OSPF - Link State Routing - Dijkstra's algorithm

Central1(config)#int loopback 0
Central1(config-if)#ip address 172.31.1.1 255.255.255.255
Central1(config)#router ospf 132
Central1(config-router)#network 10.10.10.1 0.0.0.0 area 0
Central1(config-router)#network 172.16.10.0 0.0.0.3 area 1 <--this mask is 255 minus mask, per octet (here 252)
Central1(config-router)#network 172.16.10.4 0.0.0.3 area 2
Central1(config-router)#passive-interface f0/0 <--- says no neighbors should be discovered on the interface

Have a default route for your networks (so they know the way out), propagate to other routers.
Central1(config)#ip route 0.0.0.0 0.0.0.0 Fa0/0
Central1(config)#router ospf 1
Central1(config-router)#default-information originate

Loopback and Router-IDs in OSPF
If you don't configure a loopback interface on a router, the highest active IP address on a router will become that router's RID during bootup if it isn't already specified. A loopback interface will not override the router-id command, and we don't have to reboot the router to make it take effect as the RID.

1. Highest IP on an active interface by default.
2. Highest logical interface IP (loopback) overrides a physical interface.
3. The router-id overrides the interface and loopback interface.

Reload or use "clear ip ospf process" command, to force changes to take effect

IPv6 OSPF Routing - Routing info is also attached to the interface.
Central1(config)#int f0/0
Central1(config-if)#ipv6 ospf 1 area 0
The same IPv4 OSPF RID is still there- change the RID under the OSPF process ID in the global config:
Central1(config)#ipv6 router ospf 1
Central1(config-rtr)#router-id 1.1.1.1
Central1(config-rtr)#do clear ip ospf process

Designated Router Elections
- By default, all OSPF routers are assigned a DR priority of 1.
- Elections are first won based upon a router's priority level, then highest RID (often the highest IP address)
- Backup designated router (BDR) is the runner-up in the DR election, a standby for the DR
  - receives all routing updates but does not distribute them; steps in if the DR goes down

Suppose we wanted R1 to become the DR and R2 to become the BDR:
R1(config)# **interface f0/0**
R1(config-if)# **ipv6 ospf priority 100**
R2(config)# interface f0/0
R2(config-if)# **ipv6 ospf priority 90**
Prevent routers from ever becoming a DR or BDR by configuring a priority of zero
R2(config)# interface f0/0
R2(config-if)# **ipv6 ospf priority 0**

Choosing the best route - cost=reference_bandwidth /interface_bandwidth

Interface	**Default Bandwidth**	**Formula (Kbps)**	**OSPF Cost**
Serial	1544 Kbps	100,000/1544	64
Ethernet	10,000 Kbps	100,000/10,000	10
Fast Ethernet	100,000 Kbps	100,000/100,000	1

The default ref bandwidth assumes the fastest link in the network runs at 100 Mbps.
Use **auto-cost reference-bandwidth 10000 to** accommodate links up to 10 Gbps in speed.

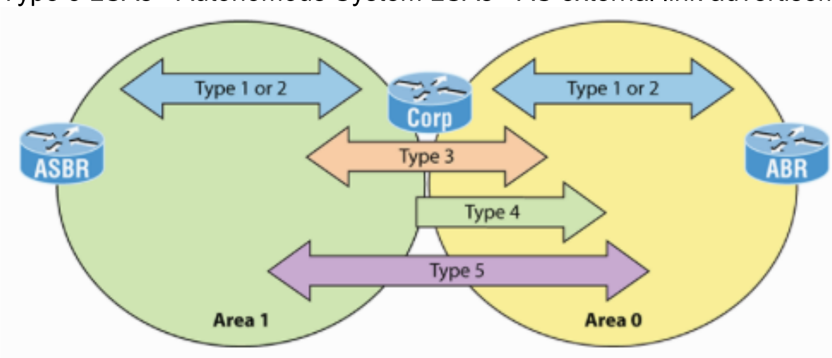
Here are the rules for how a router sets its OSPF interface costs:
- Set the cost explicitly, with **ip ospf cost x interface**, to a value between 1-65,535
- To affect all routes on the device, use **distance 80**. This also affects the AD of non-OSPF routes.
- Change interface bandwidth with the **bandwidth** *speed* command, with speed in Kbps
- Change the reference bandwidth, using subcommand **auto-cost reference-bandwidth** *ref-bw,* in Mbps

Instead of copying routes into the routing table from the LSDB, a router must do the SPF math, choose the best route, and add the route with a subnet number/mask, an outgoing interface, and a next-hop router IP address.

Left: R1–R7–R8	*10 + 180 + 10 = 200*
Middle: R1–R5–R6–R8	*20 + 30 + 40 + 10 = 100*
Right: R1–R2–R3–R4–R8	*30 + 60 + 20 + 5 + 10 = 125*

De facto load balancing occurs when metrics tie for multiple routes to the same subnet, the router can put multiple routes in the routing table (the default is four max- use **maximum-paths** subcommand to change).

<u>Link-State Advertisements - Basic LSAs</u>
Type 1 LSA - Router LSA - The common routers describe themselves amongst themselves
Type 2 - Network LSAs - The DR describes itself and it's network to it's area routers
Type 3 LSA - Summary LSAs - Area Border Routers brag to other areas about thier contents
Type 4 LSAs - Area Border Routers give directions to the ASBR
Type 5 LSAs - Autonomous System LSAs - AS external link advertisements



<u>Timers have to match for neighborship</u>
- Flood changed LSAs to neighbors   and re-flood unchanged LSAs when their lifetime expires (default 30 min)
- Maintain neighborship with Hello msgs, listening for Hellos before the dead/hold interval expires.
    - **- the dead/hold timer is 4x the hello interval**
    - **- 10-sec hello timer and 40-sec hold timer on broadcast and point-to-point links**
    - **- 30-sec hello timer and 120-sec hold timer for all other network types**

If a router goes down, the LSDB is populated so all of the routers can recalculate their Shortest Paths

Becoming neighbors. When a point-to-point link comes up, the routers on the ends go through interim neighbor states (INIT and 2-Way) exchanging their basic LSAs for discovery, compatibility checks (routerIDs, timers). When both reach 2-Way state, it means they both acknowledge each other as neighbors with matching settings and are prepared to exchange LSDB's.
ExStart/Exchange states are when they share DB descriptors, Loading means sending each other Link-State Updates, and Full means their LSDB's match with the same LSA info. These LSA structures comprise the topology. Down means no Hellos are received yet; and Attempt is when NBMA needs manual config.

LSAs in a Multi-Area Design
Migrating from a single-area design to a multi-area design has a couple of effects on LSAs:
- Each area has a smaller number of router and network LSAs.
- ABRs have a copy of the LSDB for each area they connect to and submit a router LSA in each area's LSDB.
- Each area has a need for summary (Type 3) LSAs to describe subnets in other areas.

<u>OSPF: General Verification and Troubleshooting Commands</u>

sh int [**brief**] **x0/0** - up/down, IP address, encapsulation, keepalive, and loopback status
show ip ospf interface (**brief**) - address, area, process, router ID, cost, state, priority, timers, DR and BDR
sh ip ospf - router ID, area information, SPF statistics, and LSA timer information
show ip route ospf - shows the routing table, and displays any injected routes
show ip ospf neighbor (**detail**)- neighbor table, related interfaces, hold time, queue, seq number, DR and BDR
show ip ospf database - view topology table - output per LSA, organized by type, neighbor RIDs, etc
show ip ospf topology (or topology-info)- displays topology table
show ip ospf traffic - shows the # and type of traffic received
show ip protocols - shows the routing process ID and which protocols are enabled, K values
show key-chain - display authentication info
show ip ospf border-routers
show ip ospf data --lots more on links

- Type 1, or Router LSA, is created and advertised by every router.
- Each internal router has one Router LSA, while each ABR has multiple Router LSAs, one for each area.
- Router LSAs are flooded throughout its (intended) area by sending a copy to all connected neighbors. Each one includes: all neighbors directly connected, the router Interface address the LSA was sent

Basic LSA Layout (This can vary but is a basic look)

<table>
<tr><td colspan="6">20-byte LSA Header</td></tr>
<tr><td>0 [4 bits]</td><td>V = on if virtual link</td><td>E = on if ASBR</td><td>B = on if ABR</td><td>0 [9 bits]</td><td>Number of Links: count of all router links [16 bits]</td></tr>
<tr><td colspan="6">Link state identifier ID [32 bits]</td></tr>
<tr><td colspan="6">Link Data [32 bits]</td></tr>
<tr><td colspan="3">Type [8 bits]</td><td colspan="2">Number TOS = 0</td><td>Metric</td></tr>
<tr><td colspan="6">Starting from Link ID again...</td></tr>
</table>

An overview of Link State Advertisement Types

LSA Type	**Description**	**Routing Table Code**
1	Router LSA. Advertises intra-area routes. Generated by each OSPF router to ID itself to peers. Flooded only within the area. Represents stub networks as well	O
2	Network LSA. Generated by a DR, advertises routers on a multiaccess link.. Flooded only within the area. Represents the subnet and the router interfaces connected to the subnet. One per transit network.	O
3	Network Summary LSA. Advertises interarea routes. Generated by an ABR, flooded to adjacent areas. Defines the links (subnets) in the origin area, and cost, but no topology data. "I am the ABR and these are my area's subnets"	O IA
4	ASBR Summary LSA. Advertises the route to reach an ASBR. Generated and advertised by ABR. Flooded to adjacent areas.	O IA
5	AS External LSA. Advertises external routes (in another routing domain) Generated by an ASBR and flooded to adjacent areas. E1–metric increases at each router as it is passed through the network. E2–metric does not increase (this is the default).	O
6	Multicast LSA. Used in multicast OSPF (MOSPF) operations, not supported by Cisco IOS.	
7	Not-so-stubby area (NSSA) LSA. Advertises routes in another routing domain. Generated by an ASBR, advertised within a NSSA (instead of a type-5 LSA) **Totally NSSA bends this rule thats why it accepts Type 4 LSA.** N1–metric increases as it is passed through the network. N2–metric does not increase (default).	O
8	External Attributes LSA, aka Link LSA. For OSPF and BGP interaction. Not implemented in Cisco. **Another definition at Cisco says this is an IPv6 tool:** "IPv6 local-link flooding scope (never flooded beyond), provide the link-local address to all other routers attached to the link, also gives a list of IPv6 prefixes to associate with the link. Allows the router to assert a collection of Options bits to associate with the network LSA that will be originated for the link"	
9	Intra-Area-Prefix LSAs - A router can originate multiple intra-area-prefix LSAs for each router or transit network, each with a unique link-state ID. The link-state ID for each intra-area-prefix LSA describes its association to either the router LSA or the network LSA and contains prefixes for stub and transit networks.	
8,10,11	Opaque LSAs. Used for specific applications, these are generic LSAs to allow for easy future extension of OSPF; for example, type 10 has been adapted for MPLS traffic, BGP, IPv6 stuff. Others more vendor-specific- are becoming more defined.	

EIGRP - Enhanced Interior Gateway Routing Protocol

- A "balanced hybrid" routing protocol, instead of link-state/ distance vector. Sometimes "adv distance vector"
- Sends routing table once, and uses partial updates for changes
- Updates to multicast 224.0.0.10; and the unicast IP of the neighbor if specific.
- Reliable Transport Protocol (RTP) to send updates - resend any EIGRP messages that are not received
- For route poisoning (communicating that a route has "failed" to either warn or stop traffic over the route); EIGRP uses 2^{32}-1 as "infinity" (just over 4 billion), some new IOS versions raise that value to 2^{56}-1 (over 10,000 trillion)

EIGRP default timers are 5 and 15 seconds for Hello and Hold Intervals (Hold is default 3x Hello interval) Not required, but they should be the same for stability. (if Hold time expires it's a sign the other router is down)

For Neighborship: same configured autonomous system number (ASN), the source IP in the neighbor's Hello must be from the same subnet as the interface, matching K values, and pass authentication process if needed.

3-steps when a router first joins a network, 3 tables to populate

- Neighbor discovery: Hello messages discover potential neighboring EIGRP routers to add to neighbor table.
- Topology exchange: Exchange full topology update, only partial updates later as needed on changes
- Routing table: Analyzes topology tables, choose lowest-metric route to each subnet.

Reported Distance (RD) and Feasible Distance (FD), Routing and Topology Tables

- Reported/advertised distance (RD) is how far a neighbor says it is from a remote network.
- Feasible distance (FD) is calculated by taking that and adding how far away that neighbor is.
- The route with the lowest FD is the route that you'll find in the routing table - it's considered the best path.

D   10.0.0.0/8 [90/2195456] via 172.16.10.2, 00:27:06, Serial0/0
D (for DUAL) says this an EIGRP injected route. Get to the 10.0.0.0 network via its neighbor 172.16.10.2.
The first number (90) is the administrative distance (AD) of the routing protocol, the second number is the feasible distance (FD)- the entire cost for this router to get to network 10.0.0.0/8 through that neighbor, 2195456

- The neighbor router has a reported (advertised) distance (RD) between it and network 10.0.0.0
- Feasible Distance (FD), or total cost to that network adds RD to the calculated distance to that router.

Successor Routes and Feasible Successors

Each router keeps information about adjacent neighbors in the neighbor table and the topology tables hold all destinations advertised by the neighbors, with associated distances and other metrics. That best path is called a successor route, and it is determined by which path has the lowest Feasible Distance.

Also elected is a backup "feasible successor" route, which is kept in the topology table if they are needed. If a nonsuccessor route's RD is less than the FD of the successor, the route is a feasible successor route.
Router E has 3 routers/ paths to choose to get to Router A/ Subnet 1:

Router E Topology Table:			**Router E Routing Table**
Next Hop	**FD**	**RD**	Subnet 1 **Metric 14,000**, Through D
Router B -	19,000	15,000	
Router C -	17,500	**13,000 <-- RD makes it FS**	
Router D -	**14,000**	10,000 **<-- FD makes it SR**	

Rule is, the lowest FD will determine the Successor Route, and Router D wins with a FD of 14000. You might think that the next smaller FD would be the runner up, right? Absolutely not. In the case of a Feasible Successor, we look at the Successor Route 's FD and find a Reported Distance that is smaller than *that*. Router C wins out as Feasible Successor by the rule because it's RD 13,000 < FD of the current Successor at 14,000.

Verifying EIGRP - The Configuration and the Neighbor, Topology and Routing Tables

show ip eigrp interfaces
  show ip eigrp interfaces detail
show ip eigrp interfaces *type number*
show ip protocols
show ip eigrp neighbors
show ip eigrp neighbors *type number*

show ip eigrp topology
show ip eigrp topology *subnet/prefix*
show ip route
show ip route eigrp
show ip route *subnet mask*
show ip route | section *subnet*

EIGRP Metric Calculations

$$\text{Metric} = \left(\left(\frac{10^7}{\text{least-bandwidth}}\right) + \text{cumulative-delay}\right) * 256$$

In this formula, the term least-bandwidth represents the lowest-bandwidth link in the route, using a unit of Kbps. For instance, if the slowest link in a route is a 10Mbps Ethernet link, the first part of the formula is 10^7 / 10^4, which equals 1000. You use 10^4 in the formula because 10Mbps is equal to 10,000 Kbps (10^4 Kbps).
Cumulative-delay is the sum of delay values for all outgoing interfaces in the route, *in tens of microseconds* (μsec) (most **show** commands, including **show ip eigrp topology** and **show interfaces**, list delay in μseconds)
You can set both bandwidth and delay for each link with **bandwidth** and **delay** interface commands.

A Simple Example
R1 learns about subnet 10.1.3.0/24 from R2's update listing min. BW of 100,000 Kbps, and delay of 100 μsec.
R1's S0/1 has an interface bandwidth set to 1544 Kbps and a delay of 20,000 μsec
 - 1.544 Mbps < 100,000 Kbps, or 100 Mbps. R1 needs to use this slower bandwidth in the metric calculation, (data's being squeezed down a smaller pipe)
 - For interface delay, the router always adds its interface delay to the delay listed in the EIGRP Update.
 - The update lists 100 μseconds (10 tens of μseconds.   Add R1's S0/1 is 2000 tens of = 2010 tens of μsec.
Metric = [(10^7 / 1544) + (10 + 2000)] * 256 = 2,172,416
 - Later this is revisited, for Reported Distance that R1 was given. It turns out we have the info already:
Metric = [(10^7 / 100,000) + (10)] * 256 = 28,160 - So FD for R1 calc'd at 2,172,416; and the RD from R2: 28160
 - On R1, it listed in the sh ip route like this with the AD/FD:
  D   10.1.3.0/24 [90/2172416] via ???.??.??.?, 23:58:00, S0/1 [no IP address for R2's Serial port (ooops)]
sh ip eigrp topology might have something like this, which shows the FD/RD
  P   10.1.3.0/24, 1 successors, FD is 2172416 via ?.?.?.? (2172416/28160), Serial0/1

The Entire Equation
Metric = {K1 × Bandwidth + [(K2 × Bandwidth) / (256 – Load)] + K3 × Delay} × [K5 / (Reliability + K4)]

K1	Bandwidth (Be) = lowest bandwidth of the links along the path - [10000000 / Kbps] × 256]
K2	Load (utilization on path)
K3	Delay (Dc) = sum of all the delays of the links along the path - [in 10s of μsec] × 256
K4	Reliability (r)
K5	MTU

 - K values are only multiples of the metric calculation. Default values are: K1=1, K2=0, K3=1, K4=0, K5=0.
 - K1 and K3 are static. K2, K4, and K5 are variable, and we just get overhead calculating them and reporting them if they are on. MTU is exchanged between EIGRP neighbors but not used. By default only K1 and K3 are enabled and we don't use K2 or K4. (only bandwidth and delay are used in the formula)

Serial Links and a Special Problem
Serial links default to a bandwidth of 1544 and a delay of 20,000 μseconds. A slow 64 Kbps serial link's **bandwidth** command is used to reflect the correct speed (instead of the default 1544

EIGRP Configuration Commands

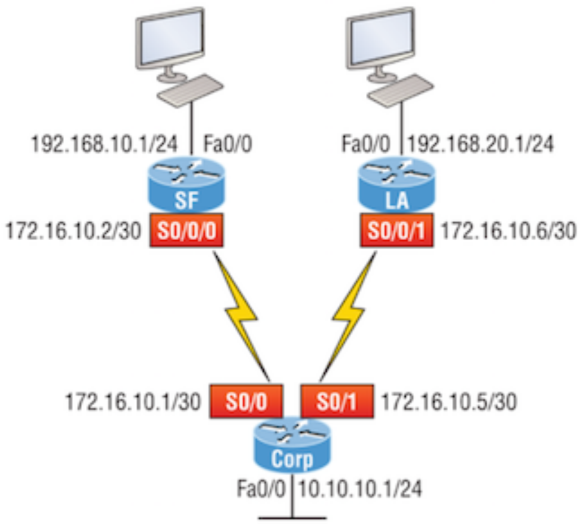
router eigrp as-number
network ip-address [wildcard-mask]   (address should match an int, and often wildcards are unavoidable*)
eigrp router-id value
ip hello-interval eigrp asn time
[for interfaces: **ip hold-time eigrp** asn time]
[for interfaces: **bandwidth** value
[for interfaces: **delay** value

maximum-paths number
variance multiplier to tweak k-values
auto-summary

Failed Routes, DUAL Query and Reply to Update Routing Table
When a route fails, and there's no feasible successor, EIGRP uses Diffusing Update Algorithm (DUAL) to choose a replacement. DUAL sends queries looking for a loop-free route, and when it's found, DUAL adds it to the routing table. Messages just confirm that a route exists, and would not create a loop. In most networks, convergence can still occur in less than 10 seconds.

Basic IGP Routing in IPv4

The three types of routing are static (in which routes are manually configured at the CLI), dynamic (in which the routers share routing information via a routing protocol), and default routing (in which a special route is configured for all traffic without a more specific destination network found in the table)



Basic layout to setup
Central1 - in diagram is CORP
Serial 0/0: 172.16.10.1/30
Serial 0/1: 172.16.10.5/30
Fa0/0: 10.10.10.1/24

DFW - in diagram is SF
S0/0/0: 172.16.10.2/30
Fa0/0: 192.168.10.1/24

HOU - in diagram is LA
S0/0/0: 172.16.10.6/30
Fa0/0: 192.168.20.1/24

Basic Local IPv4 Routing (Direct Connections)

Every interface below should have "no shutdown" added. It has been removed here for brevity

Router(config)#hostname Central1
Central1(config)#int f0/0
Central1(config-if)#desc Connection to LAN
Central1(config-if)#ip address 10.10.10.1 255.255.255.0
Central1(config-if)#int s0/0
Central1(config-if)#desc WAN connection to DFW
Central1(config-if)#ip address 172.16.10.1 255.255.255.252
Central1(config-if)#int s0/1
Central1(config-if)#desc WAN connection to HOU
Central1(config-if)#ip address 172.16.10.5 255.255.255.252
Central1>sh controllers s0/0
    Interface Serial0/0
    Hardware is PowerQUICC MPC860
    DTE V.35 TX and RX clocks detected.
Remember to set clock rates on the DCEs!

Router(config)#hostname DFW
DFW(config)#int s0/0/0
DFW(config-if)#desc WAN Connection to Central1
DFW(config-if)#ip address 172.16.10.2 255.255.255.252
DFW(config-if)#clock rate 1000000   *- DFW's DCE to Central's DTE -we need a clock rate!*
DFW(config-if)#int f0/0
DFW(config-if)#desc DFW LAN
DFW(config-if)#ip address 192.168.10.1 255.255.255.0

Router(config)#hostname HOU
HOU(config)#int s0/0/1
HOU(config-if)#ip address 172.16.10.6 255.255.255.252
HOU(config-if)#clock rate 1000000   *- HOU's DCE to Central1's DTE -we need a clock rate*
HOU(config-if)#description WAN To Central1
HOU(config-if)#int f0/0
HOU(config-if)#ip address 192.168.20.1 255.255.255.0
HOU(config-if)#description HOU LAN

Static Routing: Manually Adding to Routing Table
Router(config)#ip route 172.16.3.0 255.255.255.0 192.168.2.4
172.16.3.0 is the remote network, and 255.255.255.0 is it's mask of the remote network.
192.168.2.4 is the next hop that packets will be sent to. Can also be the interface out to it.

Below, the 150 is where the administrative distance goes if you want to override the default. This is set here because in the next example, we will add routes with RIP, and using 150 (rather than the default of 1) means we won't have to remove static routes first- RIP (120) will just override them.

Administrative Distances (the smaller # wins out):

Connected	0	OSPF	110
Static route	1	RIP	120
EIGRP	90	Unknown	255

Central1(config)#ip route 192.168.10.0 255.255.255.0 172.16.10.2 150 --use the dest IP out
Central1(config)#ip route 192.168.20.0 255.255.255.0 s0/1 150 -- use an interface out

DFW(config)#ip route 10.10.10.0 255.255.255.0 172.16.10.1 150
DFW(config)#ip route 172.16.10.4 255.255.255.252 172.16.10.1 150
DFW(config)#ip route 192.168.20.0 255.255.255.0 172.16.10.1 150

LA#config t
HOU(config)#ip route 10.10.10.0 255.255.255.0 172.16.10.5 150
HOU(config)#ip route 172.16.10.0 255.255.255.252 172.16.10.5 150
HOU(config)#ip route 192.168.10.0 255.255.255.0 172.16.10.5 150

A stub indicates that the networks in this design have only one way out to reach all other networks; use only a default route. Here's an alt config instead of typing in the static routes. to make this a "stubby network" (first we turn off the routes we just configured):
HOU(config)#no ip route 10.10.10.0 255.255.255.0 172.16.10.5 150
HOU(config)#no ip route 172.16.10.0 255.255.255.252 172.16.10.5 150
HOU(config)#no ip route 192.168.10.0 255.255.255.0 172.16.10.5 150
HOU(config)#ip route 0.0.0.0 0.0.0.0 172.16.10.5

Convert from Static IPv4 to Dynamic IPv4 RIPv2
As a shortcut, you can verify directly connected networks to know what to configure RIP with:
Central1#sh ip int brief

Interface	IP-Address	OK?	Method	Status	Protocol
FastEthernet0/0	10.10.10.1	YES	manual	up	up
Serial0/0	172.16.10.1	YES	manual	up	up
FastEthernet0/1	unassigned	YES	unset	admin. down	down
Serial0/1	172.16.10.5	YES	manual	up	up

When we declare our routes in RIP, we need to refer to them in a classful way instead of by the specific subnet. This is illustrated below. RIP then finds the subnets and fills in the routing table (RIP is NOT a classful routing protocol btw).

Central1(config)#router rip
Central1(config-router)#network 10.0.0.0
Central1(config-router)#network 172.16.0.0
Central1(config-router)#version 2
Central1(config-router)#no auto-summary
Add the default as a static route, and enter RIP config to set default-info originate to propagate it.
Central1(config)#ip route 0.0.0.0 0.0.0.0 Fa0/0
Central1(config)#router rip
Central1(config-router)#default-information originate

DFW(config)#router rip
DFW(config-router)#network 192.168.10.0
DFW(config-router)#network 172.16.0.0
DFW(config-router)#version 2
DFW(config-router)#no auto-summary ---*disabling auto-summary makes RIP look at our subnets*

DFW(config-router)#do show ip route

```
C    192.168.10.0/24 is directly connected, FastEthernet0/0
L    192.168.10.1/32 is directly connected, FastEthernet0/0
     172.16.0.0/30 is subnetted, 3 subnets
R       172.16.10.4 [120/1] via 172.16.10.1, 00:00:08, Serial0/0/0
C       172.16.10.0 is directly connected, Serial0/0/0
L       172.16.10.2/32 is directly connected, Serial0/0
S    192.168.20.0/24 [150/0] via 172.16.10.1
     10.0.0.0/24 is subnetted, 1 subnets
R       10.10.10.0 [120/1] via 172.16.10.1, 00:00:08, Serial0/0/0
```

- Note above the administrative distances set for RIP (R) and our previous static routes (S)

HOU(config)#no ip route 0.0.0.0 0.0.0.0 *--- get rid of that temporary default route we set for HOU*
HOU(config)#router rip
HOU(config-router)#network 192.168.20.0
HOU(config-router)#network 172.16.0.0
HOU(config-router)#no auto
HOU(config-router)#vers 2

Switch from IPv4 RIP to Dynamic IPv4 OSPF

Central1(config)#no router rip
Central1(config)#router ospf 132
Central1(config-router)#network 10.10.10.1 0.0.0.255 area 0
Central1(config-router)#network 172.16.10.1 0.0.0.3 area 0
Central1(config-router)#network 172.16.10.5 0.0.0.3 area 0

Central1(config)#ip route 0.0.0.0 0.0.0.0 Fa0/0
Central1(config)#router ospf 1
Central1(config-router)#default-information originate

DFW(config)#no router rip
DFW(config)#router ospf 300
DFW(config-router)#network 192.168.10.1 0.0.0.255 area 0
DFW(config-router)#network 172.16.10.0 0.0.0.7 area 0
[may need "area 1 range" for this, since it's a summary of two listed on Central1- see below]

HOU(config)#router ospf 100
HOU(config-router)#network 192.168.20.0 0.0.0.255 area 0
HOU(config-router)#network 172.16.10.0 0.0.0.7 area 0

Adding a non-OSPF network? Use passive-interface:
HOU(config)#router ospf 100
HOU(config-router)#passive-interface fastEthernet 0/1

Add a SanAnt router:
Router(config)#hostname SanAnt
SanAnt(config)#int f0/0
SanAnt(config-if)#ip address 10.10.10.2 255.255.255.0
SanAnt(config-if)#no shut
SanAnt(config-if)#router ospf 2
SanAnt(config-router)#network 10.10.10.0 0.0.255.255 area 0

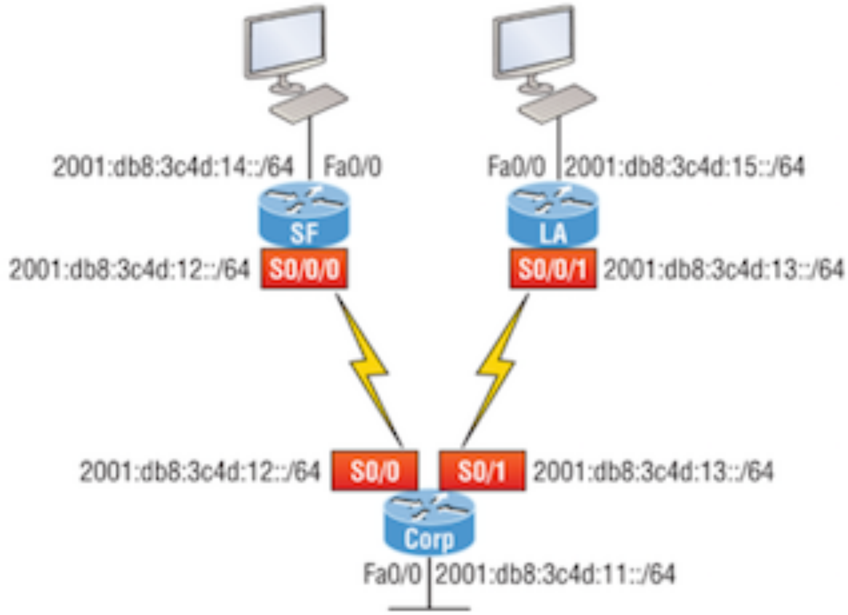
OSPF Route summarization:

Router(config)#router ospf 100
Interarea: area 1 range 192.168.5.8 0.0.0.63
External: summary-address: 192.168.64.0 0.224.0

RouterID - So what if you didn't put in a loopback first and need to force a router to become DR?

Corp(config-router)#router-id 223.255.255.254
Corp(config-router)#do clear ip ospf process
[Just set a routerID which will beat any other RID or loopback set on other routers, then reset OSPF]

Basic IGP Routing in IPv6



Adding IPv6 (including local default routing)

Add IPv6 to the Central1, DFW, and HOU routers by using a simple subnet scheme of 11, 12, 13, 14, and 15

Central1#config t
Central1(config)#ipv6 unicast-routing
Central1(config)#int f0/0
Central1(config-if)#ipv6 address 2001:db8:3c4d:11::/64 eui-64
Central1(config-if)#int s0/0
Central1(config-if)#ipv6 address 2001:db8:3c4d:12::/64 eui-64
Central1(config-if)#int s0/1
Central1(config-if)#ipv6 address 2001:db8:3c4d:13::/64 eui-64

DFW(config)#ipv6 unicast-routing
DFW(config)#int s0/0/0
DFW(config-if)#ipv6 address 2001:db8:3c4d:12::/64 eui-64
DFW(config-if)#int fa0/0
DFW(config-if)#ipv6 address 2001:db8:3c4d:14::/64 eui-64

HOU(config)#ipv6 unicast-routing
HOU(config)#int s0/0/1
HOU(config-if)#ipv6 address 2001:db8:3c4d:13::/64 eui-64
HOU(config-if)#int f0/0
HOU(config-if)#ipv6 address 2001:db8:3c4d:15::/64 eui-64

Static IPv6 Routing

First static route line uses the next-hop address, and the exit interface on the second entry
(On the DFW router, use show ipv6 int brief, and then copy the interface address used for the next hop)

Central1(config)#ipv6 route 2001:db8:3c4d:14::/64 2001:DB8:3C4D:12:21A:2FFF:FEE7:4398 150
Central1(config)#ipv6 route 2001:DB8:3C4D:15::/64 s0/1 150
Central1(config)#do sho ipv6 route static
S   2001:DB8:3C4D:14::/64 [150/0]
via 2001:DB8:3C4D:12:21A:2FFF:FEE7:4398

For DFW and HOU routers put a single entry in each router to get to remote subnet 11 (Central1):

DFW(config)#ipv6 route 2001:db8:3c4d:11::/64 s0/0/0 150
HOU(config)#ipv6 route ::/0 s0/0/1 -- a default route

IPv6 RIPng (a different pair of routers for this one)

```
Austin(config)#ipv6 unicast-routing
Austin(config)#interface fastethernet 0/0
Austin(config-if)#ipv6 enable
Austin(config-if)#ipv6 address 2001:db8:c18:2::/64 eui-64
Austin(config-if)#ipv6 rip RIPNG1 enable
Austin(config-if)#interface fastethernet 0/1
Austin(config-if)#ipv6 enable
Austin(config-if)#ipv6 address 2001:db8:c18:1::/64 eui-64
Austin(config-if)#ipv6 rip RIPNG1 enable
Austin(config-if)#no shutdown

Houston(config)#ipv6 unicast-routing
Houston(config)#interface fastethernet 0/0
Houston(config-if)#ipv6 enable
Houston(config-if)#ipv6 address 2001:db8:c18:2::/64 eui-64
Houston(config-if)#ipv6 rip RIPNG1 enable
Houston(config-if)#interface fastethernet 0/1
Houston(config-if)#ipv6 enable
Houston(config-if)#ipv6 address 2001:db8:c18:3::/64 eui-64
Houston(config-if)#ipv6 rip RIPNG1 enable
```

Switch to IPv6 OSPF Routing

```
Central1(config)#int f0/0
Central1(config-if)#ipv6 ospf 1 area 0
Central1(config-if)#int s0/0
Central1(config-if)#ipv6 ospf 1 area 0
Central1(config-if)#int s0/1
Central1(config-if)#ipv6 ospf 1 area 0

DFW(config)#int f0/0
DFW(config-if)#ipv6 ospf 1 area 0
DFW(config-if)#int s0/0/0
DFW(config-if)#ipv6 ospf 1 area 0
[Same for others]

SanAnt(config)#int f0/0
SanAnt(config-if)#ipv6 address autoconfig default
SanAnt(config-if)#ipv6 ospf 1 area 0
```

The same IPv4 OSPF RID is still there- change the RID under the OSPF process ID in the global config:

```
Central1(config)#ipv6 router ospf 1
Central1(config-rtr)#router-id 1.1.1.1
Central1(config-rtr)#do clear ip ospf process
```

Switching from IPv6 OSPF to IPv6 EIGRP

(you have to turn off OSPF on the interfaces, then add)

```
Central1(config)#int f0/0
Central1(config-if)#no ipv6 ospf 1 area 0
Central1(config-if)# ipv6 eigrp 1
Central1(config-if)#exit
        [Do for all interfaces]
DFW(config)#int f0/0
DFW(config-if)#no ipv6 ospf 1 area 0
DFW(config-if)# ipv6 eigrp 1
DFW(config-if)#exit
DFW(config-if)#int s0/0/0
 [Same for others]
```

Dynamic IGP Routing Protocols - Quick Overview

RIP for IPv4
Central1(config)#router rip
Central1(config-router)#network 10.0.0.0
Central1(config-router)#network 172.16.0.0
Central1(config-router)#version 2
Central1(config-router)#no auto-summary
Add the default as a static route, and enter RIP config to set default-info originate to propagate it.
Central1(config)#ip route 0.0.0.0 0.0.0.0 Fa0/0
Central1(config)#router rip
Central1(config-router)#default-information originate

RIPng for IPv6 - add to interfaces
Austin(config)#ipv6 unicast-routing
Austin(config)#interface fastethernet 0/0
Austin(config-if)#ipv6 enable
Austin(config-if)#ipv6 address 2001:db8:c18:2::/64 eui-64
Austin(config-if)#ipv6 rip RIPNG1 enable
Austin(config-if)#interface fastethernet 0/1
Austin(config-if)#ipv6 enable
Austin(config-if)#ipv6 address 2001:db8:c18:1::/64 eui-64
Austin(config-if)#ipv6 rip RIPNG1 enable
Austin(config-if)#no shutdown

OSPF for IPv4
int loopback 0
ip address 172.31.1.1 255.255.255.255
router ospf 300
Test(config-router)#network 192.168.10.64 0.0.0.15 area 0
Test(config-router)#network 192.168.10.80 0.0.0.15 area 0

OSPFv3 for IPv6 - add to interfaces
Corp(config)#ipv6 router ospf 1
Corp(config)#ipv6 router-id 1.1.1.1
Corp(config)#int f0/0
Corp(config-if)#ipv6 ospf 1 area 0

EIGRP for IPv4
Corp#config t
Corp(config)#router eigrp 20
Corp(config-router)#network 10.10.11.0 0.0.0.255
Corp(config-router)#network 172.16.10.0 0.0.0.3
Corp(config-router)#network 172.16.10.4 0.0.0.3
Corp(config-router)#no auto-summary

SF(config)#router eigrp 20
SF(config-router)#network 172.16.0.0
SF(config-router)#network 10.0.0.0
SF(config-router)#no auto-summary

EIGRPv6 for IPv6 - add to interfaces
Corp(config)#ipv6 unicast-routing
Corp(config)#ipv6 router eigrp 10
Corp(config-rtr)#no shut
Corp(config-rtr)#router-id 1.1.1.1
Corp(config-rtr)#int s0/0/0
Corp(config-if)#ipv6 eigrp 10
Corp(config-if)#int s0/0/1
Corp(config-if)#ipv6 eigrp 10

Bigger Picture: Routing Table Manager; Timers

Administrative Distance- Lowest score wins
How the device's Routing Table Manager (RTM) chooses from multiple active routing protocols available to get to the same subnet advertised on one of them. Got a router with a few turned on? Lower AD is chosen.

To understand this, a directly connected device has an AD of 0 (as it should)

Static route	1	IS-IS	115
EIGRP summary	5	RIP	120
external BGP	20	external EIGRP	170
Internal EIGRP	90	internal BGP	200
OSPF	110	Unknown*	255

Timers - How to choose a good protocol in your designs:
These are the defaults. Refer to documentation to how to change them, like "ip hello-interval eigrp" or "ip hold-time eigrp"

Protocol	**Type**	**Hello/Keepalive**	**Hold/Dead**	**Notes**
			Interior Routing Protocols	
RIP	DV	Update 30 sec	90 sec	Timeout 180 sec; Flush 120 sec
OSPF	LS	BC+PtP 10 sec	BC+PtP 40 sec (4x hello)	For NBMA 30 sec hello/ 120 sec dead (4x)
EIGRP	AdDV	BC+PtP 5 sec	BC+PtP 15 sec (3x hello)	For NBMA 60 sec hello/ 180 sec dead (3x)
			Exterior Routing Protocols	
IS-IS	LS	10 sec Juniper 9 sec?	30 sec (3x hello) Juniper 27 sec?	Also has L1 and L2 timers. PtP vs NBMA. Differ in Juniper. See documentation.
		(IS-IS has several timers and issues that are outside the scope of this table)		
BGP	PathV	60 sec keepalive	180 sec (3x keepalive)	
		(BGP also has iBGP and eBGP with timers outside the scope of this table)		

OSPF Path Cost in Routing - Don't get confused with Spanning Tree Cost in Switching!

Choosing the best route - cost=reference_bandwidth /interface_bandwidth

Interface	**Default Bandwidth**	**Formula (Kbps)**	**OSPF Cost**
Serial	1544 Kbps	100,000/1544	64
Ethernet	10,000 Kbps	100,000/10,000	10
Fast Ethernet	100,000 Kbps	100,000/100,000	1

The default ref bandwidth assumes the fastest link in the network runs at 100 Mbps.
Use **auto-cost reference-bandwidth 10000 to** accommodate links up to 10 Gbps in speed.

Here are the rules for how a router sets its OSPF interface costs:
- Set the cost explicitly, with **ip ospf cost x interface**, to a value between 1-65,535
- To affect all routes on the device, use **distance 80**. This also affects the AD of non-OSPF routes.
- Change interface bandwidth with the **bandwidth** *speed* command, with speed in Kbps
- Change the reference bandwidth, using subcommand **auto-cost reference-bandwidth** *ref-bw,* in Mbps

STP Path Cost:

10 Mbps	100	2000000
100 Mbps	19	200000
1 Gbps	4	20000
10 Gbps	2	2000
100 Gbps		200

THIS IS WHERE TO PUT A DISCUSSION OF ROUTING METRICS/TROUBLESHOOTING
Seeing RIP maximum hops, spotting OSPF and EIGRP similar issues

Other timers
STP - hello-time 1-10 sec default 2; forward-time 4-30 default 15; max-age 6-40 sec default 20
RSTP

Rapid convergence of RSTP is achieved by the use of timer-independent ‘proposal-agreement’ handshake so it is difficult to say a given value.

every time you plug in a cable the led above the interface was orange and after a while became green. What is happening at this moment is that spanning tree is determining the state of the interface.
STP:
Hello time = 2 secs (BPDU frequency)
Max Age = 20 secs (or 10 x hello) (length of BPDU validity/storage)
Listening = 15 secs (the forward delay)
Learning = 15 secs (also the forward delay)
(means 30 seconds to move from listening to forwarding)

When an interface is in blocking mode and the topology changes, if port moves to the forwarding state
- blocking mode will last for 20 seconds before it moves to the listening state.
- 20sec (blocking) + 30sec (listening and learning) = 50 sec to forwarding state (to convergence)

RSTP:
Hello time = 2 secs
Max Age = 6 secs (3 x hello, 3 missed BDPUs)

no blocking port in RSTP. Discarding replaces blocking and listening. So you only have discarding, learning and forwarding.

VTP - sync 300 sec (5 min) intervals, also when vlan.dat changes (revision # increments)