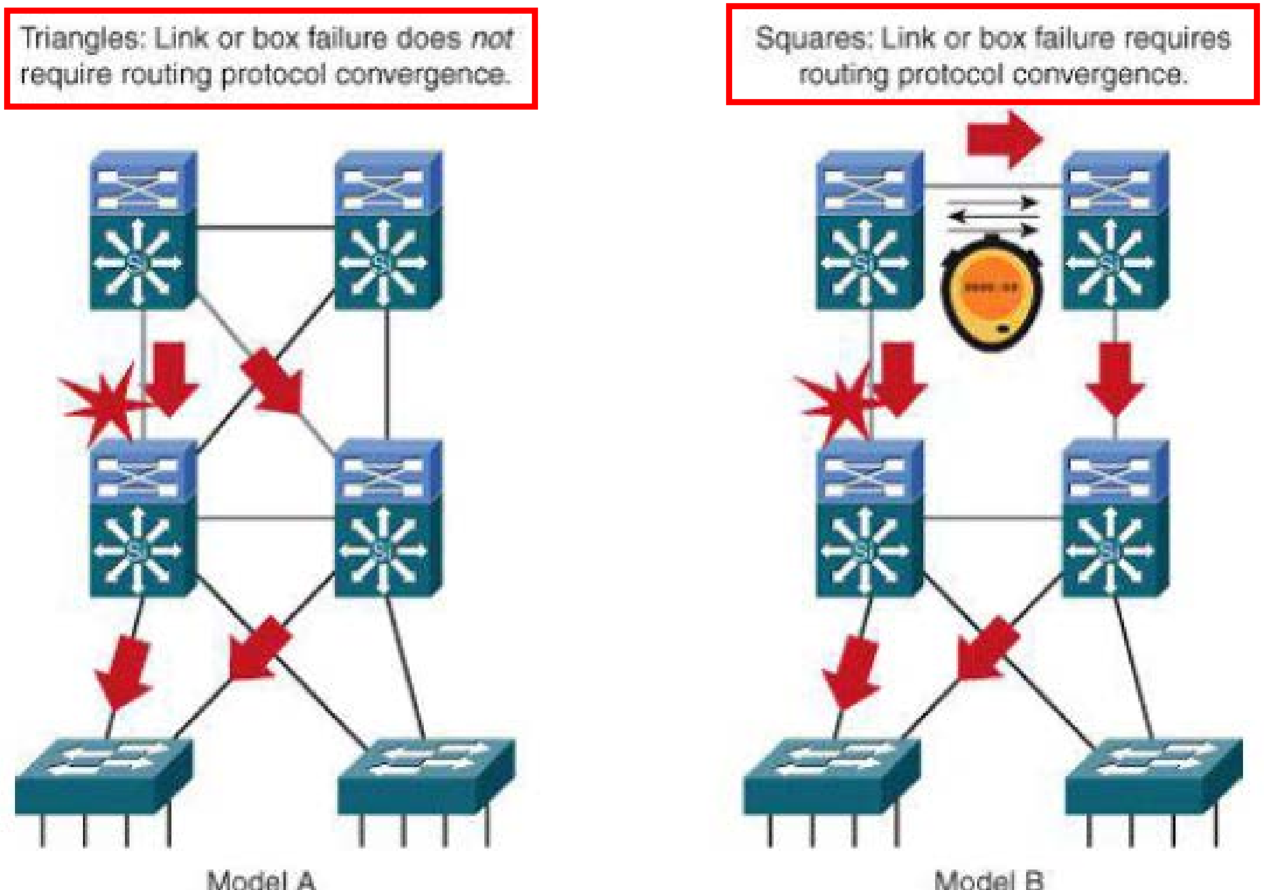
- Layer 3 routing protocols are used to quickly reroute around failed nodes or links while providing load balancing over redundant paths.

- Routing protocols are usually deployed across the distribution-to-core and core-to-core interconnections.

- Layer 3 routing design can be used in the access layer, too, but this design is currently not as common.

Build Redundant Triangles

- For optimum distribution-to-core layer convergence, build redundant triangles, not squares, to take advantage of equal-cost, redundant paths for the best deterministic convergence.



Build Redundant Triangles

- Model A uses dual equal-cost paths to avoid timer-based, nondeterministic convergence.
  - Instead of indirect neighbor or route-loss detection using hellos and dead timers, the triangle design failover is hardware based and relies on physical link loss to mark a path as unusable and reroute all traffic to the alternate **equal-cost path**.
- Model B requires routing protocol convergence to fail over to an alternate path in the event of a link or node failure.
  - It is possible to build a topology that does not rely on equal-cost, redundant paths to compensate for limited physical fiber connectivity or to reduce cost.
  - It is not possible to achieve the same deterministic convergence in the event of a link or node failure, and for this reason the design will not be optimized for high availability.