Chapter 5

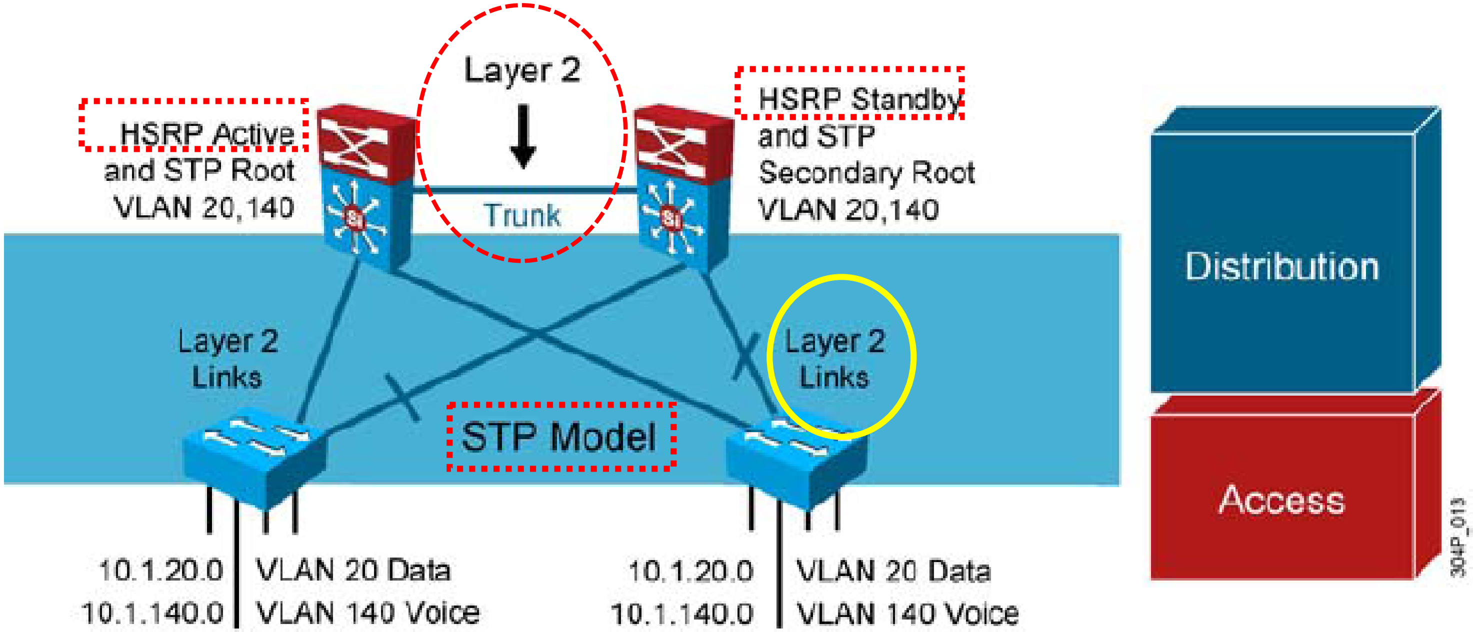
Layer 2 to Layer 3 Boundary Design

Objectives

- Designs to support the Layer 2 to Layer 3 boundary in enterprise campus networks.
- Includes being able to meet these objectives:
  - Describe and select the appropriate Layer 2 to Layer 3 boundary design models
  - Describe and avoid potential design issues with the design models

Layer 2 Distribution Switch Interconnection

- If the enterprise campus requirements must support VLANs spanning multiple access layer switches, the design model uses a Layer 2 link for interconnecting the distribution switches.



- Use only if Layer 2 VLAN spanning flexibility required
- STP convergence required for uplink failure and recovery
- More complex because STP root and HSRP should match
- Distribution-to-distribution link required for route summarization

Layer 2 Distribution Switch Interconnection

- This design is **more complex** than the Layer 3 interconnection of the distribution switches.
- The STP convergence process will be initiated for uplink failures and recoveries.
- Following steps to improve this suboptimal design:

1. Must to use Rapid STP (RSTP).
   - RPVST+ is a Cisco enhancement of RSTP that uses **PVST+**.
   - It provides a separate instance of 802.1W per VLAN.
     - supports PortFast, UplinkFast, BackboneFast, BPDU guard, BPDU filter, root guard, and loop guard.
2. Provide a Layer 2 trunk between the two distribution switches to avoid unexpected traffic paths and multiple convergence events.

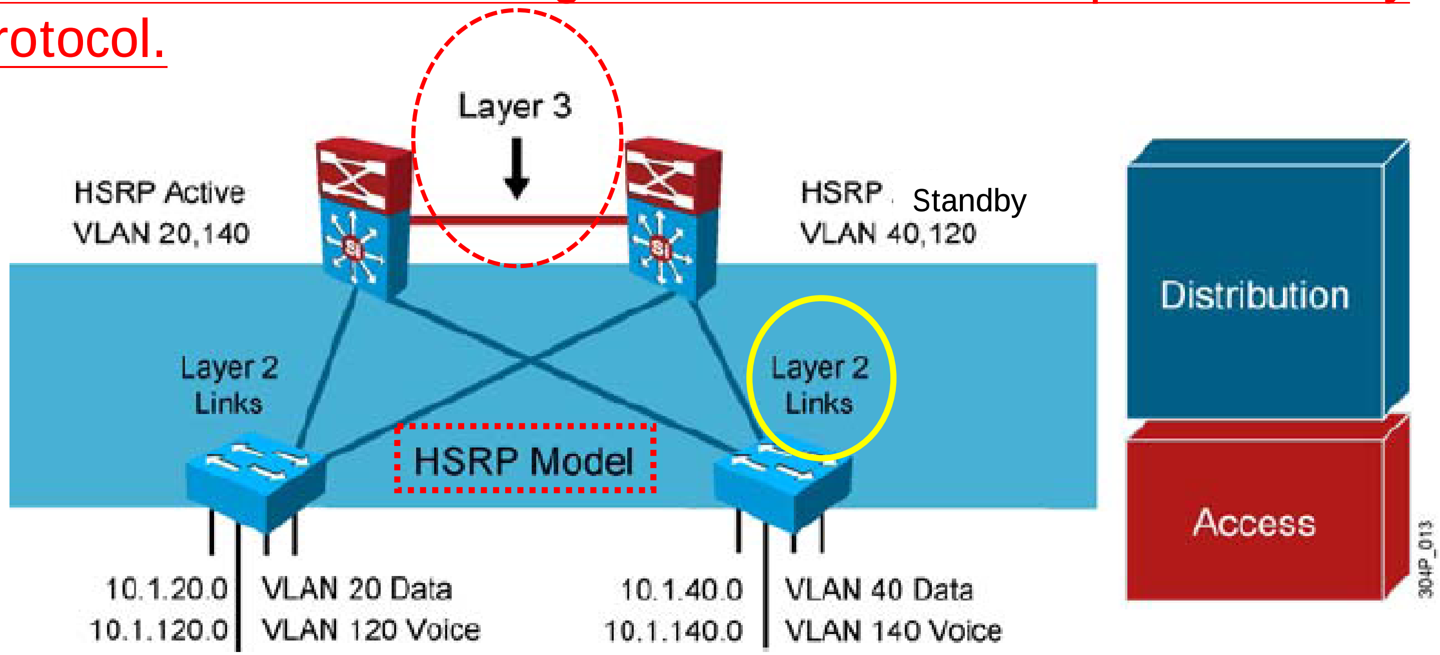
Layer 2 Distribution Switch Interconnection

3. If you choose to load-balance VLANs across uplinks, be sure to place the Hot Standby Router Protocol (HSRP) primary and the STP primary on the same distribution layer switch.

4. The HSRP and RSTP root should be collocated on the same distribution switches to avoid using the interdistribution link for transit.

Layer 3 Distribution Switch Interconnection

- This model supports a Layer 3 interconnection between distribution switches using **HSRP** as the first hop redundancy protocol.



- Recommended practice—tried and true
- No STP convergence required for uplink failure and recovery
- Distribution-to-distribution link required for route summarization
- Map Layer 2 VLAN number to Layer 3 subnet for ease of use and management

This recommended design provides the highest availability.

HSRP

- **Hot Standby Router Protocol (HSRP)** is a Cisco proprietary redundancy protocol.
  - establishing a fault-tolerant default gateway, detail in RFC 2281.
- To establish a framework between network routers in order to achieve default gateway failover.
  - if the primary gateway becomes inaccessible, the standby gateway handle the traffic immediately.
- By multicasting packets, HSRP sends its hello messages to the multicast address 224.0.0.2 (all routers) for version 1, or 224.0.0.102 for version 2, using UDP port 1985, to other HSRP-enabled routers, defining priority between the routers.

HSRP

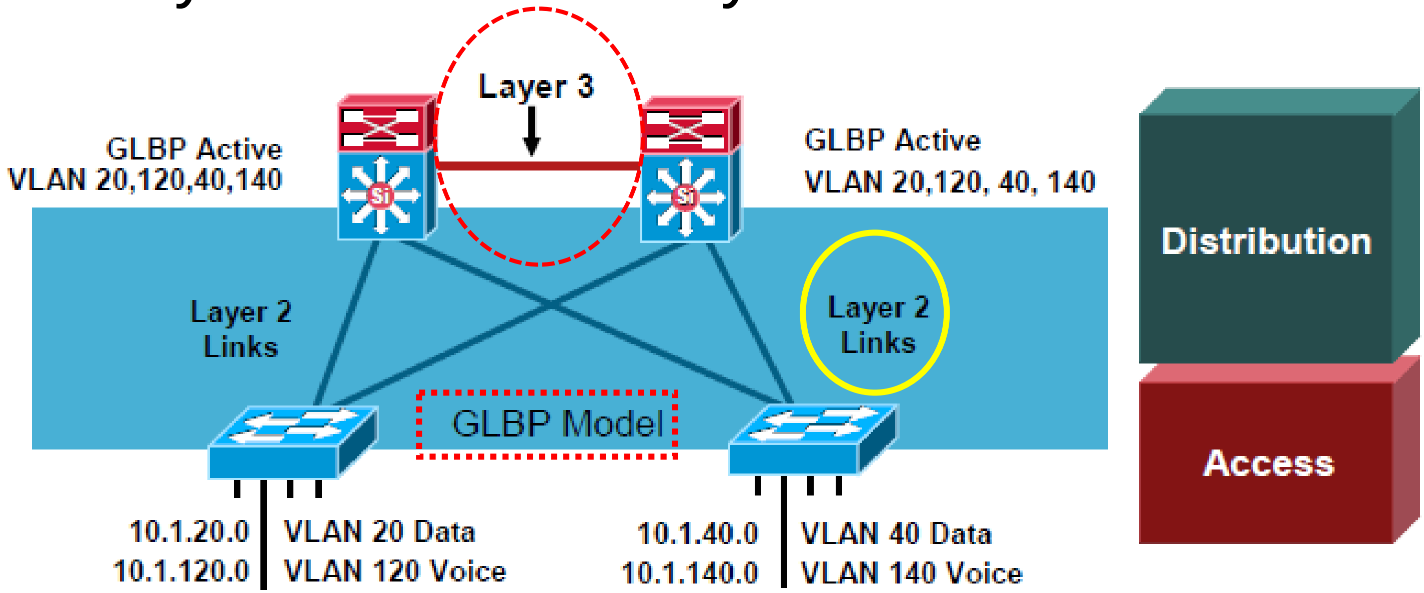
- The primary router with the highest configured priority will act as a **virtual router** with a pre-defined gateway IP address
  - respond to the ARP request from machines connected to the LAN with the MAC address 0000.0c07.acXX where XX is the group ID in hex.
- If the primary router fails, the router with the next-highest priority would take over the gateway IP address and answer ARP requests with the same mac address, thus achieving transparent default gateway fail-over.

Layer 3 Distribution Switch Interconnection

- Characteristics:
  - No VLANs span between access layer switches across the distribution switches.
  - A subnet equals a VLAN which equals an access switch.
    - A recommended practice is to map the Layer 2 VLAN.
  - The root for each VLAN is aligned with the active HSRP instance.
  - A distribution-to-distribution link is required for route summarization.

GLBP

- **Global Load Balancing Protocol (GLBP)** can also be used as the **first hop redundancy protocol** with the Layer 3 distribution layer interconnection model.



- Fully utilize uplinks via GLBP
- Distribution-to-distribution required for route summarization
- No STP convergence required for uplink failure/recovery

GLBP

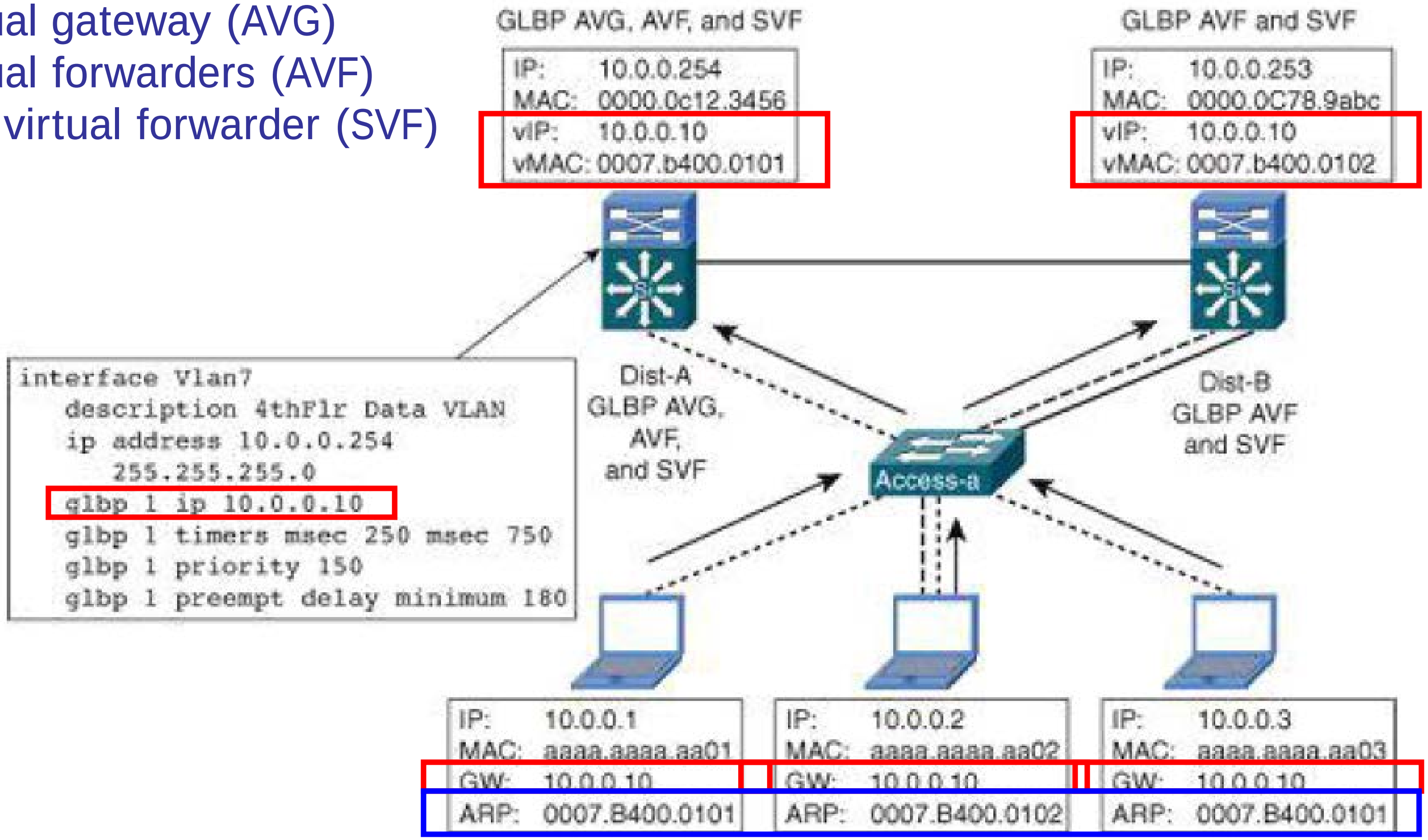
- GLBP allows full utilize of the uplinks from the access layer.
- The distribution to distribution link is still required for route summarization.
- Since the VLANs do not span access switches, STP convergence is not required for uplink failure and recovery.

GLBP

- GLBP is a first-hop redundancy protocol designed by Cisco that allows packet load sharing among groups of redundant routers.
- HSRP or VRRP (Virtual Router Redundancy Protocol) is used to provide default-gateway redundancy, the backup members of the peer relationship are **idle**.
  - waiting for a failure event to occur before they take over and actively forward traffic.
- Also to use multiple HSRP groups on a single interface, and to use DHCP to alternate between the multiple default gateways.
  - These techniques work but are not optimal from a configuration, maintenance, or management perspective.
- **GLBP provides all the benefits of HSRP and includes load balancing, too**.

Example

Active virtual gateway (AVG)
Active virtual forwarders (AVF)
Secondary virtual forwarder (SVF)

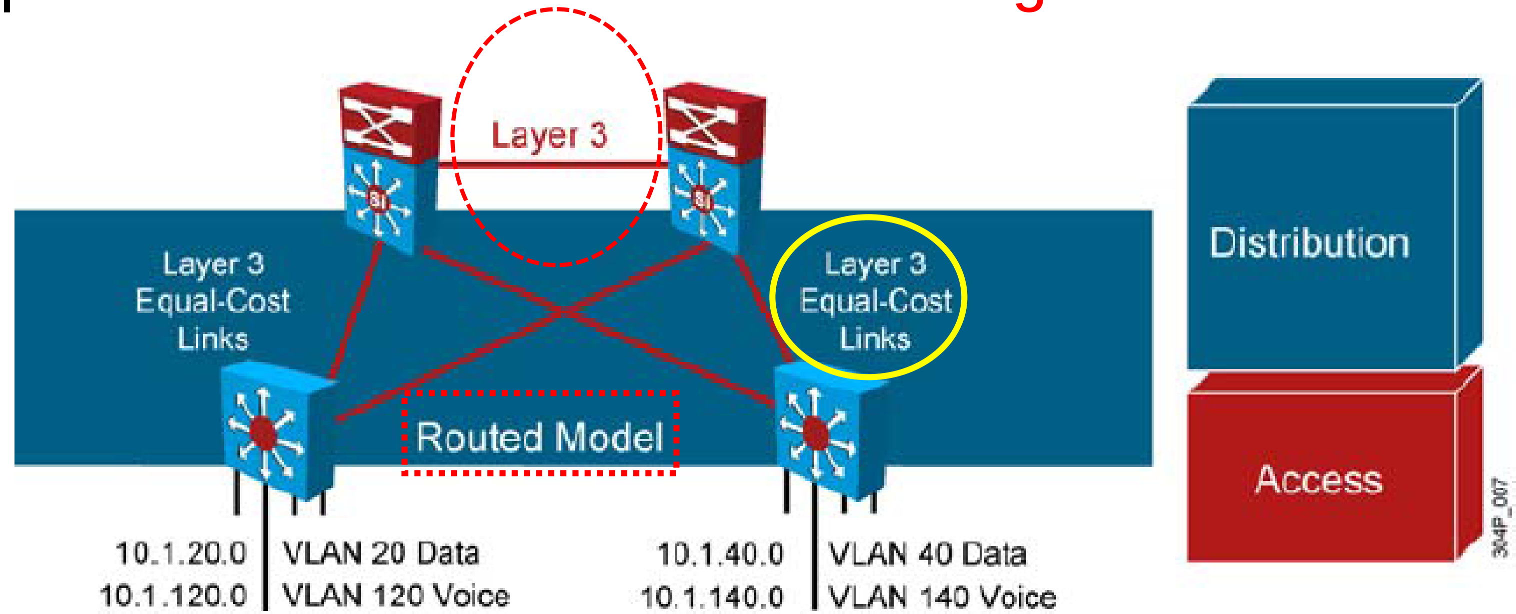


GLBP

- Advantage:
  1. allows for the automatic selection and simultaneous use of multiple available gateways as well as automatic failover between those gateways
  2. none of the clients has to be pointed toward a specific gateway address; they can all have the same default gateway set to the virtual router IP address.
- Principle :
  Single virtual IP address and multiple virtual MAC addresses
  1. As a client sends an ARP request looking for the virtual router IP address,
  2. GLBP sends back an ARP reply with the virtual MAC address of a selected router in the group.
  3. All clients use the same gateway IP address but have differing MAC addresses for it.

Layer 3 Access to Distribution Interconnection

- The design extending Layer 3 to the access layer provides the fastest network convergence.



- Best option for *fast* convergence and ease to implement
- Equal-cost Layer 3 load balancing on all links
- No spanning tree required for convergence
- No HSRP or GLBP configuration required
- No VLAN spanning possible

Layer 3 Access to Distribution Interconnection

- A routing protocol (i.e., EIGRP) can achieve better convergence results than designs that rely on STP to resolve convergence events.
  - A routing protocol can even achieve better convergence results than the time-tested design placing the Layer 2 to Layer 3 boundary at the distribution layer.
- The design is easier to implement than configuring Layer 2 in the distribution layer because you do not need to align STP with HSRP or GLBP.
  - No HSRP or GLBP configuration.
- VLANs can not span access switches in this design.

Layer 3 Access to Distribution Interconnection

- This design supports equal-cost Layer 3 load balancing on all links between the network switches.
- Because this switch is a multilayer switch, it serves as the default gateway for the end users.
  - VLANs cannot span access switches.

Drawback:

- Some additional complexity associated with uplink IP addressing and subnetting as well as the loss of flexibility are associated with this design alternative.
- Deploying a Layer 3 access layer may be **prohibited** because of conformance with the existing architecture, price of multilayer switches, and application or service requirements.

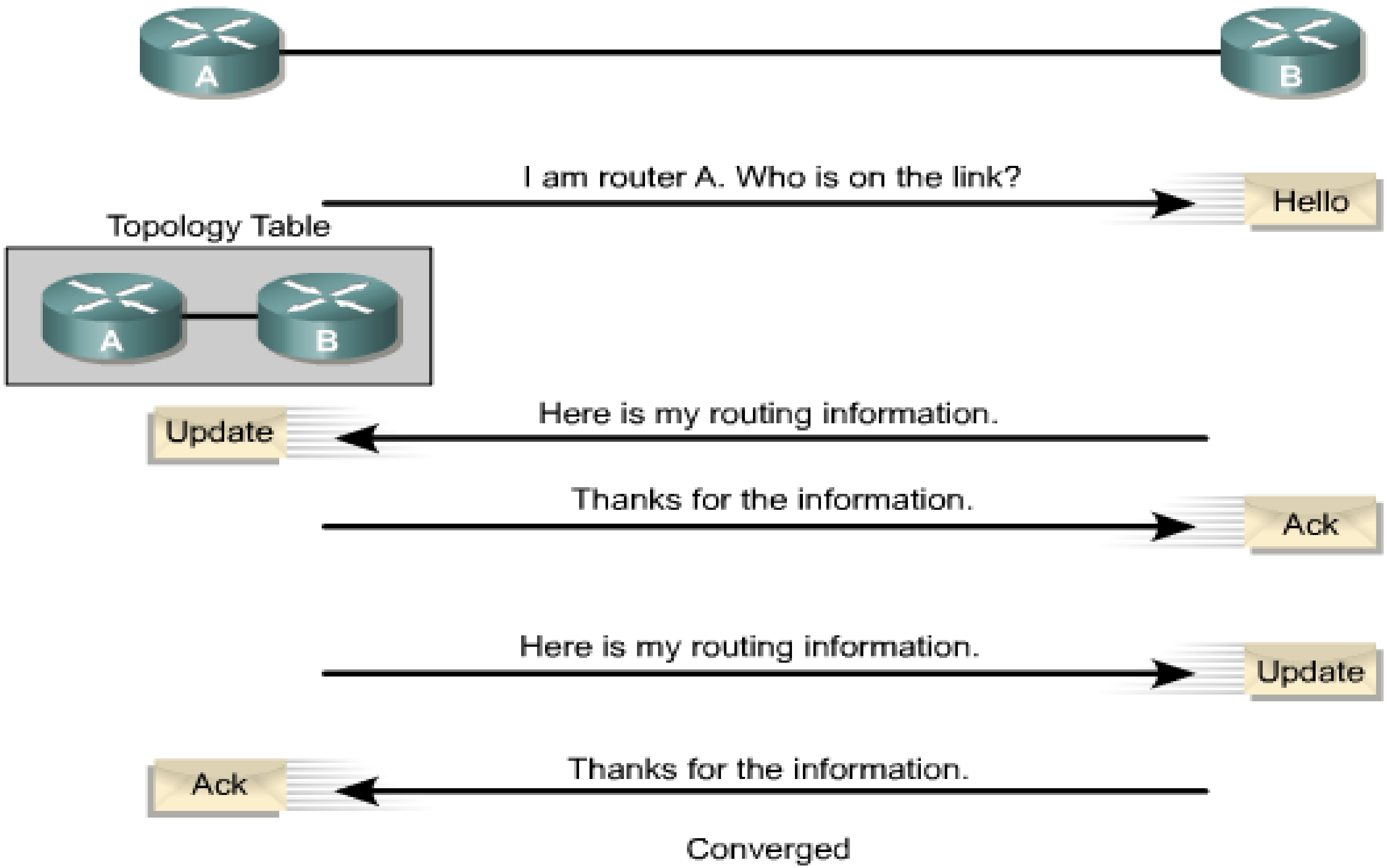
Enhanced Interior Gateway Protocol (EIGRP)

- Released in 1994 as successor to IGRP and compatible with IGRP.
- Hybrid routing protocol with best of distance vector algorithms.
  - Each node has information only about the next hop.
- Uses partial updates and neighbors discovery.
- Like OSPF but easier to configure.
- Good for large multiprotocol networks that primarily use Cisco routers.

EIGRP key features

- EIGRP automatically shares routing information with IGRP and vice versa
- Rapid convergence from Diffused Updating Algorithm (DUAL)
- Guaranteed no loops – all routers running EIGRP update at the same time if change occurs
- Efficient use of BW – partial incremental updates only
- Sent only to routers that need information – not all routers

Neighbour Discovery and Rediscovery



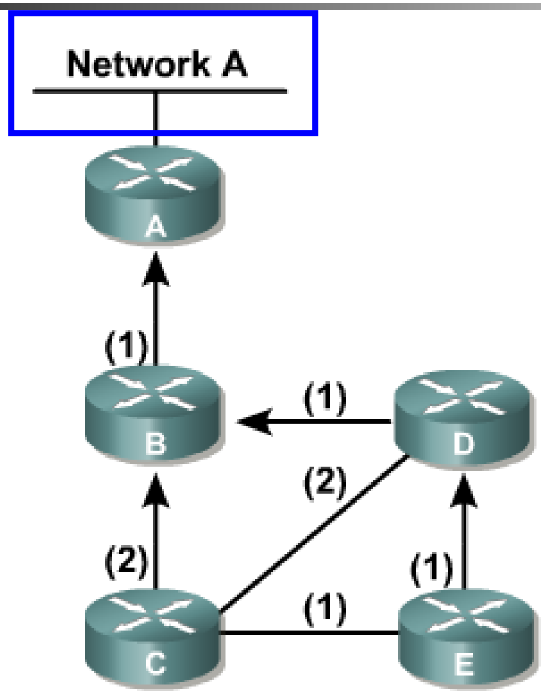
Diffusing Update Algorithm (DUAL)

- Successor
  - 到目標的最佳路徑
- Feasible successor (FS)
  - 到目標的次佳路徑
  - 亦即Reported Distance (RD) ≤ Feasible Distance (FD)
- Passive route
  - 穩定可用的路徑
- Active route
  - 不穩定，仍在計算中的路徑
  - 當勝利路徑失效，並找不到合適最佳路徑時

Select Routes

- If a link goes down, DUAL looks for an alternative route path, or feasible successor, in the topology table.
- If a feasible successor is not found, the route is flagged as Active, or unusable at present.
- Query packets are sent to neighboring routers requesting topology information.
- DUAL uses this information to recalculate successor and feasible successor routes to the destination.

DUAL (1)



Numbers in () = metric

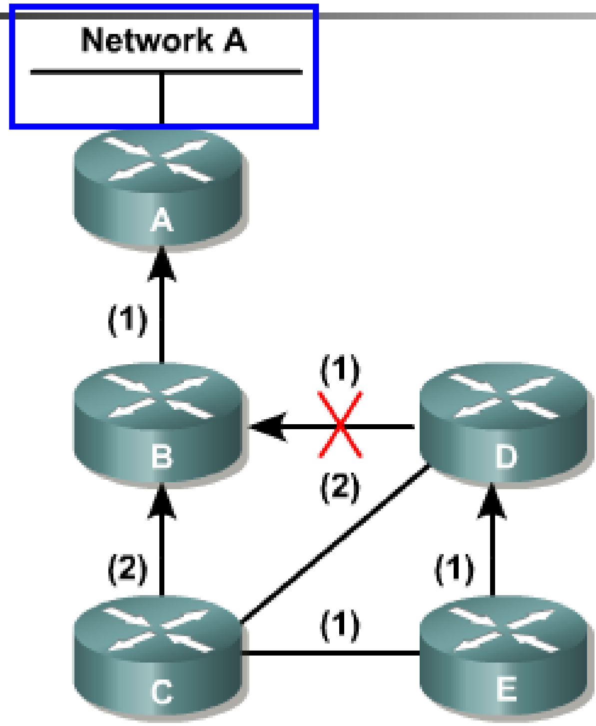
C EIGRP	FD	RD	Topology
Network A	3		(FD)
via B	3	1	(Successor)
via D	4	2	(FS)
via E	4	3	

D EIGRP	FD	RD	Topology
Network A	2		(FD)
via B	2	1	(Successor)
via C	5	3	

E EIGRP	FD	RD	Topology
Network A	3		(FD)
via D	3	2	(Successor)
via C	4	3	

Legend	
EIGRP	Protocol Type
FD	Feasible Distance
RD	Reported Distance as advertised by neighbor router
Successor	Primary Route to Destination
FS	Feasible Successor - Backup route to Destination

DUAL(2)



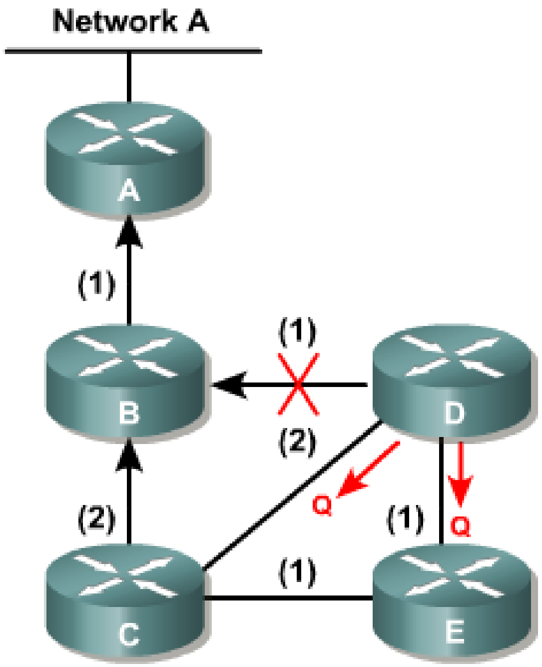
C	EIGRP	FD	RD	Topology
Network A		3		(FD)
	via B	3	1	(Successor)
	via D	4	2	(FS)
	via E	4	3	

D	EIGRP	FD	RD	Topology
Network A		2		(FD)
	~~via B~~	~~2~~	~~1~~	~~(Successor)~~
	via C	5	3	

E	EIGRP	FD	RD	Topology
Network A		3		(FD)
	via D	3	2	(Successor)
	via C	4	3	

Legend	
C	Destination
EIGRP	Protocol Type
FD	Feasible Distance
RD	Reported Distance as advertised by neighbor router
Successor	Primary Route to Destination
FS	Feasible Successor - Backup Route to Destination

DUAL (3)



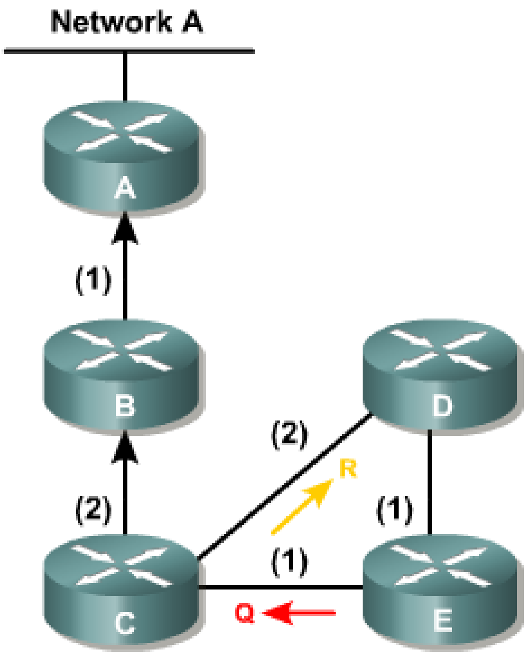
C EIGRP	FD	RD	Topology
Network A	3		(FD)
via B	3	1	(Successor)
via D			
via E	4	3	

D EIGRP	FD	R	Topology
Network A **ACTIVE**	-1	2	(FD)
via B			(q)
via C	5	3	(q)

E EIGRP	FD	RD	Topology
Network A	3		(FD)
~~via D~~	~~3~~	~~2~~	(Successor)
via C	4	3	

Legend	
EIGRP	Protocol Type
FD	Feasible Distance
RD	Reported Distance as advertised by neighbor router
Successor	Primary Route to Destination
FS	Feasible Successor - Backup Route to Destination

DUAL(4)



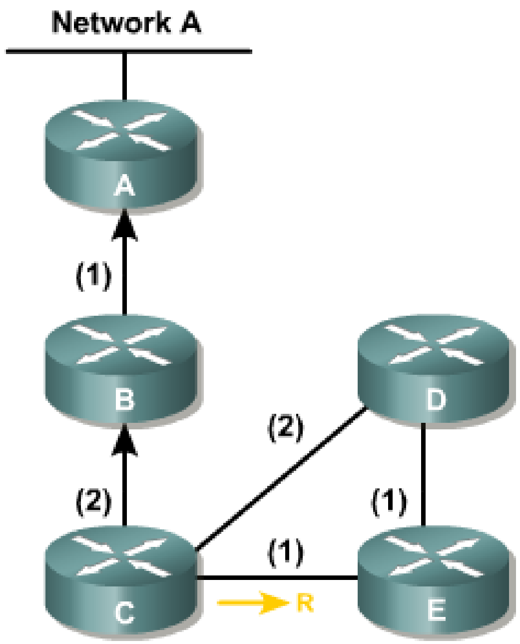
C EIGRP FD RD Topology
Network A 3 (FD)
via B 3 1 (Successor)
via D
via E

D EIGRP FD R Topology
Network A **ACTIVE** -1 (FD)
via B (q)
via C 5 3 (q)

E EIGRP FD R Topology
Network A **ACTIVE** -1 (FD)
via D
via C 4 3 (q)

Legend	
C	Destination
EIGRP	Protocol Type
FD	Feasible Distance
RD	Reported Distance as advertised by neighbor router
Successor	Primary Route to Destination
FS	Feasible Successor - Backup Route to Destination

DUAL(5)



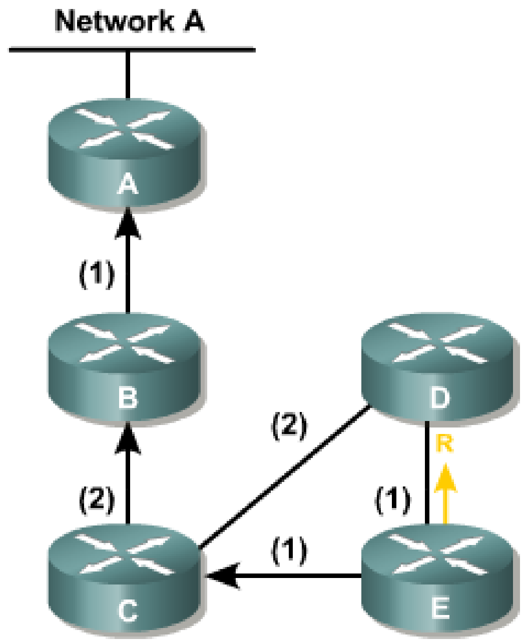
C	EIGRP	FD	RD	Topology
Network A		3		(FD)
	via B	3	1	(Successor)
	via D			
	via E			

D	EIGRP	FD	RD	Topology
Network A	**ACTIVE**	-1		(FD)
	via B			(q)
	via C	5	3	

E	EIGRP	FD	RD	Topology
Network A	**ACTIVE**	4		(FD)
	via C	4	3	(Successor)
	via D			

Legend	
C	Destination
EIGRP	Protocol Type
FD	Feasible Distance
RD	Reported Distance as advertised by neighbor router
Successor	Primary Route to Destination
FS	Feasible Successor - Backup Route to Destination

DUAL(6)



C EIGRP		FD	RD	Topology
Network A		3		(FD)
	via B	3	1	(Successor)
	via D			
	via E			

D EIGRP		FD	RD	Topology
Network A		5		(FD)
	via C	5	3	(Successor)
	via E	5	4	

E EIGRP		FD	RD	Topology
Network A		4		(FD)
	via C	4	3	(Successor)
	via D			

Legend	
C	Destination
EIGRP	Protocol Type
FD	Feasible Distance
RD	Reported Distance as advertised by neighbor router
Successor	Primary Route to Destination
FS	Feasible Successor - Backup Route to Destination

EIGRP to the Edge Design Recommendations

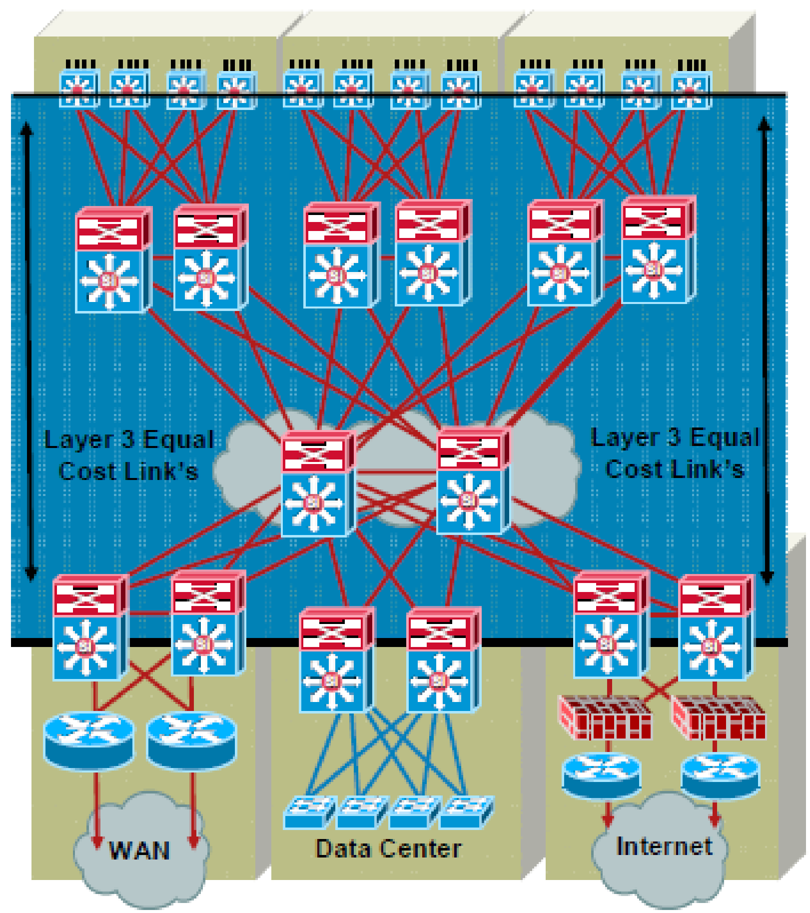
Enhanced Interior Gateway Routing Protocol

- When EIGRP is used as the routing protocol for a fully routed or routed access layer solution, with tuning EIGRP can achieve sub-200 ms convergence.
  - EIGRP to the edge is similar to EIGRP in the branch but tuned for speed
  - Limit scope of queries to a single neighbor
    - Summarize to campus core at the distribution layer
    - Control route propagation to edge switch via distribute lists
  - Configure all edge switches to use EIGRP 'stub'
  - Set hello and dead timers to '1' and '3'

Access Node EIGRP Configuration

```
interface GigabitEthernet1/1
 ip hello-interval eigrp 100 1
 ip hold-time eigrp 100 3

router eigrp 100
 eigrp stub connected
```



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EIGRP to the Edge Design Recommendations

- This confines impact of an individual access link failure to the distribution pair by stopping EIGRP queries from propagating beyond the core of the network.
  - Configure all edge switches to use **EIGRP stub**, so the edge devices are not queried by the distribution switches for routes.
  - EIGRP stub nodes are not able to act as transit nodes and do not participate in EIGRP query processing.

- When the distribution node learns through the EIGRP hello packet that it is talking to a stub node, it does not flood queries to that node.

EIGRP to the Edge Design Recommendations

- Control route propagation to edge switches using distribute lists.
  - The access switches only need a default route to the distribution switches.

- An outbound distribute list applied to all interfaces facing the access layer from the distribution switch will conserve memory and optimize performance at the access layer.

EIGRP stub

- stub receive-only
  - (optional) Sets the router as a receive-only neighbor.
- stub static
  - (optional) Advertises static routes.
- stub connected
  - (optional) Advertises connected routes.
- stub summary
  - (optional) Advertises summary routes.

OSPF to the Edge Design Recommendations

Open Shortest Path First (OSPF)

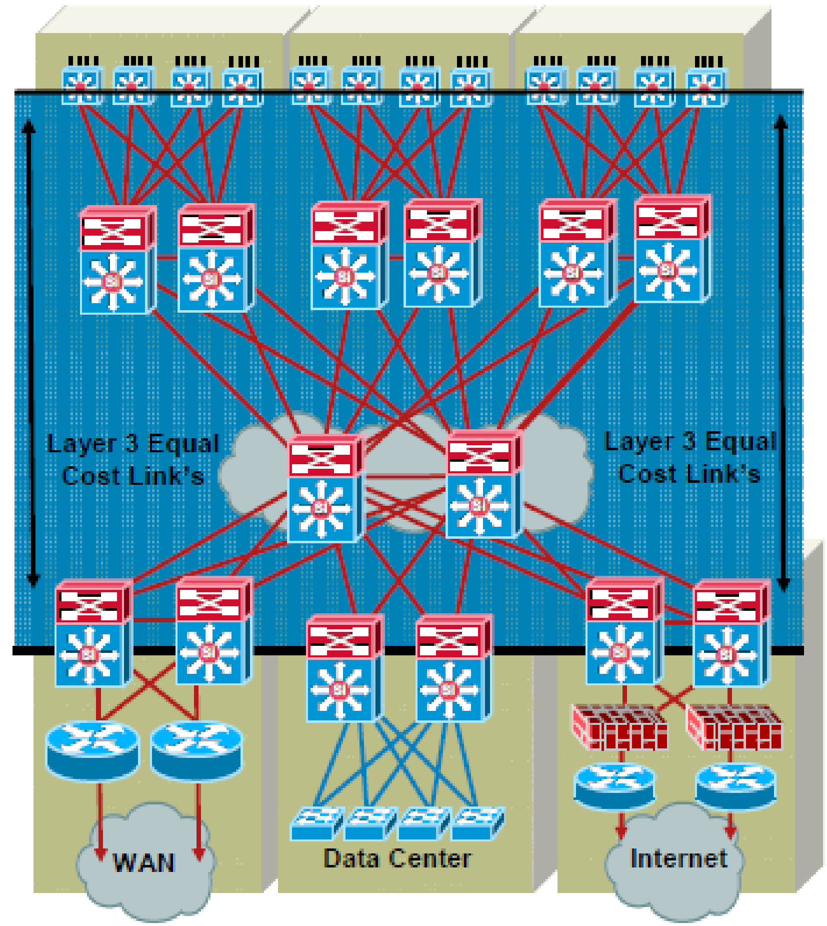
- When OSPF is used as the routing protocol for a fully routed or routed access layer solution with tuning OSPF can also achieve sub-200 ms convergence.

- OSPF in the distribution block is similar to OSPF in the branch but tuned for speed
- Control number of routes and routers in each area
- Configure each distribution block as a separate totally stubby OSPF area
- Do not extend area 0 to the edge switch
- Tune OSPF millisecond hello, dead-interval, SPF, and LSA throttle timers

Access Node OSPF Configuration

```
interface GigabitEthernet1/1
 ip ospf dead-interval minimal
 hello-multiplier 4

router ospf 100
 area 120 stub no-summary
 timers throttle spf 10 100
   5000
 timers throttle lsa all 10 100
   5000
 timers lsa arrival 80
```

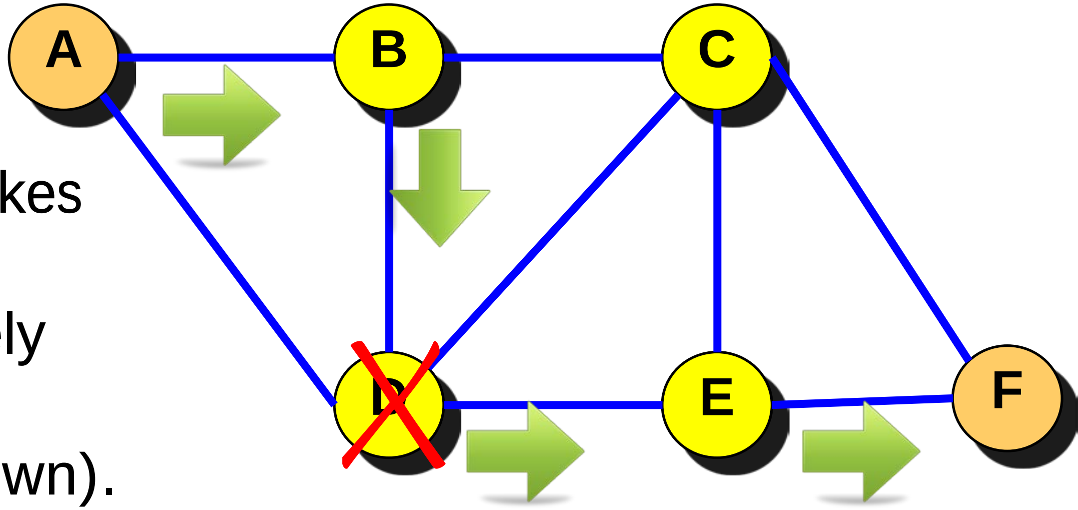


Dynamic Routing Protocol

Open Shortest Path First (OSPF) routing protocol.

Distance Vector vs. Link State Routing

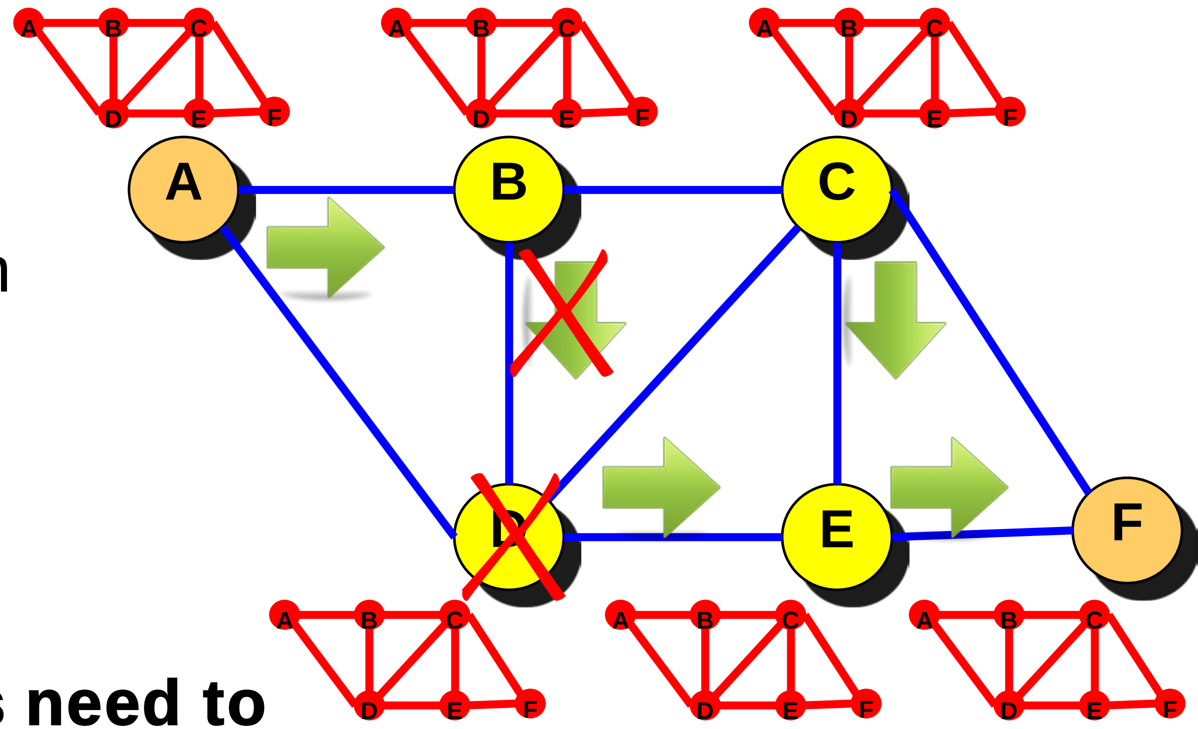
- Distance vector routing, each node has information only about the next hop:
  - Node A: to reach F go to B
  - Node B: to reach F go to D
  - Node D: to reach F go to E
  - Node E: go directly to F
- Distance vector routing makes poor routing decisions if directions are not completely correct (e.g., because a node is down).



- If parts of the directions incorrect, the routing may be incorrect until the routing algorithms has re-converged.

Distance Vector vs. Link State Routing

- <u>Link state routing</u>, <u>each node has a complete map of the topology</u>



- If a node fails, each node can calculate the new route

Difficulty: All nodes need to have a consistent view of the network

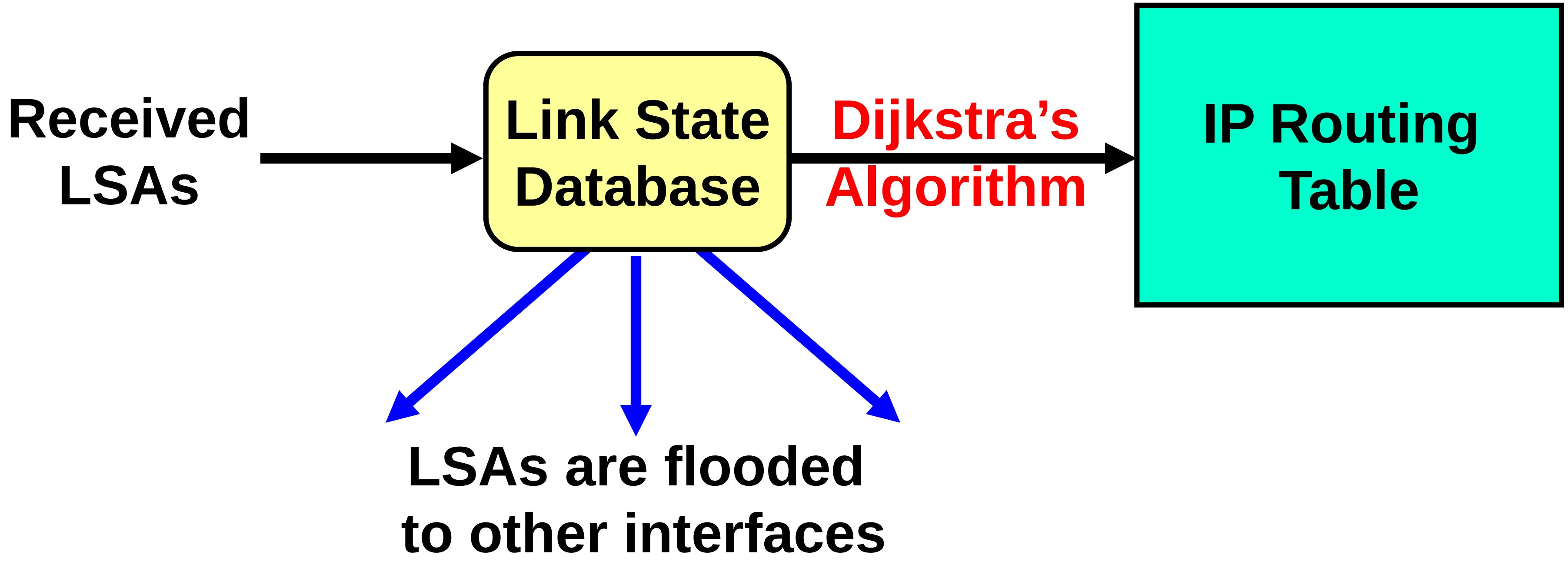
Link State Routing: Properties

- Each node requires complete topology information
- Link state information must be **flooded** to all nodes
- Guaranteed to converge

Link State Routing

- Basic princples
  1. Each router establishes a relationship ("adjacency") with its neighbors
  2. Each router generates link state advertisements (LSAs) which are distributed to all routers
     - LSA = (link id, state of the link, cost, neighbors of the link)
  3. Each router maintains a database of all received LSAs (topological database or link state database), which describes the network is a graph with weighted Edges
  4. Each router uses its link state database to run a shortest path algorithm (Dijkstra's algorithm) to produce the shortest path to each network

Operation of a Link State Routing protocol



Dijkstra's Algorithm for a Graph

Input: Graph (N,E) with

N : the set of nodes and E : the set of edges

d_{vw} : link cost (d_{vw} = infinity if $(v,w) \notin E$, $d_{vv} = 0$)

s : source node.

Output: D_n : cost of the least-cost path from node s to node n

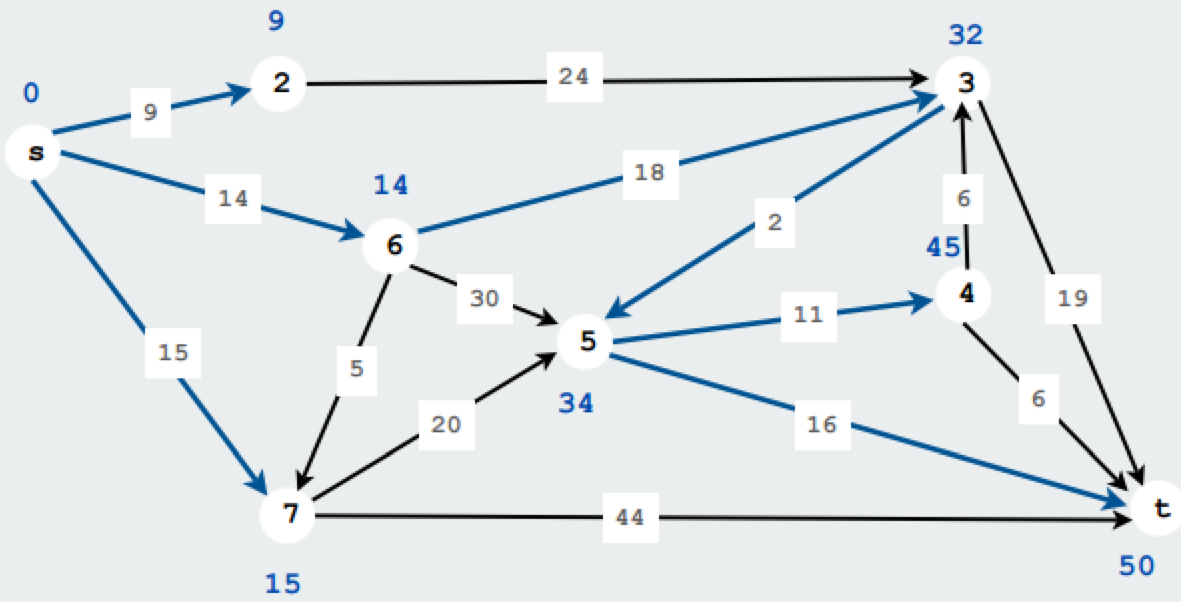
$M = \{s\}$;
for each $n \notin M$
    $D_n = d_{sn}$;
while ($M \neq$ all nodes) do
    Find $w \notin M$ for which $D_w = \min\{D_j \; ; \; j \notin M\}$;
    Add w to M;
    for each $n \notin M$
        $D_n = \min_w [\, D_n, D_w + d_{wn} \,]$;
        Update route;
end do

Single-source shortest-paths

Given. Weighted digraph, single source s.

Distance from s to v: length of the shortest path from s to v .

Goal. Find distance (and shortest path) from s to every other vertex.



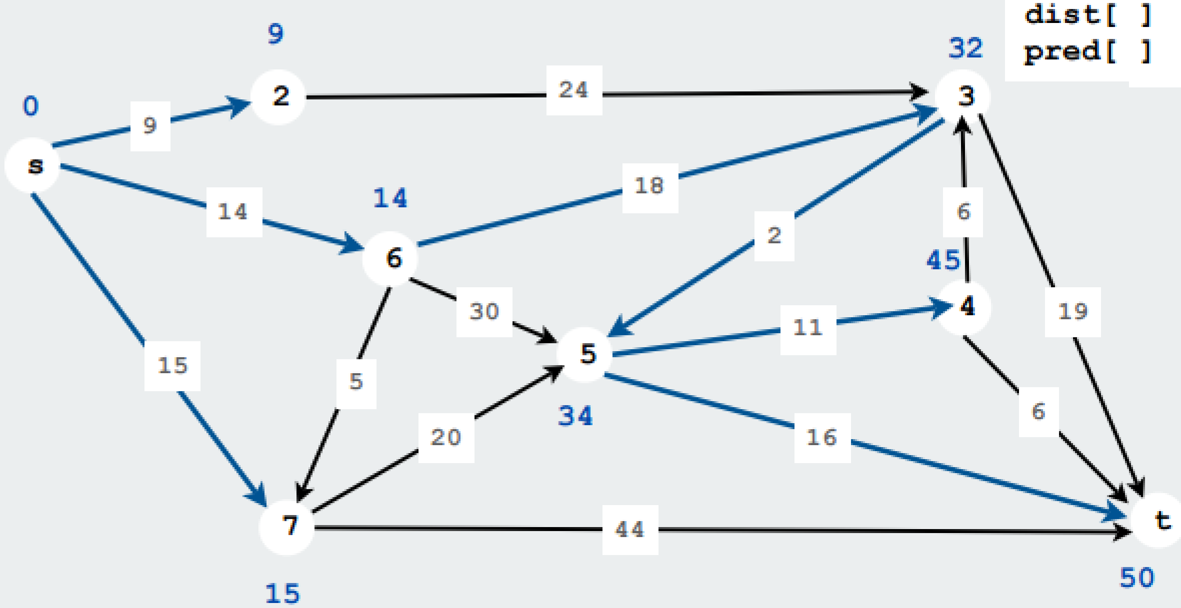
Shortest paths form a tree

Single-source shortest-paths: basic plan

Goal: Find distance (and shortest path) from `s` to every other vertex.

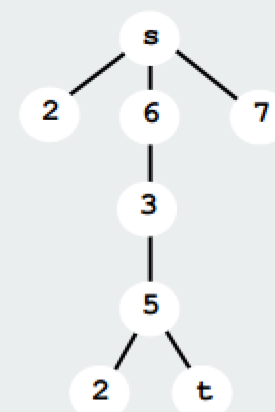
Design pattern:

- `ShortestPaths` class (`WeightedDigraph` client)
- instance variables: vertex-indexed arrays `dist[]` and `pred[]`
- client query methods return distance and path iterator



v	s	2	3	4	5	6	7	t
dist[ ]	0	9	32	45	34	14	15	50
pred[ ]	0	0	6	5	3	0	0	5

shortest path tree
(parent-link representation)



Note: Same pattern as Prim, DFS, BFS; BFS works when weights are all 1.

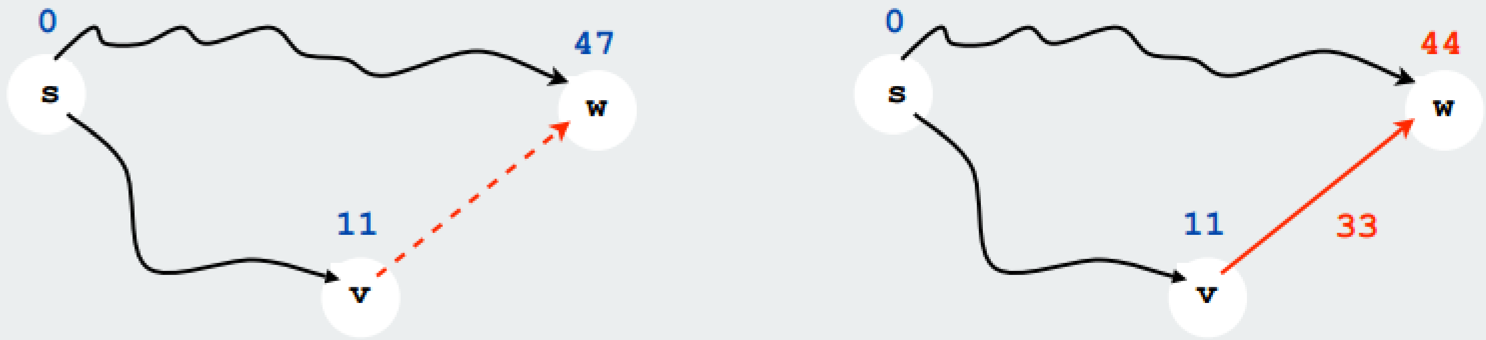
Edge relaxation

For all v, dist[v] is the length of some path from s to v.

Relaxation along edge e from v to w.

- dist[v] is length of some path from s to v
- dist[w] is length of some path from s to w
- if v-w gives a shorter path to w through v, update dist[w] and pred[w]

```
if (dist[w] > dist[v] + e.weight())
{
    dist[w] = dist[v] + e.weight();
    pred[w] = e;
}
```



Relaxation sets dist[w] to the length of a shorter path from s to w (if v-w gives one)

Dijkstra's algorithm

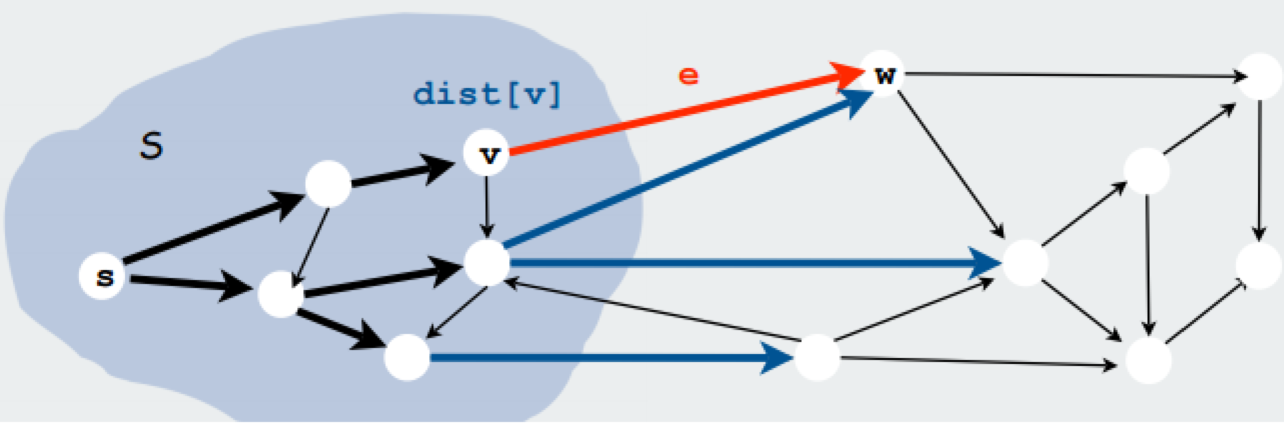
S: set of vertices for which the shortest path length from `s` is known.

Invariant: for `v` in S, `dist[v]` is the length of the shortest path from `s` to `v`.

Initialize S to `s`, `dist[s]` to `0`, `dist[v]` to ∞ for all other `v`

Repeat until S contains all vertices connected to `s`

- find `e` with `v` in S and `w` in S' that minimizes `dist[v] + e.weight()`
- relax along that edge
- add `w` to S



Dijkstra's algorithm

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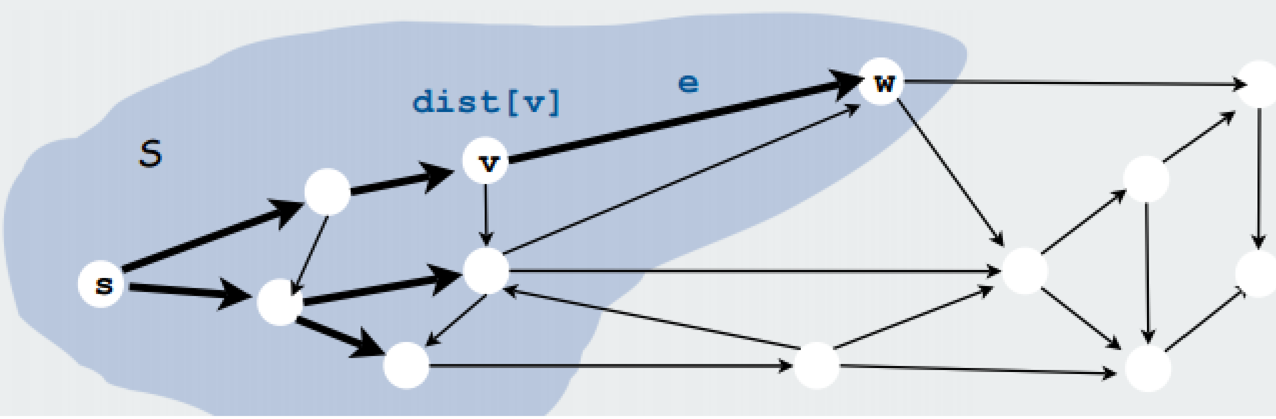
- relax along that edge
- add `w` to S



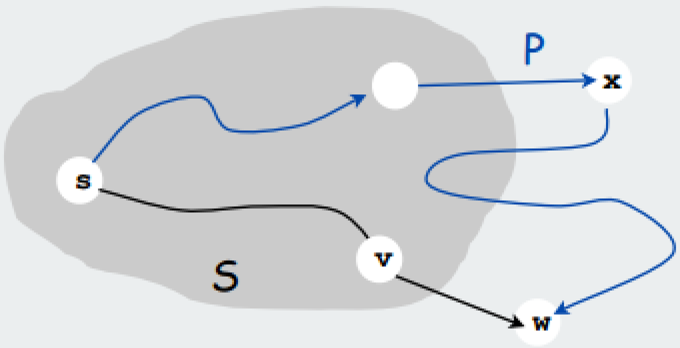
Dijkstra's algorithm proof of correctness

S: set of vertices for which the shortest path length from s is known.

Invariant: for v in S, `dist[v]` is the length of the shortest path from s to v.

Pf. (by induction on |S|)

- Let w be next vertex added to S.
- Let P* be the s-w path through v.
- Consider any other s-w path P, and let x be first node on path outside S.
- P is already longer than P* as soon as it reaches x by greedy choice.



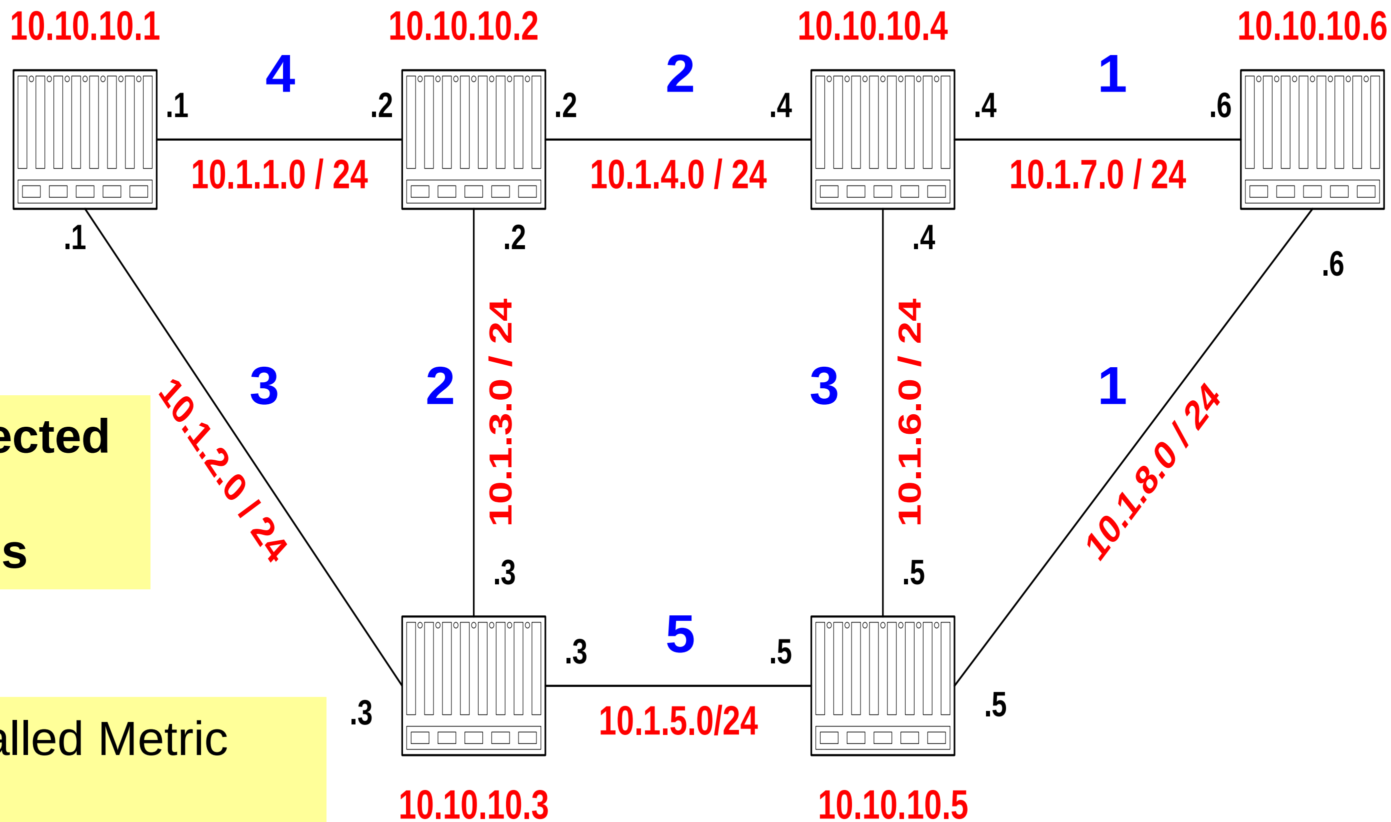
OSPF

- The OSPF routing protocol is the most important link state routing protocol on the Internet
- The complexity of OSPF is significant
- History:
  - 1989: RFC 1131 OSPF Version 1
  - 1991: RFC 1247 OSPF Version 2
  - 1994: RFC 1583 OSPF Version 2 (revised)
  - 1997: RFC 2178 OSPF Version 2 (revised)
  - 1998: RFC 2328 OSPF Version 2 (current version)

Features

- Provides authentication of routing messages
- Enables load balancing by allowing traffic to be split evenly across routes with equal cost
- Type-of-Service (TOS) routing allows to setup different routes dependent on the TOS field
- Supports subnetting
- Supports multicasting
- Allows hierarchical routing

Example Network



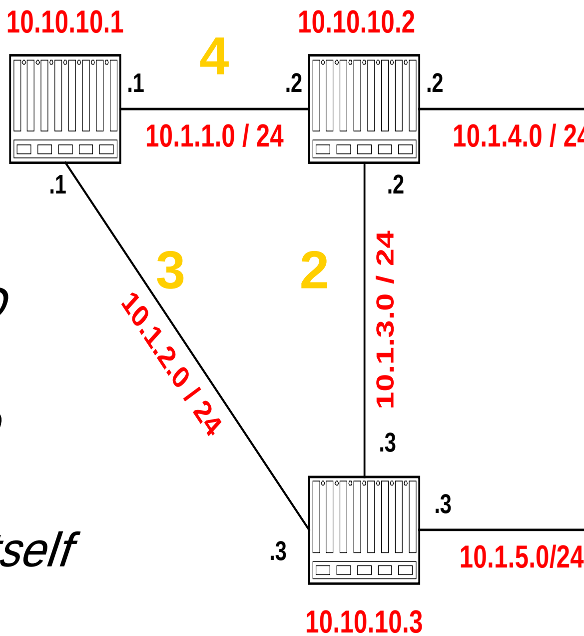
Router IDs are selected independent of interface addresses

1. Link costs are called Metric
2. Metric is in the range [0 , 2^{16}]
3. Metric can be asymmetric

LSA = (link id, state of the link, cost, neighbors of the link)

Link State Advertisement (LSA)

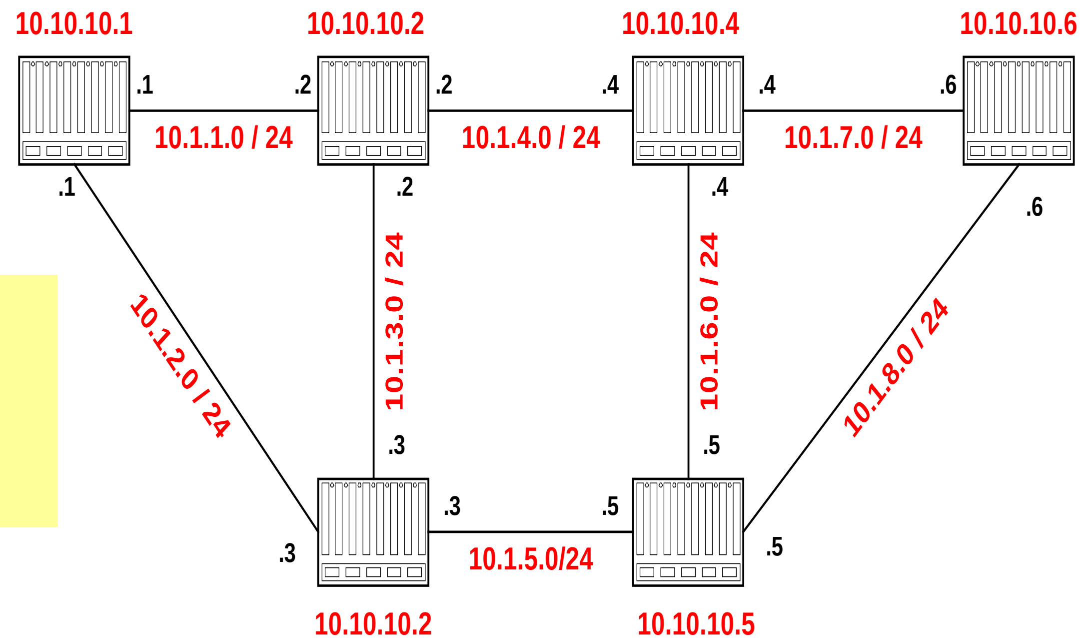
- The LSA of router 10.10.10.1 is as follows:



- **Link State ID**: 10.10.10.1 *= Router ID*
- **Advertising Router:** 10.10.10.1 *= Router ID*
- **Number of links:** 3 *= 2 links plus router itself*
- **Description of Link 1:** Link ID = 10.1.1.1, Metric = 4
- **Description of Link 2:** Link ID = 10.1.2.1, Metric = 3
- **Description of Link 3:** Link ID = 10.10.10.1, Metric = 0

Each router sends its LSA to all routers in the network (using a method called reliable flooding)

Network and Link State Database



Each router has a database which contains the LSAs from all other routers

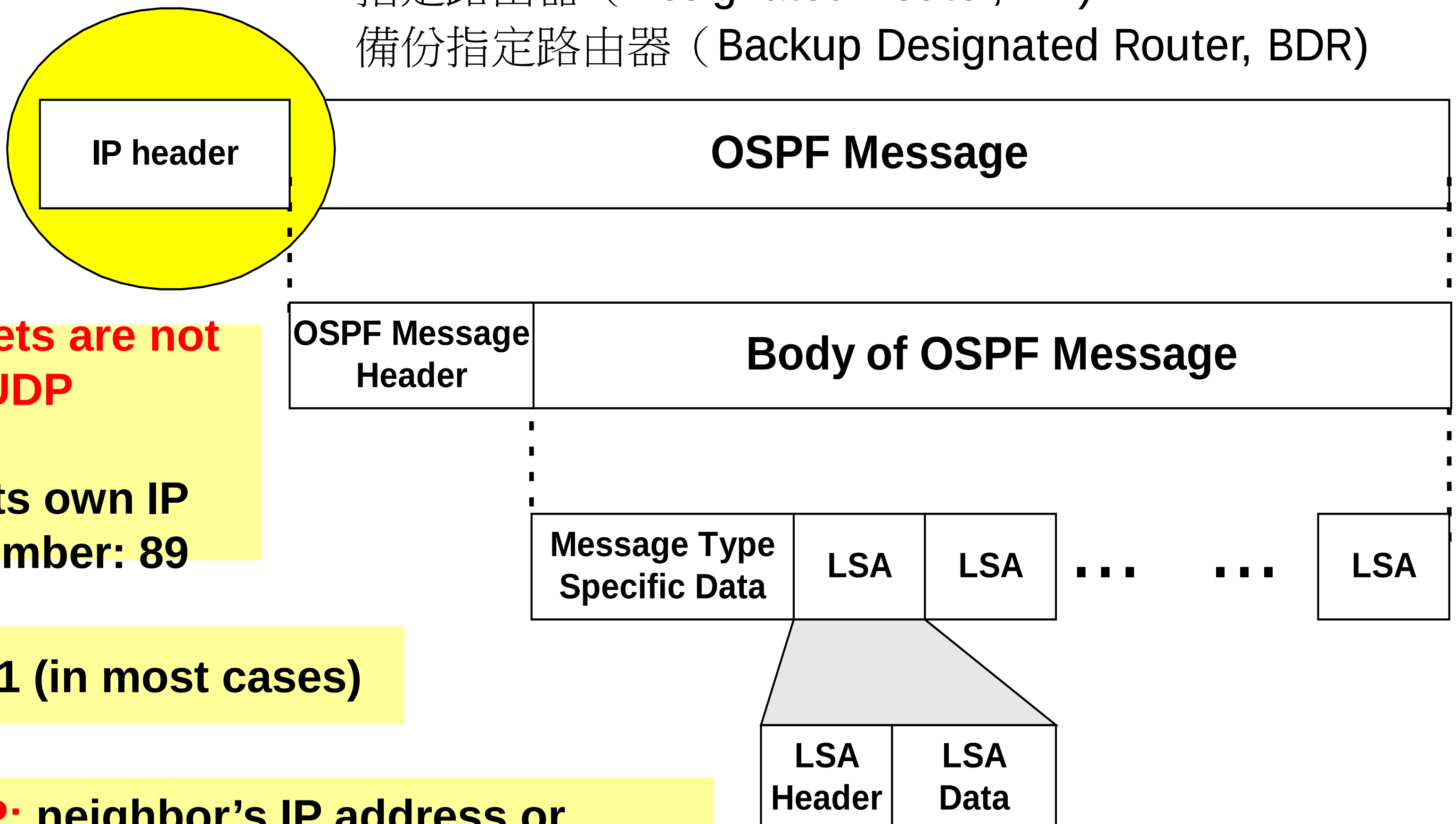
LS Type	Link StateID	Adv. Router	Checksum	LS SeqNo	LS Age
Router-LSA	10.1.10.1	10.10.10.1	0x9b47	0x80000006	0
Router-LSA	10.1.10.2	10.10.10.2	0x219e	0x80000007	1618
Router-LSA	10.1.10.3	10.10.10.3	0x6b53	0x80000003	1712
Router-LSA	10.1.10.4	10.10.10.4	0xe39a	0x8000003a	20
Router-LSA	10.1.10.5	10.10.10.5	0xd2a6	0x80000038	18
Router-LSA	10.1.10.6	10.10.10.6	0x05c3	0x80000005	1680

Link State Database

- The collection of all LSAs is called the link-state database
- Each router has an identical link-state database and has a complete description of the network
- If neighboring routers discover each other in the first time, they will exchange their link-state databases
- The link-state databases are synchronized using reliable flooding

OSPF Packet Format

指定路由器（Designated Router, DR)
備份指定路由器（Backup Designated Router, BDR)



OSPF packets are not carried as UDP payload!
OSPF has its own IP protocol number: 89

TTL: set to 1 (in most cases)

Destination IP: neighbor’s IP address or 224.0.0.5 (ALLSPFRouters) or 224.0.0.6 (All DRouters)

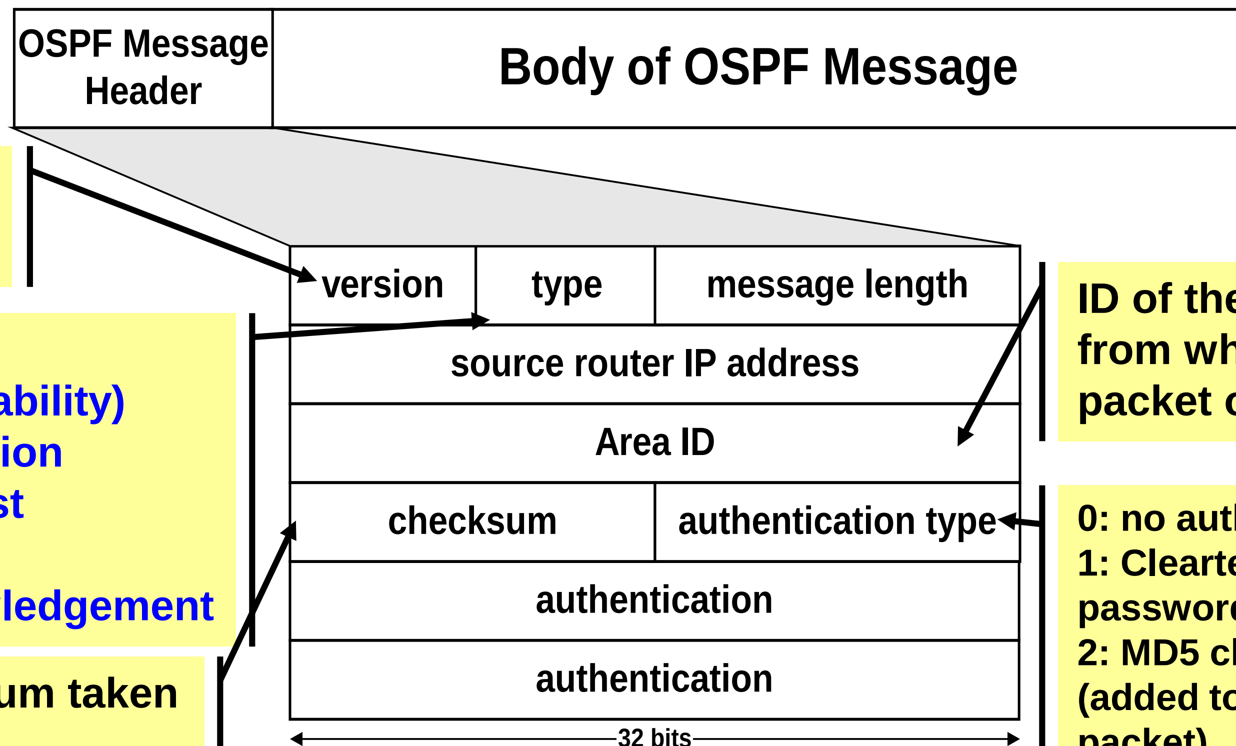
AllSPFRouters: Used to send OSPF messages to all OSPF routers on the same network.
AllDRouters: Used to send OSPF messages to all OSPF DRs (the DR and the BDR) on the same network.

OSPF Packet Format

- AllSPFRouters (224.0.0.5): Used to send OSPF messages to all OSPF routers on the same network.
  - The AllSPFRouters address is used for Hello packets.
- The designated router (DR) and backup designated router (BDR) use this address to send Link State Update and Link State Acknowledgment packets.

- AllDRouters (224.0.0.6): Used to send OSPF messages to all OSPF DRs (the DR and the BDR) on the same network.
- All OSPF routers except the DR use this address to send Link State Update and Link State Acknowledgment packets to the DR.

OSPF Packet Format



2: current version is OSPF V2

Message types:
1: Hello (tests reachability)
2: Database description
3: Link status request
4: Link state update
5: Link state acknowledgement

Standard IP checksum taken over entire packet

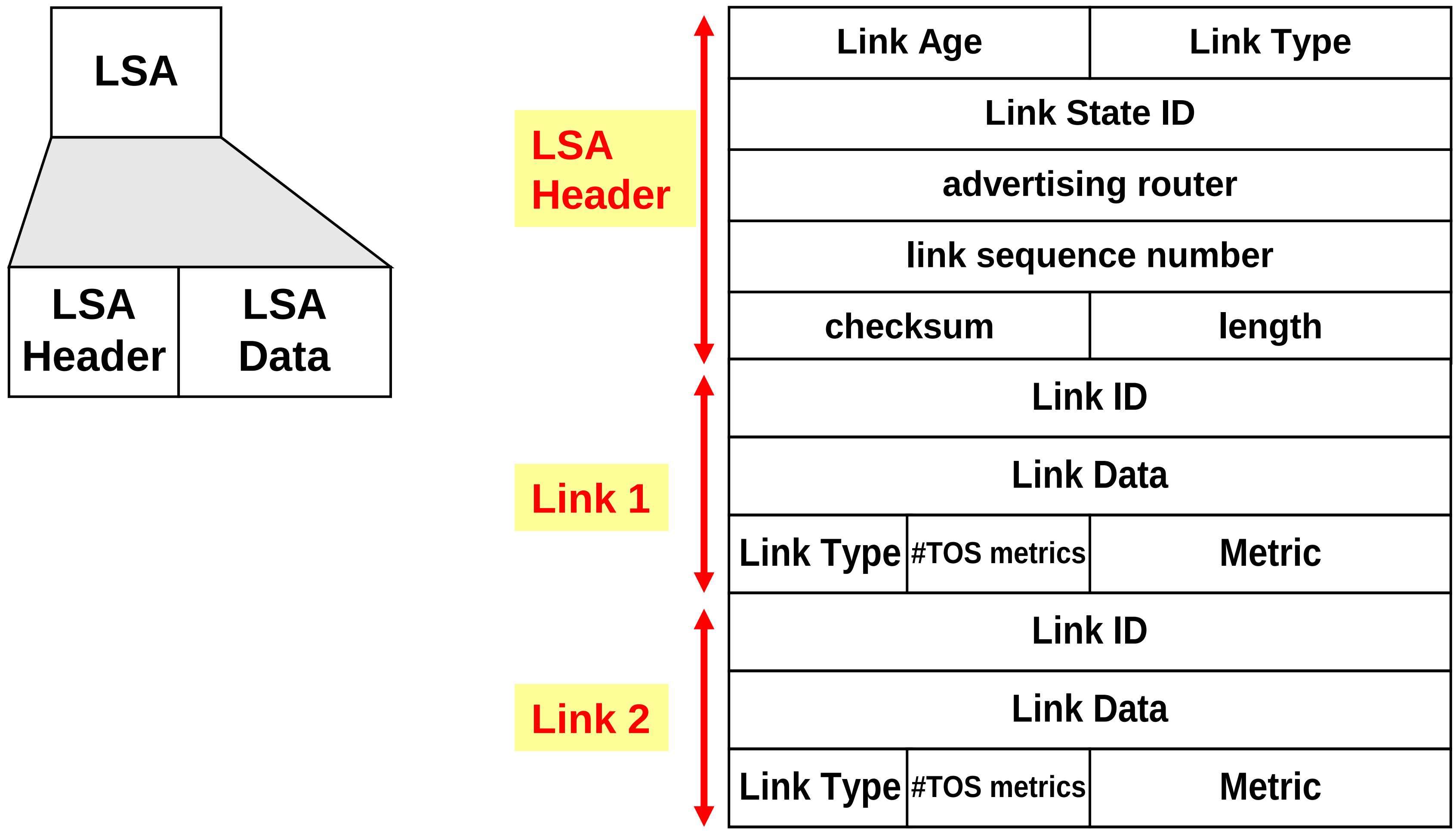
ID of the Area from which the packet originated

0: no authentication
1: Cleartext password
2: MD5 checksum (added to end packet)

Authentication passwd = 1: 64 cleartext password
Authentication passwd = 2: 0x0000 (16 bits)
KeyID (8 bits)
Length of MD5 checksum (8 bits)
Nondecreasing sequence number (32 bits)

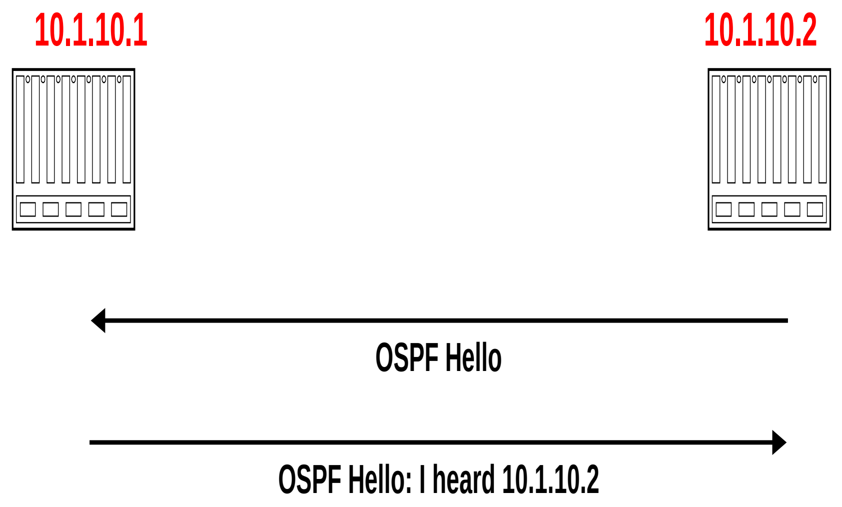
Prevents replay attacks

OSPF LSA Format



Discovery of Neighbors

- Routers multicasts OSPF Hello packets on all OSPF-enabled interfaces.
- If two routers share a link, they can become neighbors, and establish an adjacency

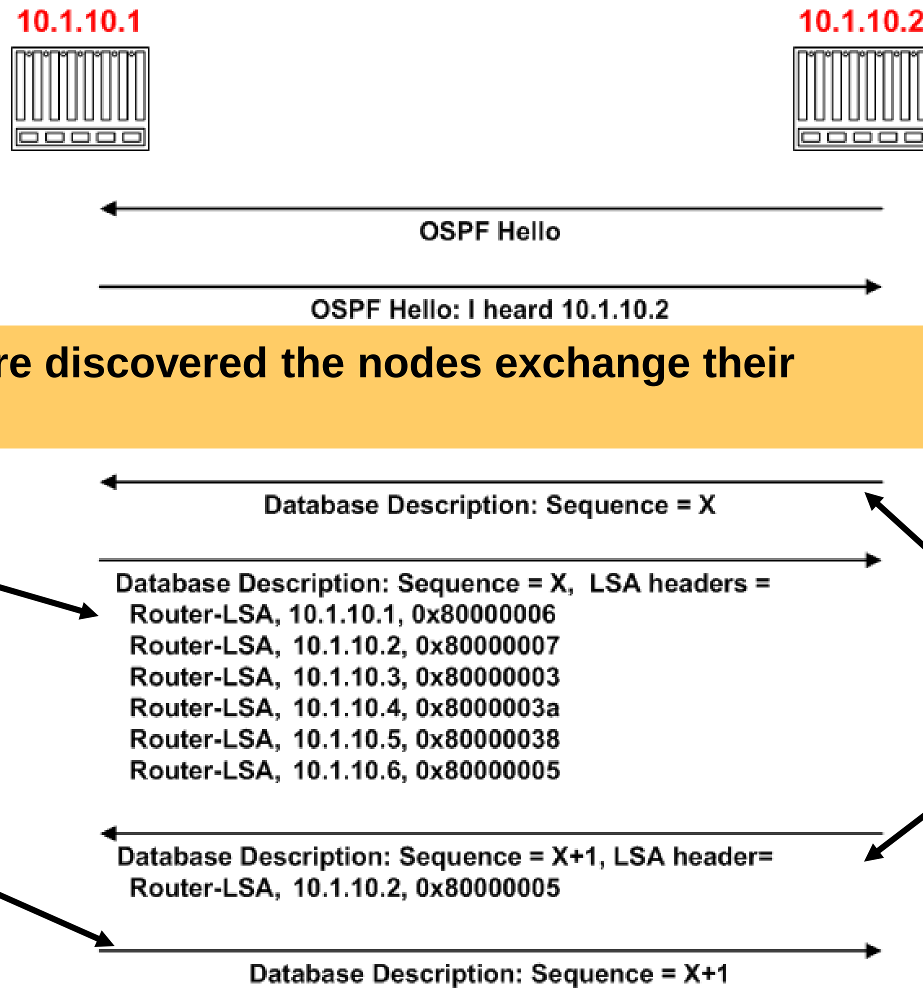


Scenario:
Router 10.1.10.2 restarts

- After becoming a neighbor, routers exchange their link state databases

Neighbor discovery and database synchronization

Scenario:
Router 10.1.10.2 restar



Discovery of adjacency

After neighbors are discovered the nodes exchange their databases

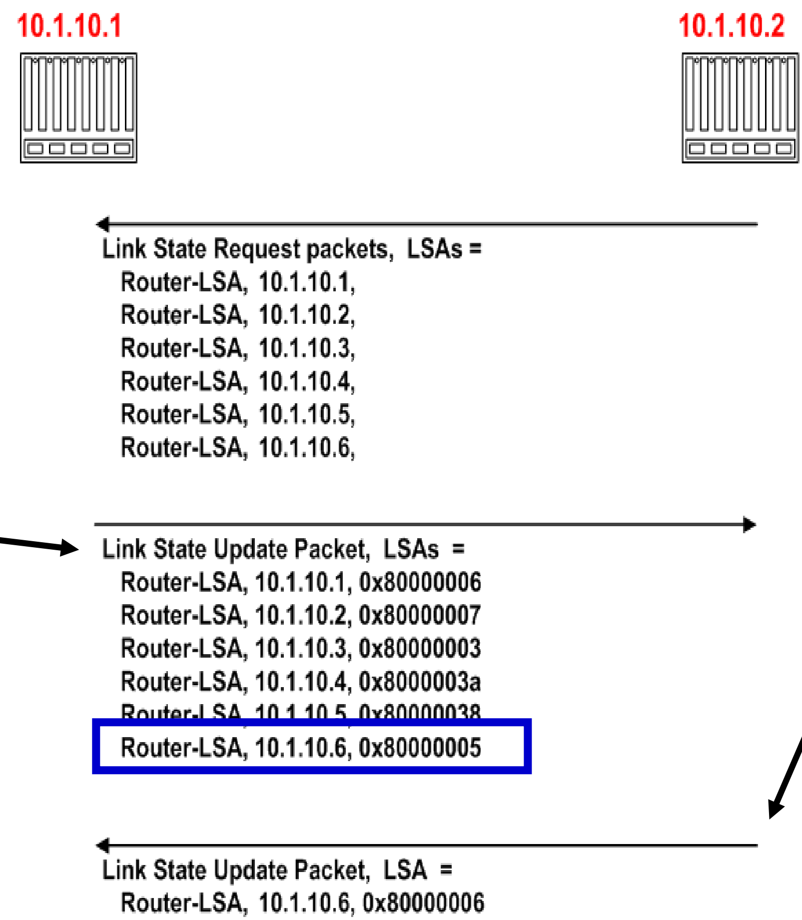
Sends database description. (description only contains LSA headers)

Sends empty database description

Database description of 10.1.10.2

Acknowledges receipt of description

Regular LSA exchanges



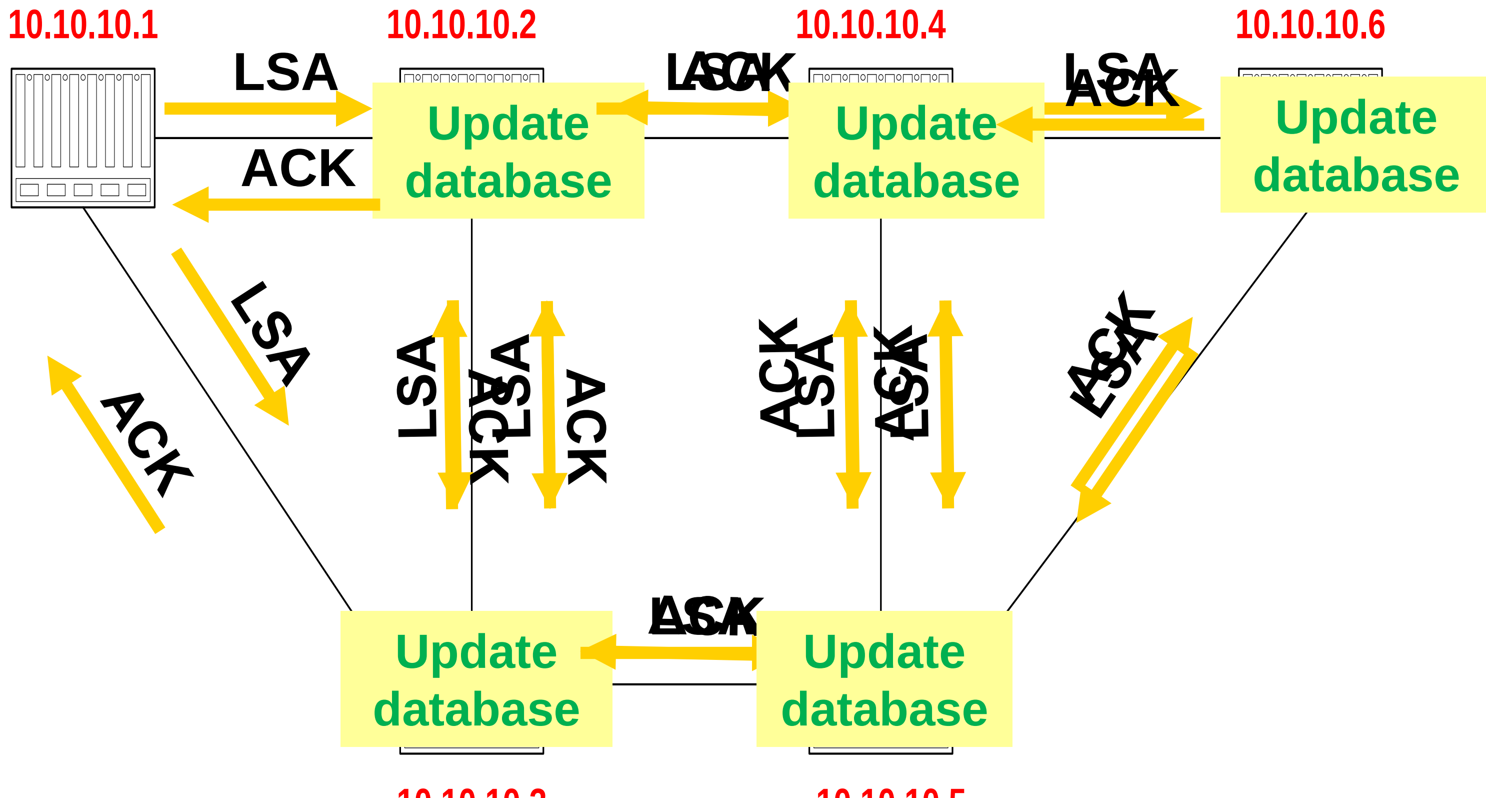
10.1.10.2 explicitly requests each LSA from 10.1.10.1

10.1.10.1 sends requested LSAs

10.1.10.2 has more recent value for 10.0.10.6 and sends it to 10.1.10.1 (with higher sequence number)

Routing Data Distribution

- LSA-Updates are distributed to all other routers via <u>Reliable Flooding</u>
- Example: Flooding of LSA from 10.10.10.1



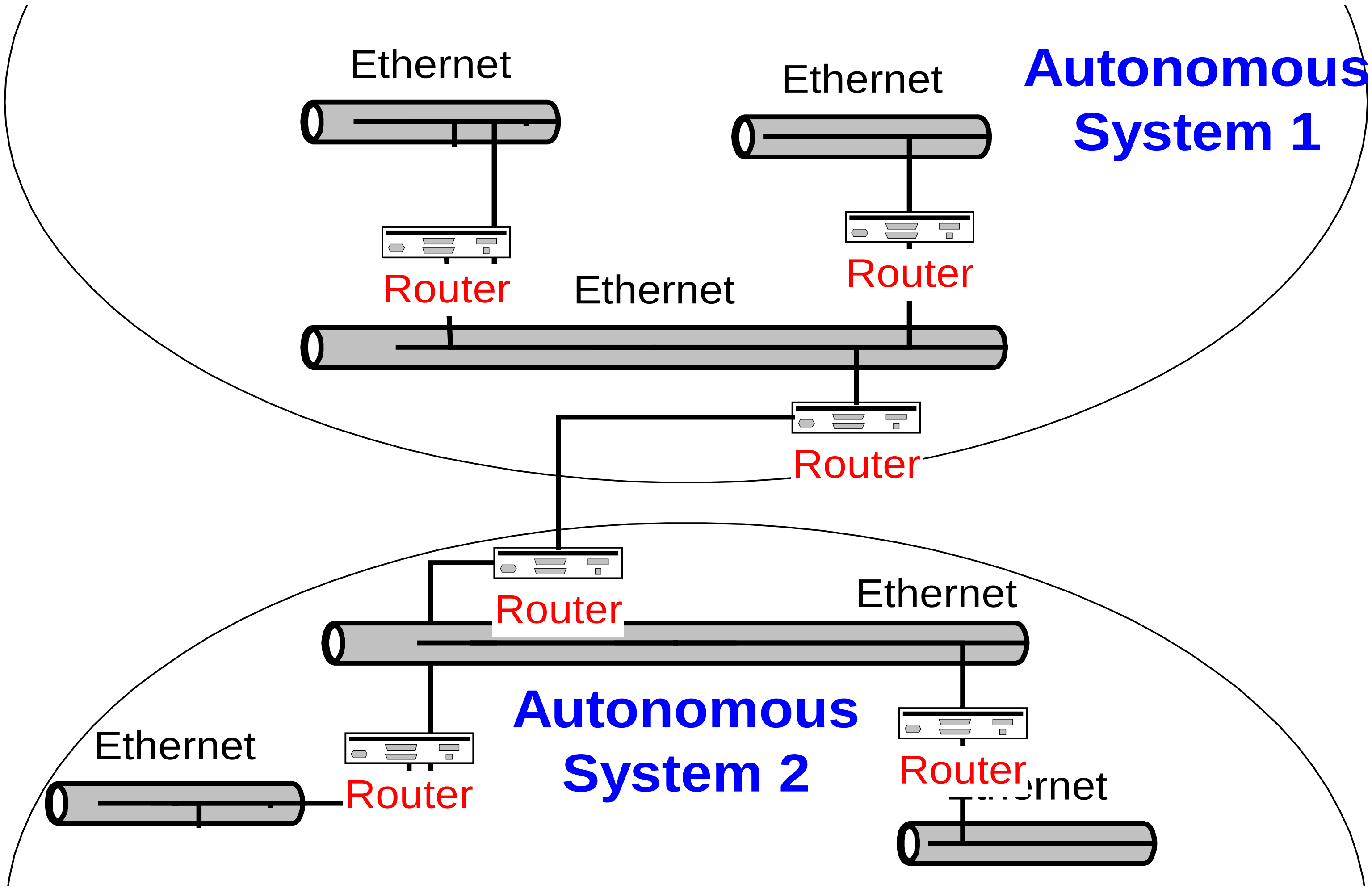
Dissemination of LSA-Update

- A router sends and refloods LSA-Updates, whenever the topology or link cost changes.
  - If a received LSA does not contain new information, the router will not flood the packet.
- Period change information: Infrequently (every 30 minutes), a router will flood LSAs even if there are not new changes.
- Acknowledgements of LSA-updates:
    - explicit ACK, or
    - implicit via reception of an LSA-Update

Autonomous Systems

- An **autonomous system** is a region of the Internet that is administered by a single entity.
- Examples of autonomous regions are:
  - Campus network
  - Backbone network
  - Regional Internet Service Provider
- Routing is done differently within an autonomous system (intradomain routing) and between autonomous system (interdomain routing).

Autonomous Systems (AS)



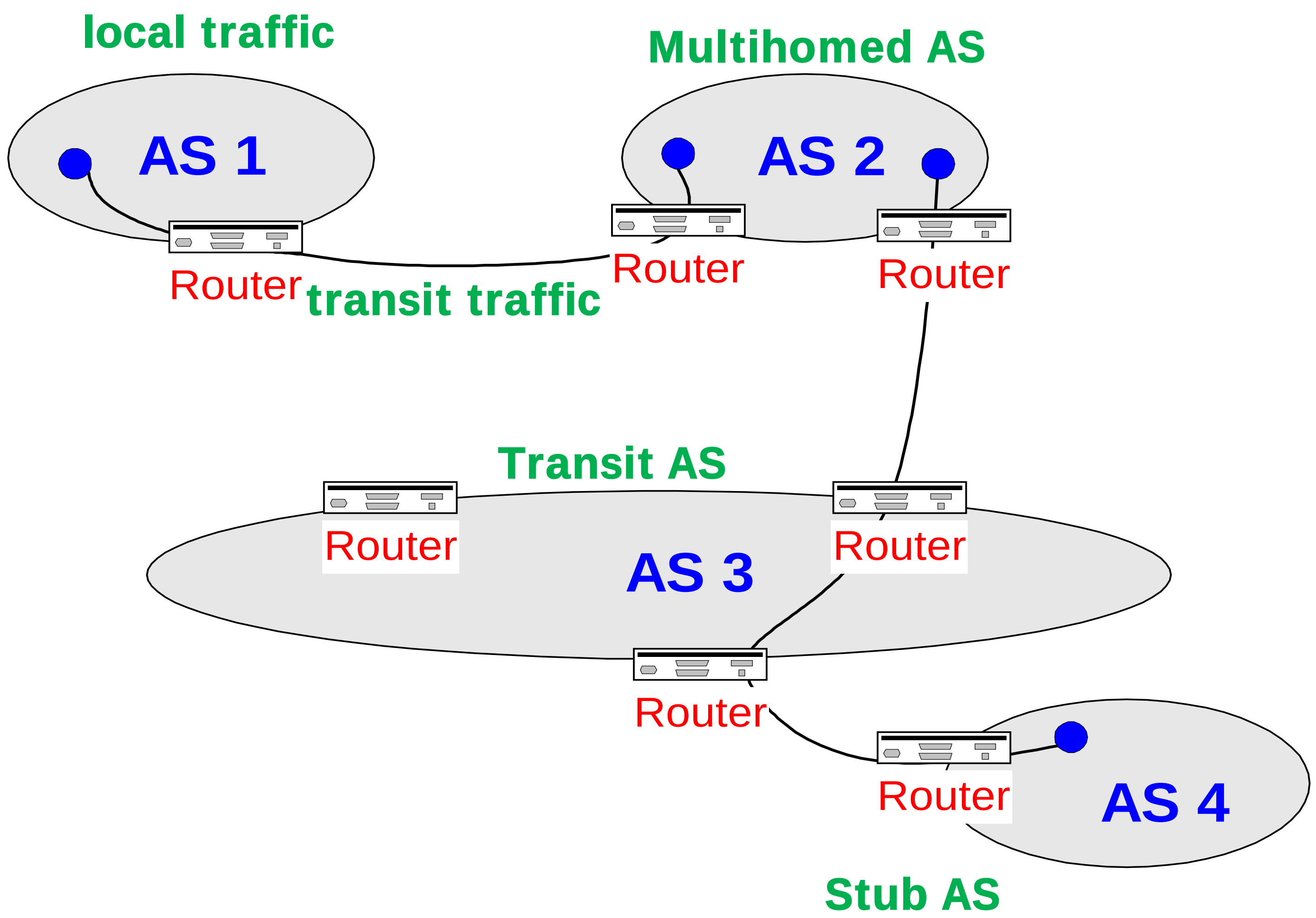
Border Gateway Protocol (BGP)

- Currently in version 4
- Note: In the context of BGP, a gateway is nothing else but an IP router that connects autonomous systems.
- **Border Gateway Protocol** (**BGP**) is a standardized exterior gateway protocol designed to exchange routing and reachability information among autonomous systems (AS) on the Internet.
- Interdomain routing protocol is used for routing between autonomous systems
  - Uses TCP to send routing messages
- BGP is neither a link state, nor a distance vector protocol.
- Routing messages in BGP contain complete routes.
- Network administrators can specify routing policies

BGP

- Since the internals of the AS are never revealed, finding an optimal path is not feasible.
- BGP's goal is to find any path (not an optimal one).
- For each autonomous system (AS), BGP distinguishes:
  - local traffic: traffic with source or destination in the same AS
  - transit traffic: traffic that passes through the AS
  - Stub AS: has connection to only one AS, only carry local traffic
  - Multihomed AS: has connection to >1 AS, but does not carry transit traffic
  - Transit AS: has connection to >1 AS and carries transit traffic

BGP



local traffic
Multihomed AS
AS 1
AS 2
Router
Router
Router
transit traffic
Transit AS
Router
Router
AS 3
Router
Router
AS 4
Stub AS

OSPF

- OSPF area: composed of routers and hosts.
- OSPF area are composed of the areas.
- Area 0 represents backbone area.
- OSPF must have an area 0.
- All areas have to connect with backbone area, and the all routes of same area are shared in this area.
- One router can belong to one or more areas.
- The all routes of same area have same topology.
- Using the area of hierarchy architecture: only effect on self-area, fast convergence, scalable, robust.

OSPF

- Hierarchy architecture:
  - backbone router: the router of area 0
  - internal router: the inner routers of the same area
  - ABR (area broder router): each interface connects to different areas, but at least one interface connects with area 0.
  - ASBR (autonomous system border router): connect with other as, and imports other as's (Autonomous System) routing information into own OSPF.
- Advantage:
  - confine network instability to an area(可將網路的不穩定性限制在一區域內)
  - speed up convergence
  - decrease routing overhead
  - improve performance
- Disadvantage:
  - Design complexity.

OSPF to the Edge Design Recommendations

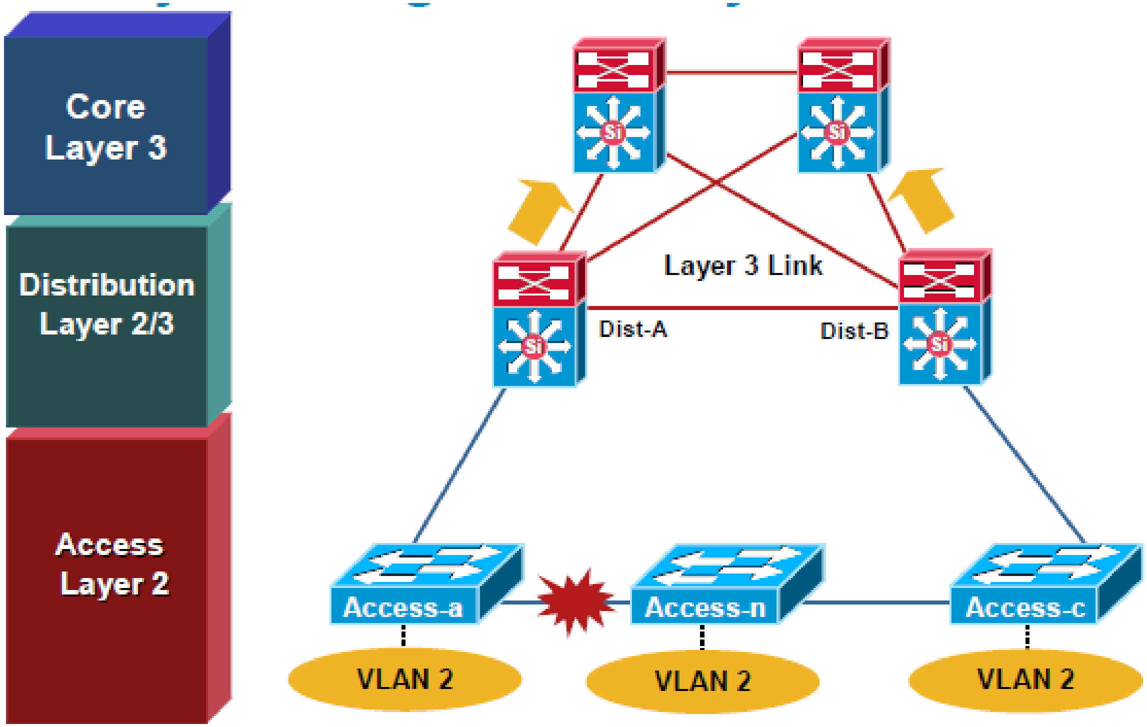
- Configure each distribution block as a separate totally stubby OSPF area.
- The distribution switches become Area Border Routers (ABRs) with their core-facing interfaces in area 0 and the access layer interfaces in unique totally stubby areas for each access layer switch.

- Each access layer switch is configured into its own unique totally stubby area.
- Link-state advertisements (LSAs) are isolated to each access layer switch, so that a link flap for one access layer switch is not communicated beyond the distribution pairs.

Potential Design Issues

Daisy Chaining Access Layer Switches

- Multiple fixed-configuration switches are **daisy chained** together in the access layer.
- There is a danger that black holes occur in the event of a link or node failure.



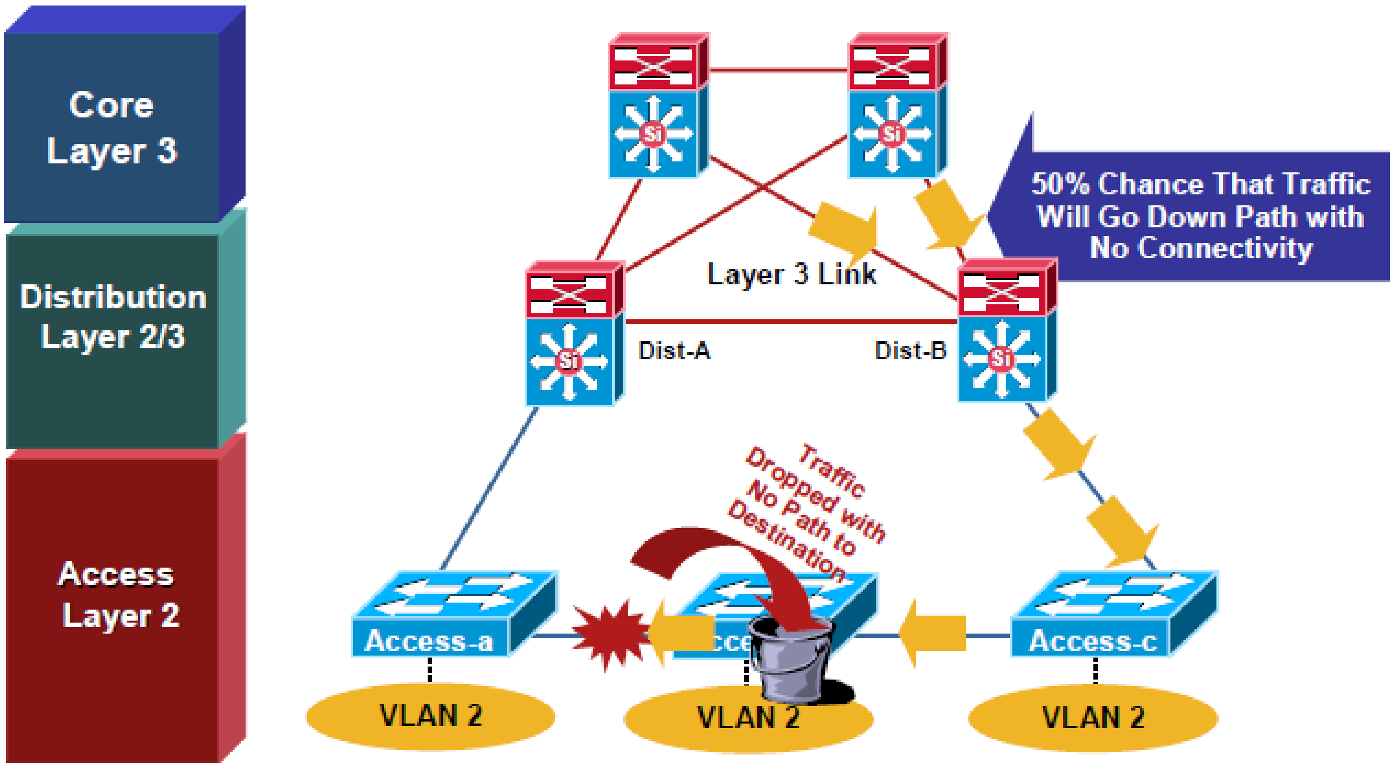
- Primary and secondary HSRP is active after failure
- Outbound traffic sent from both HSRP instances

Potential Design Issues

- Both distribution nodes can forward traffics from the rest of the network towards the access layer.
- If a link or node in the middle of the chain or stack fails, two scenarios can occur
    1. First case, the standby HSRP peer can go active as it loses connectivity to its primary peer, forwarding traffic outbound for the devices that still have connectivity to it.
    2. The primary HSRP peer remains active and also forwards outbound traffic for its half of the stack. It is also not detrimental from the perspective of outbound traffic.

Potential Design Issues

- The second scenario, return path traffic has a 50% chance of arriving on a distribution switch.
- The traffic that arrives on the wrong distribution switch is dropped.



- Potential for black holes if loopback cable is not used

Potential Design Issues

- To provide alternate connectivity across the stack in the form of a loop-back cable running from the top to the bottom of the stack.
  - This link needs to be carefully deployed so the appropriate STP behavior will occur in the access layer.

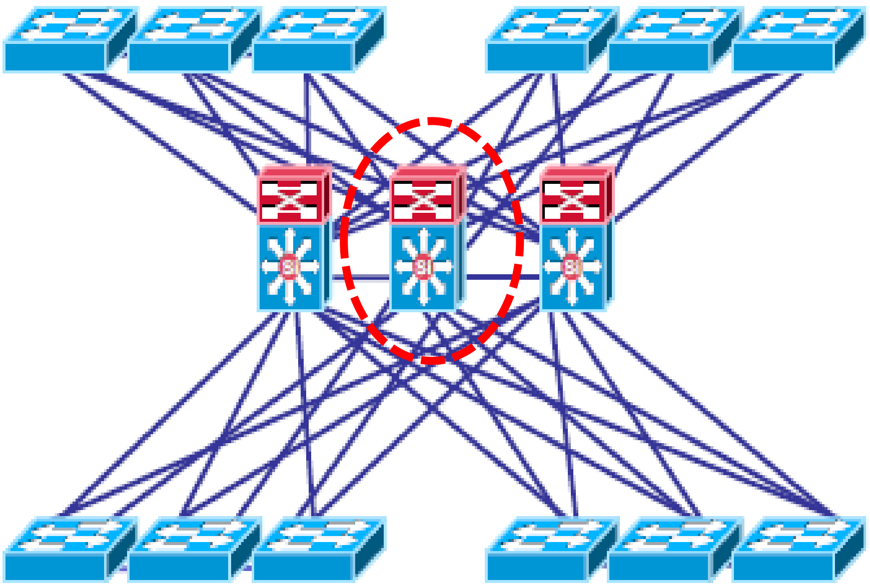
- An alternate design uses a Layer 2 link between the distribution switches.

Too Much Redundancy

- More redundancy is not necessarily better.

Too much redundancy can lead to design issues:

- Root placement
- Number of blocked links
- Convergence process
- Complex fault resolution

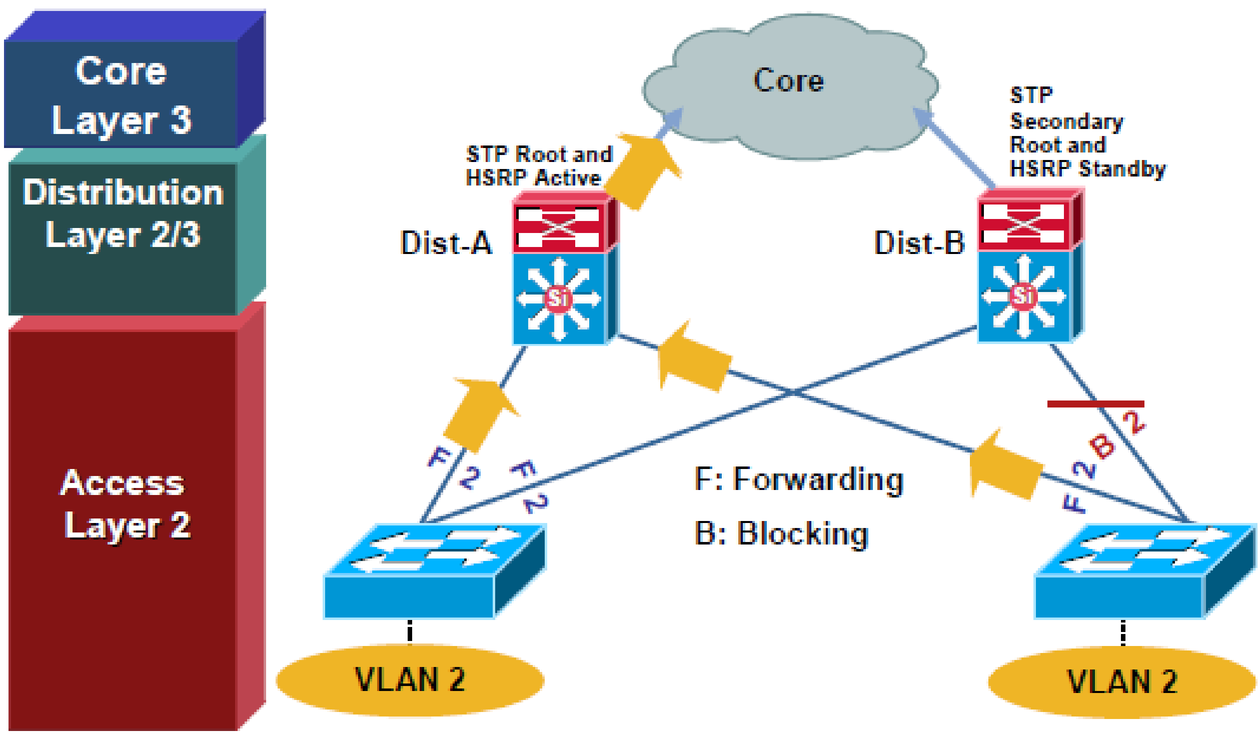


Added a New Switch

- A third switch is added to the distribution switches.
- This extra switch adds unneeded complexity to the design and leads to design questions:
  - Where should the root switch be placed?
    - It is not easy to determine where the root switch is located.
  - What links should be in a blocking state?
    - It is very hard to determine how many ports will be in a blocking state.
  - What are the implications of STP/RSTP convergence?
    - The network convergence is definitely not deterministic.
  - When something goes wrong, how do you find the source of the problem?
    - The design is much harder to troubleshoot.

Too Little Redundancy

- A link between the distribution layer switches is required for redundancy.



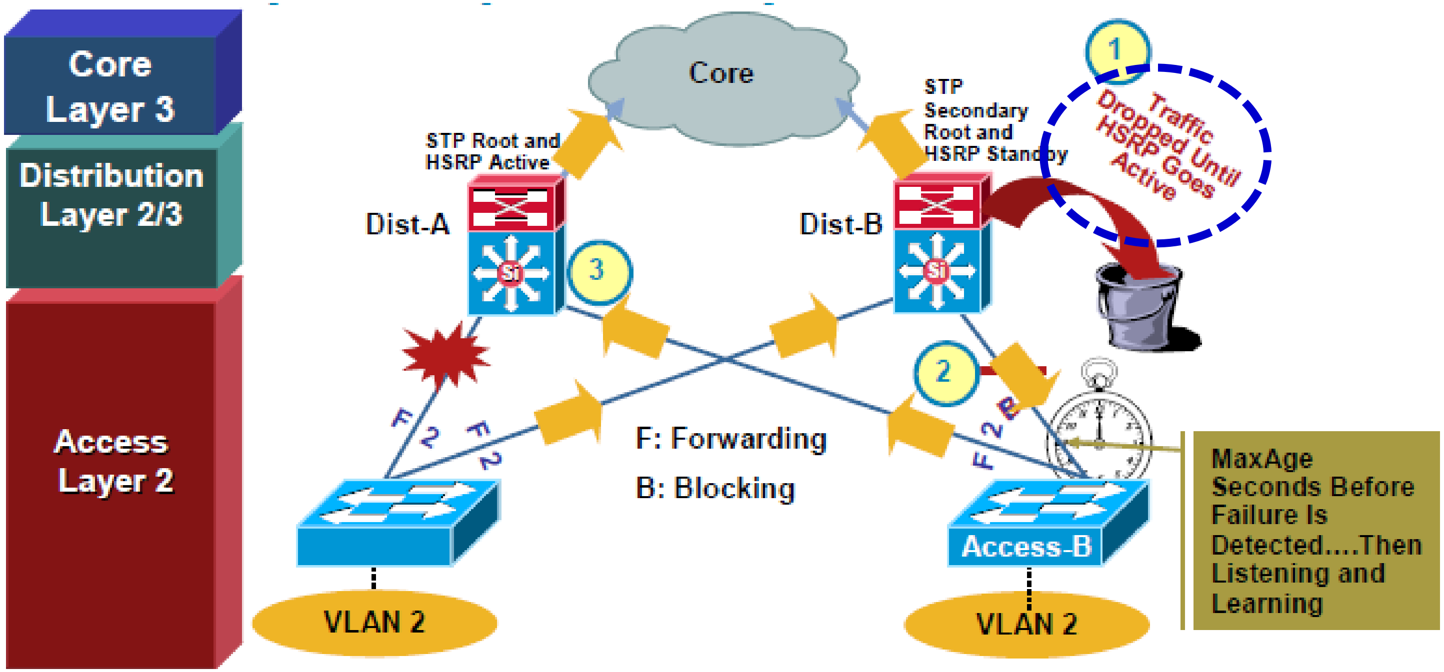
- Looped figure 8 topology for VLANs spanning access switches
- Blocking on uplink from Access-B
- Initially forwarding traffic

Without a Layer 2 Link

- Without a Layer 2 link between the distribution switches, the design is a looped topology.
  - One access layer uplink will be blocking.
- HSRP hellos are exchanged by transiting the access switches.
- Initially traffic is forwarded from both access switches to Dist-A switch which supports the STP root and the HSRP primary for VLAN 2.
- However, this design will be black hole traffic and be affected by multiple convergence events with a single network failure.

Example: Impact of an Uplink Failure

- Looks at the impact of an uplink failure on the design when there is **not** a link between the distribution layer switches.



- Traffic from Access-A will be dropped until HSRP goes active on Dist-B.
- Blocking link on Access-B will take 50 seconds to move to forwarding.
- After STP converges, HSRP preempt causes another transition. Access-B used as transit for Access-A traffic.

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Impact of an Uplink Failure

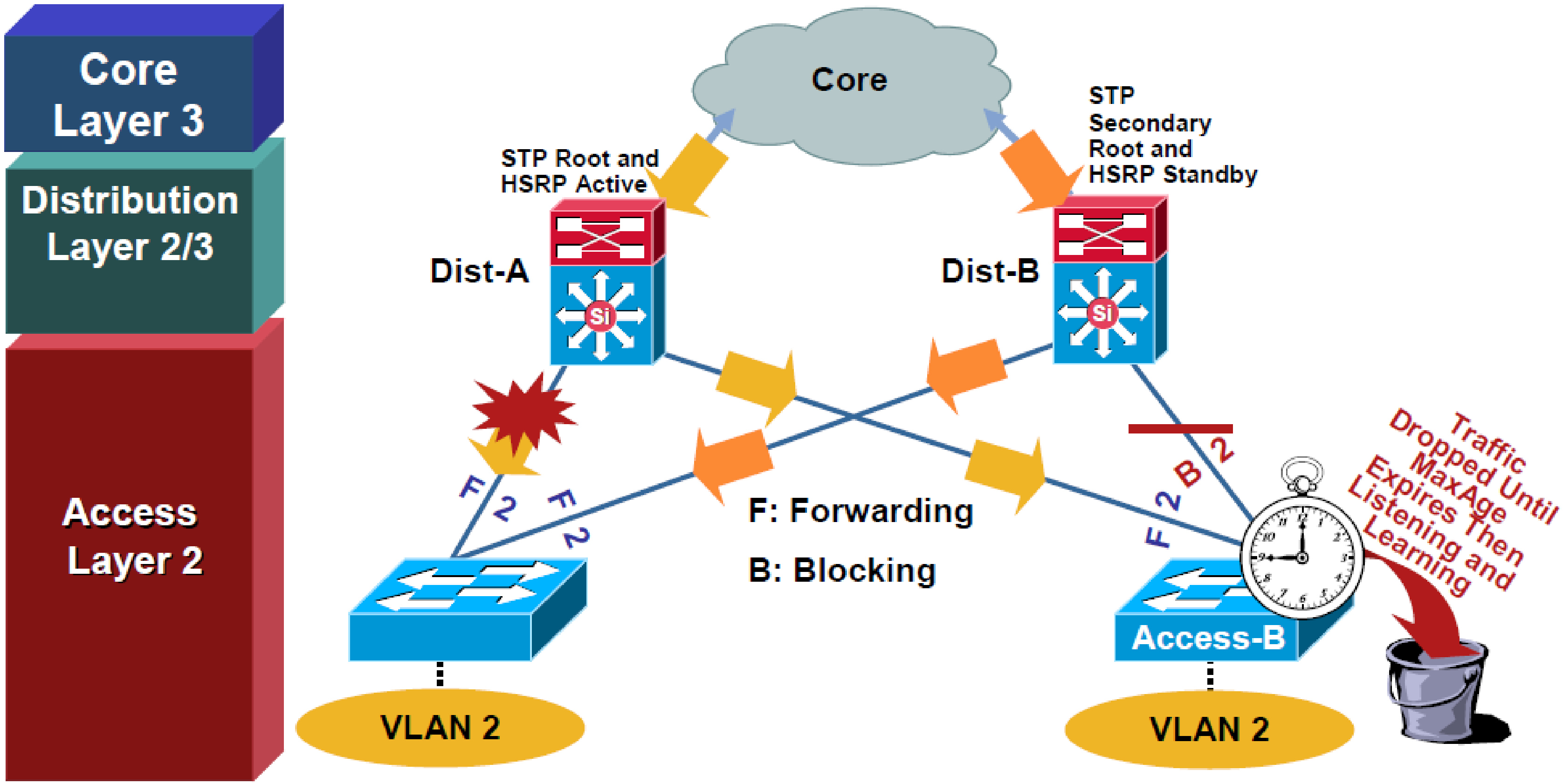
- When the uplink from Access-A to the Dist-A fails there are three convergence events:

1. Access-A sends traffic across its active uplink to Dist-B to get to its default gateway.
    1. The traffic is **black holed** at Dist-B because Dist-B does not initially have a path to HSRP primary on Dist-A due to the STP blocking.
    2. The traffic is dropped until the standby HSRP peer takes over as the default gateway after not receiving HSRP hellos from Dist-A.
2. The indirect link failure is eventually detected by Access-B after the MaxAge timer expires, and Access-B removes blocking on the uplink to Dist-B.
    1. With standard STP, transitioning to forwarding can take as long as 50 seconds.
        - If BackboneFast is enabled with Per VLAN Spanning Tree + (PVST+), this time can be reduced to 30 seconds, and RSTP can reduce this interval to as little as one second.

Impact of an Uplink Failure

3. After STP/RSTP converges, the distribution nodes reestablish their HSRP relationships and the Dist-A, the primary HSRP peer, preempts.
4. This causes yet another convergence event when Access-A end points start forwarding traffic to the primary HSRP peer.
   - The Access-A traffic goes through Access-B to reach its default gateway.
5. The Access-B uplink to Dist-B is now a transit link for Access-A traffic, and the Access-B uplink to Dist-A must now carry traffic for both the originally intended Access-B and for Access-A.

Impact on Return Path Traffic



Blocking link on Access-B will take 50 seconds to move to forwarding
→return traffic black hole until then

Impact on Return Path Traffic

- This indirect link failure convergence can take as long as 50 seconds.
  - PVST+ with UplinkFast reduces the time to 3 to 5 seconds, and RSTP further reduces the outage to one second.
- After the STP/RSTP convergence, the Access-B uplink to Dist-B is used as a transit link for Access-A return path traffic.
- These significant <u>outages</u> could affect the performance of mission-critical applications such as voice or video.

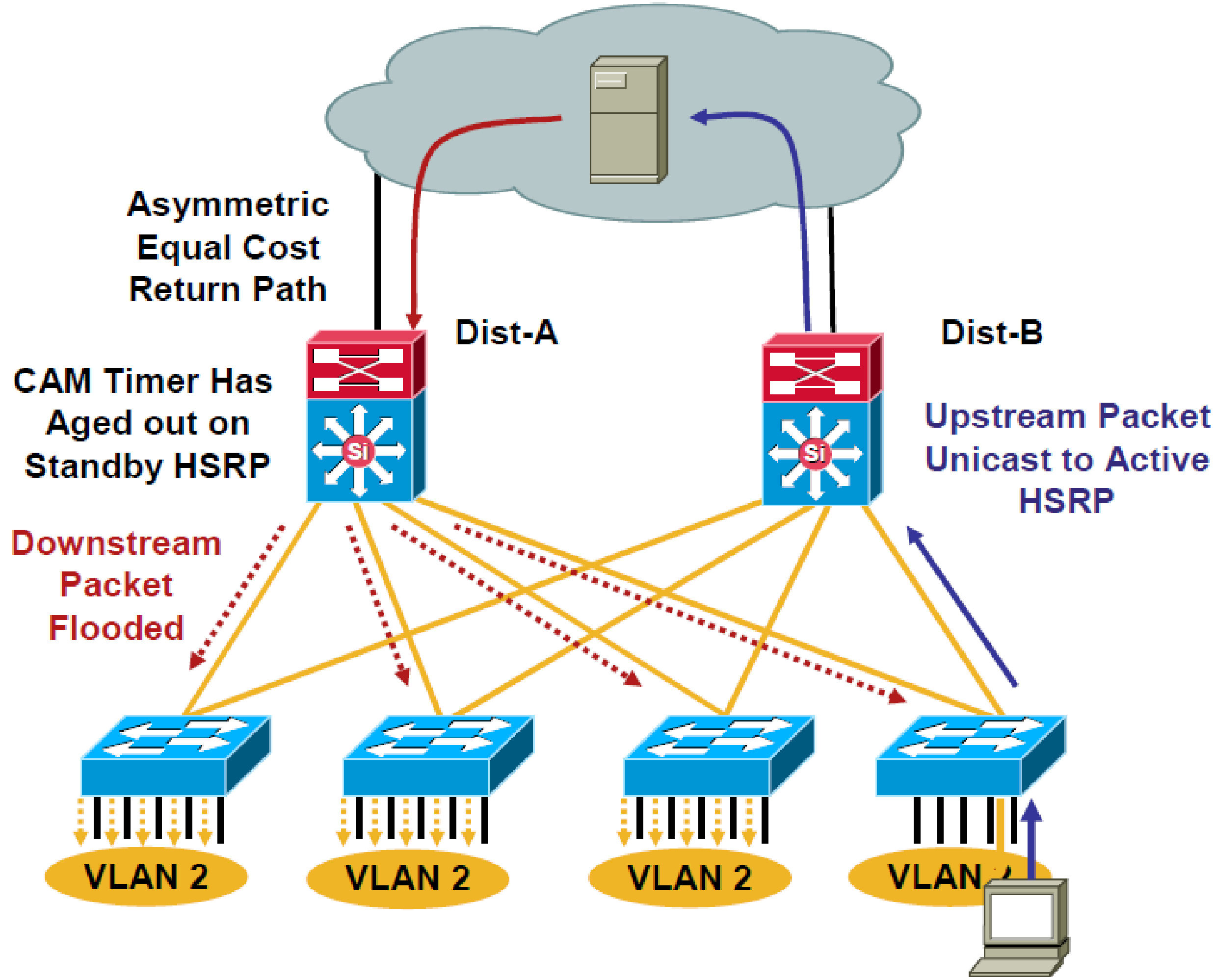
Impact on Return Path Traffic

- Both outbound and return path traffic are difficult and complex, and must support the traffic for at least one additional access layer switch.
- The conclusion is that if VLANs must span the access switches, a Layer 2 link is needed either between the distribution layer switches or the access switches.

Asymmetric Routing (Unicast Flooding)

Case Study

- 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



Content Addressable Memory (CAM)

Asymmetric Routing (Unicast Flooding)

- If the CAM table entry **ages out** before the ARP entry for the end node, the peer flood the traffic to all access layer switches and end points in the VLAN.
  - The CAM table entry ages out on the standby HSRP router because the **default ARP timers are 4 hours** and **CAM aging timers are 5 minutes**.

- The CAM timer expires because no traffic (asymmetric) is sent upstream by the end point towards the standby HSRP peer after the end point initially ARPs for its default gateway

Asymmetric Routing (Unicast Flooding)

- The majority of the access layer switches also do not have a CAM entry for the target MAC, and they also broadcast the return traffic on all ports in the common VLAN.

- This unicast traffic flooding can have a significant performance impact on the connected end stations because they may receive a large amount of traffic that is not intended for them.

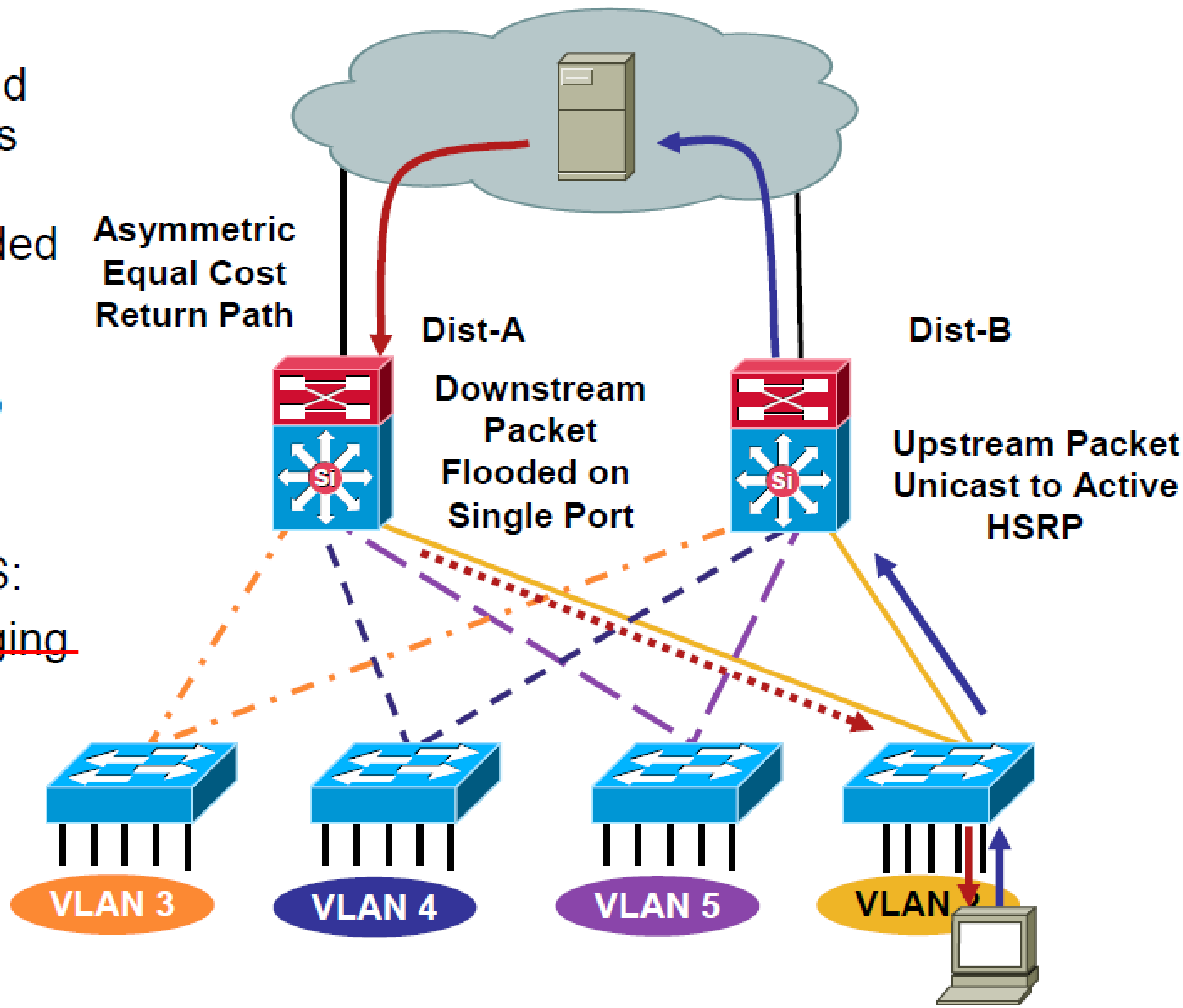
Unicast Flooding Prevention

Assign one unique data and voice VLAN to each access switch:

- Traffic is now only flooded down one link.
- Access switch unicasts correctly; no flooding to all ports.

If you have to span VLANS:

- Tune ARP and CAM aging timers; CAM timer exceeds ARP timer.
- Bias routing metrics to remove equal cost routes.



Unicast Flooding Prevention

Case1: (VLANs are not present across multiple access layer switches)

- Unicast flooding is not an issue when VLANs are **not** present across multiple access layer switches because the flooding occurs only to switches supporting the VLAN where the traffic would have normally been switched.

- If the VLANs are local to individual access layer switches, asymmetric routing traffic is only flooded on the one interface in the VLAN on the distribution switch.

- Additionally, the access layer switch receiving the flooded traffic has a CAM table entry for the host because the host is directly attached, so traffic is switched only to the intended host.

Unicast Flooding Prevention

Case2: (VLANs span more than one access layer switch)

- If you must implement a topology where VLANs span more than one access layer switch, the recommended work-around is to tune the **ARP timer** to be equal to or less than the CAM aging timer. (No ARP timeout occurrence)

- A shorter ARP cache timer causes the standby HSRP peer to ARP for the target IP address before the CAM entry timer expires and the MAC entry is removed. (ARP time out first)

Summary

- Layer 2 to Layer 3 boundary design has three models:
  - Layer 2 distribution switch interconnection
  - Layer 3 distribution switch interconnection
  - Layer 3 access to distribution switch interconnection
- There are a few potential design issues with the layered model:
  - Daisy chaining access layer switches
  - Too much redundancy
  - Too little redundancy
  - Asymmetric flooding