Chapter 8

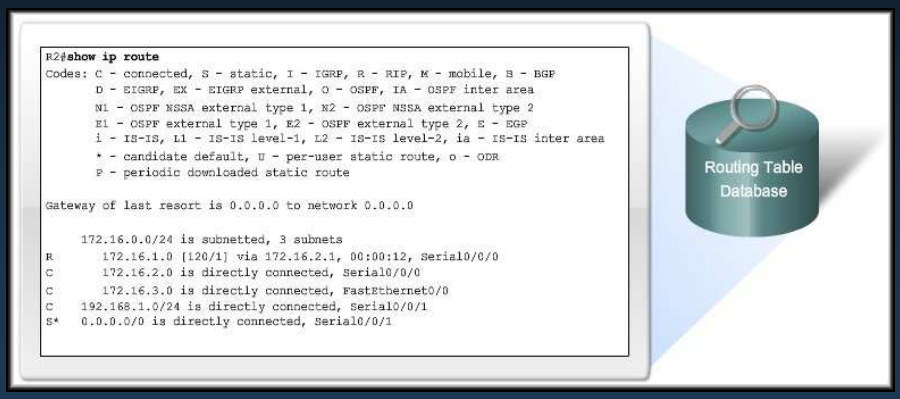
The Routing Table: A Closer Look

Note for Instructors

- These presentations are the result of a collaboration among the instructors at St. Clair College in Windsor, Ontario.
- Thanks must go out to Rick Graziani of Cabrillo College. His material and additional information was used as a reference in their creation.
- If anyone finds any errors or omissions, please let me know at:
  - tdame@stclaircollege.ca.

The Routing Table: A Closer Look

The Routing Table Structure



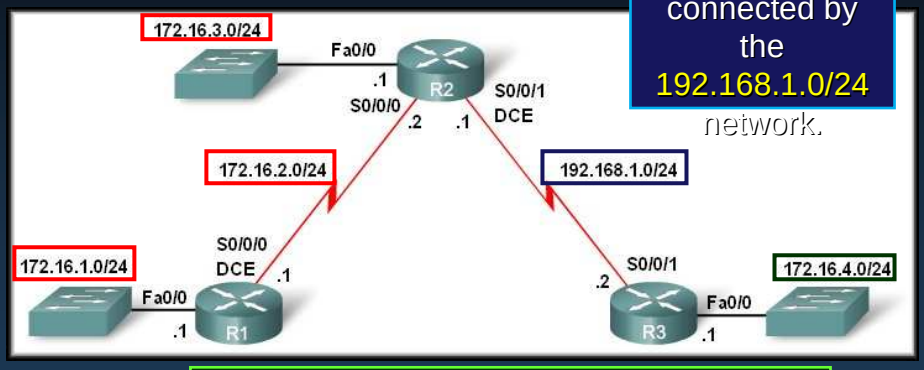
Introduction

- As a network administrator, it is important to know the routing table in depth when troubleshooting network issues.
- Understanding the structure and lookup process of the routing table will help you diagnose any routing table issue.
- Assist you in answering questions like:
  - Is the packet being forwarded as expected?
  - Is the packet is being sent elsewhere?
  - Why isn't the packet being forwarded to the correct destination?
  - Has the packet has been discarded?

Lab Topology

Router R1 and R2 share a common 172.16.0.0/16 network that is divided into /24 subnets.

R2 and R3 are connected by the 192.168.1.0/24 network.



R3 also has a 172.16.4.0/24 subnet that is disconnected, or discontiguous, from the 172.16.0.0 network that R1 and R2 share.

Lab Topology

- Interface Configurations for R1 and R3:

R1

```
R1(config)# interface FastEthernet0/0
R1(config-if)# ip address 172.16.1.1 255.255.255.0
R1(config-if)# no shutdown
R1(config-if)# interface Serial0/0/0
R1(config-if)# ip address 172.16.2.1 255.255.255.0
R1(config-if)# clock rate 64000
R1(config-if)# no shutdown
```

R3

```
R3(config)# interface FastEthernet0/0
R3(config-if)# ip address 172.16.4.1 255.255.255.0
R3(config-if)# no shutdown
R3(config-if)# interface Serial0/0/1
R3(config-if)# ip address 192.168.1.2 255.255.255.0
R3(config-if)# no shutdown
```

Routing Table Entries

```
Router# show ip route
<output omitted>

Gateway of last resort is not set

     10.0.0.0/16 is subnetted, 1 subnets
S       10.1.0.0 is directly connected, Serial0/0/1
     172.16.0.0/24 is subnetted, 4 subnets
R       172.16.1.0 [120/1] via 172.16.2.1, 00:00:08, Serial0/0/0
C       172.16.2.0 is directly connected, Serial0/0/0
C       172.16.3.0 is directly connected, FastEthernet0/0
S       172.16.4.0 is directly connected, Serial0/0/1
C    192.168.1.0/24 is directly connected, Serial0/0/1
S    192.168.100.0/24 is directly connected, Serial0/0/1
```

- Routing table entries from the following sources:
  - Directly connected networks.
  - Static routes.
  - Dynamic routing protocols.

Routing Table Entries

```
Router# show ip route
<output omitted>

Gateway of last resort is not set

     10.0.0.0/16 is subnetted, 1 subnets
S       10.1.0.0 is directly connected, Serial0/0/1
     172.16.0.0/24 is subnetted, 4 subnets
R       172.16.1.0 [120/1] via 172.16.2.1, 00:00:08, Serial0/0/0
C       172.16.2.0 is directly connected, Serial0/0/0
C       172.16.3.0 is directly connected, FastEthernet0/0
S       172.16.4.0 is directly connected, Serial0/0/1
C    192.168.1.0/24 is directly connected, Serial0/0/1
S    192.168.100.0/24 is directly connected, Serial0/0/1
```

- The routing table hierarchy in Cisco IOS software was originally implemented with the classful routing scheme.
- It incorporates both classful and classless addressing but the overall structure is still built around this classful scheme.

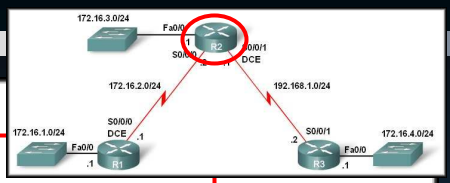
Routing Table Entries

```
Router# show ip route
<output omitted>

Gateway of last resort is not set

     10.0.0.0/16 is subnetted, 1 subnets
S       10.1.0.0 is directly connected, Serial0/0/1
     172.16.0.0/24 is subnetted, 4 subnets
R       172.16.1.0 [120/1] via 172.16.2.1, 00:00:08, Serial0/0/0
C       172.16.2.0 is directly connected, Serial0/0/0
C       172.16.3.0 is directly connected, FastEthernet0/0
S       172.16.4.0 is directly connected, Serial0/0/1
C    192.168.1.0/24 is directly connected, Serial0/0/1
S    192.168.100.0/24 is directly connected, Serial0/0/1
```

Hierarchy

- The routing table is actually a **hierarchical structure** that is used to speed up the lookup process when locating routes and forwarding packets.
- For simplicity, we discuss all routes as one of two levels: **level 1 or level 2**.

Level 1 Routes




```
R2# debug ip routing
IP routing debugging is on
R2# conf t
R2(config)# interface serial 0/0/1
R2(config-if)# ip address 192.168.1.1 255.255.255.0
R2(config-if)# clock rate 64000
R2(config-if)# no shutdown
R2(config-if)#
00:11:06: %LINK-3-UPDOWN: Interface Serial0/0/1, changed state to up
R2(config-if)#
RT: add 192.168.1.0/24 via 0.0.0.0, connected metric [0/0]
RT: interface Serial0/0/1 added to routing table
R2(config-if)# end
R2# undebug all
All possible debugging has been turned off
```

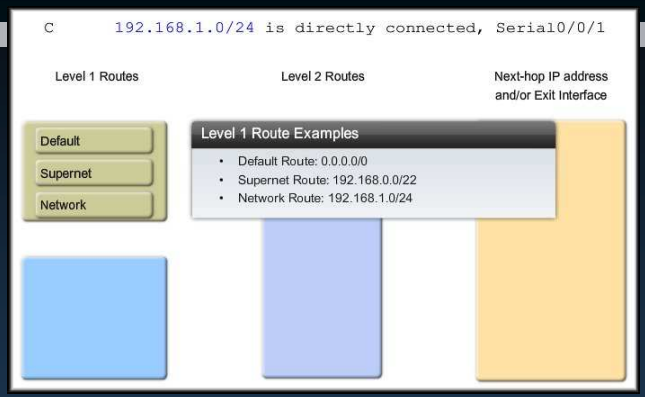
- Debugging is enabled and the Serial 0/0/1 interface for R2 is configured with the 192.168.1.1/24 address.

Level 1 Routes

```
RT: add 192.168.1.0/24 via 0.0.0.0, connected metric [0/0]
RT: interface Serial0/0/1 added to routing table
R2(config-if)# end

R2# show ip route
<output omitted>

C    192.168.1.0/24 is directly connected, Serial0/0/1
```

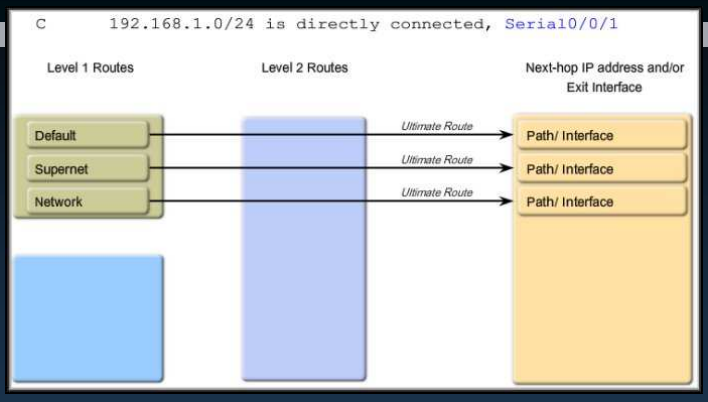
- *A level 1 route is a route with a subnet mask equal to or less than the classful mask of the network address.*
  - 192.168.1.1 is a Class C address.
  - Classful Mask – 255.255.255.0 or /24.
- 192.168.1.0/24 is a level 1 network route because the subnet mask is equal to the network's classful mask.

Level 1 Routes



- A Level 1 route can function as any of the following:
  - Default Route: A static route with the address 0.0.0.0 / 0.
  - Supernet Route: Mask less than the classful mask.
  - Network Route: A route that has a subnet mask equal to that of the classful mask.

Level 1 Routes



- The level 1 route 192.168.1.0/24 can also be defined as an **ultimate route**.
  - A route that includes one or both of the following:
    - A next-hop IP address (another path).
    - An exit interface.

Level 1 Routes

```
RT: add 192.168.1.0/24 via 0.0.0.0, connected metric [0/0]
RT: interface Serial0/0/1 added to routing table
R2(config-if)# end

R2# show ip route
<output omitted>

C    192.168.1.0/24 is directly connected, Serial0/0/1
```

- The directly connected network 192.168.1.0/24 is a **level 1 network route** because it has a subnet mask that is the same as its classful mask.
- This same route is also an **ultimate route** because it contains the exit interface Serial 0/0/1.

Parent and Child Routes: Classful Networks

```
R2(config)# interface fastethernet 0/0
R2(config-if)# ip address 172.16.3.1 255.255.255.0
R2(config-if)# no shutdown
R2(config-if)# end

R2# show ip route
<output omitted>

     172.16.0.0/24 is subnetted, 1 subnets
C       172.16.3.0 is directly connected, FastEthernet0/0
C    192.168.1.0/24 is directly connected, Serial0/0/1
```

Parent Route

- Level 1 Parent Route:
  - Two entries in the routing table.
  - When the 172.16.3.0 subnet was added to the routing table, another route (172.16.0.0) was also added.
  - This first entry does not contain any next-hop IP address or exit interface information.

Parent and Child Routes: Classful Networks

```
R2(config)# interface fastethernet 0/0
R2(config-if)# ip address 172.16.3.1 255.255.255.0
R2(config-if)# no shutdown
R2(config-if)# end

R2# show ip route
<output omitted>

     172.16.0.0/24 is subnetted, 1 subnets
C       172.16.3.0 is directly connected, FastEthernet0/0
C    192.168.1.0/24 is directly connected, Serial0/0/1
```

Parent Route

Child Route

- Level 1 Parent Route:
  - The heading indicates the presence of level 2 routes or Child Routes.
  - A level 1 parent route is created whenever a route with a mask greater than the classful mask is entered into the routing table.

Parent and Child Routes: Classful Networks

```
R2(config)# interface fastethernet 0/0
R2(config-if)# ip address 172.16.3.1 255.255.255.0
R2(config-if)# no shutdown
R2(config-if)# end

R2# show ip route
<output omitted>

     172.16.0.0/24 is subnetted, 1 subnets
C       172.16.3.0 is directly connected, FastEthernet0/0
C    192.168.1.0/24 is directly connected, Serial0/0/1
```

Parent Route

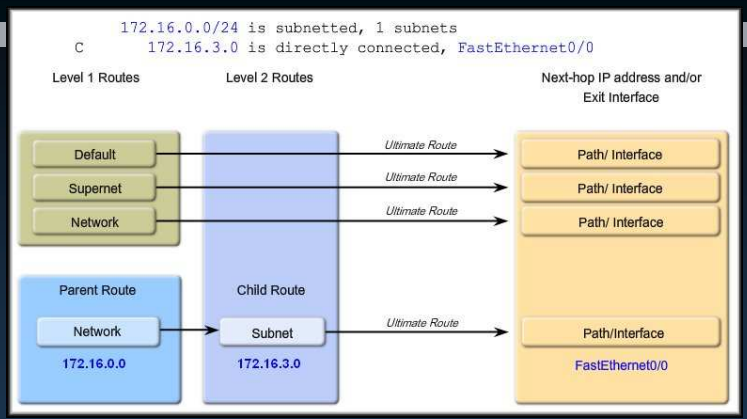
Child Route

- 172.16.3.1 /24 configured on the Fast Ethernet interface.
- 172.16.3.1 is a Class B Address
- Classful Subnet Mask: 255.255.0.0 or /16

- Automatically creates the Parent Route with no exit interface.
  - Adds the level 2 Child Route.

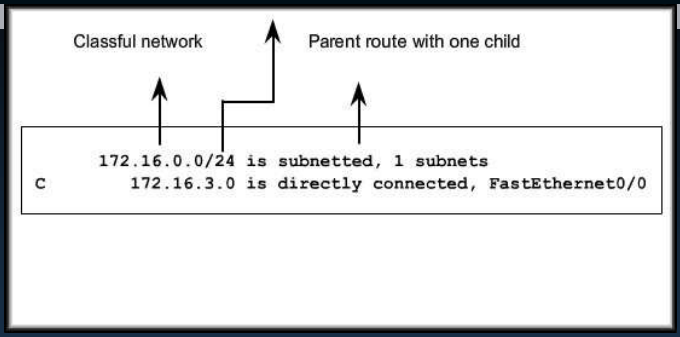
Parent and Child Routes: Classful Networks

```
     172.16.0.0/24 is subnetted, 1 subnets
C       172.16.3.0 is directly connected, FastEthernet0/0
```



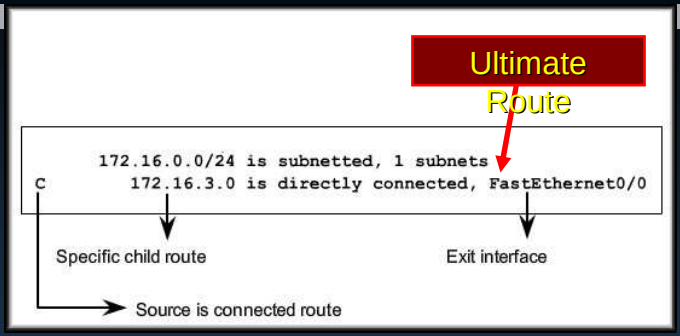
- *A level 2 route, then, is a route that is a subnet of a classful network address.*
  - The source of a level 2 route can be a directly connected network, a static route, or a dynamic routing protocol.

Parent and Child Routes: A Closer Look



- Parent Route:
  - 172.16.0.0: The Classful network address for our subnet.
  - /24: The subnet mask for all of the child routes
  - is subnetted, 1 subnets: This part of the route specifies that this is a parent route and in this case has one child route (that is, one subnet).

Parent and Child Routes: A Closer Look



- Child Route:
  - C: The route code for a directly connected network.
  - 172.16.3.0: The specific route entry.
  - is directly connected: A directly connected network with an administrative distance of 0.
  - FastEthernet0/0: Exit interface for forwarding packets.

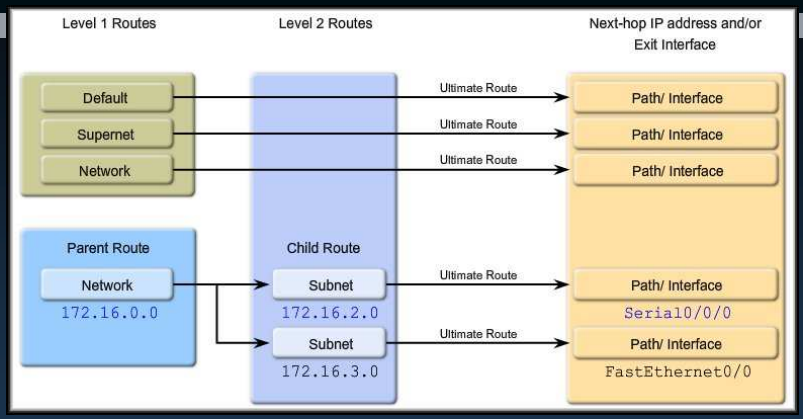
Adding Another Child Route

```
R2(config)# interface serial 0/0/0
R2(config-if)# ip address 172.16.2.2 255.255.255.0
R2(config-if)# no shutdown
R2(config-if)# end

R2# show ip route
<output omitted>

     172.16.0.0/24 is subnetted, 2 subnets
C       172.16.2.0 is directly connected, Serial0/0/0
C       172.16.3.0 is directly connected, FastEthernet0/0
C    192.168.1.0/24 is directly connected, Serial0/0/1
```

Ultimate Routes

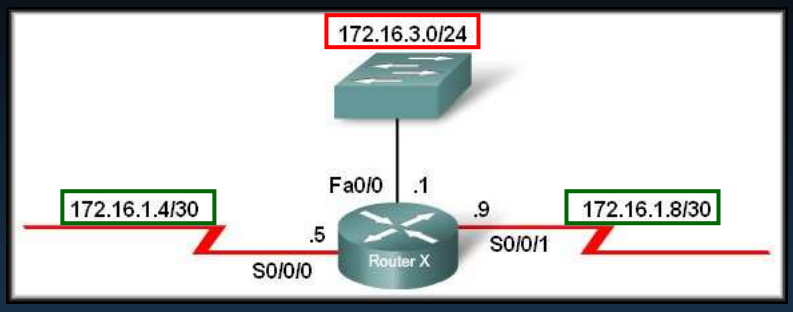
- Both 172.16.2.0 and 172.16.3.0 are members of the same parent route because they are both members of the 172.16.0.0/16 classful network.
- Because both child routes have the same subnet mask, the parent route still maintains the /24 mask but now shows two subnets.

Adding Another Child Route



- *If there is only a single level 2 child route and that route is removed, the level 1 parent route is automatically deleted.*
- A level 1 parent route exists only when there is at least one level 2 child route.

Parent and Child Routes: Classless Networks



- Topology for discussing parent and child routes for classless networks.
- Classless:
  - VLSM has been used to subnet the 172.16.0.0/16 network into subnets with variable length subnet masks.

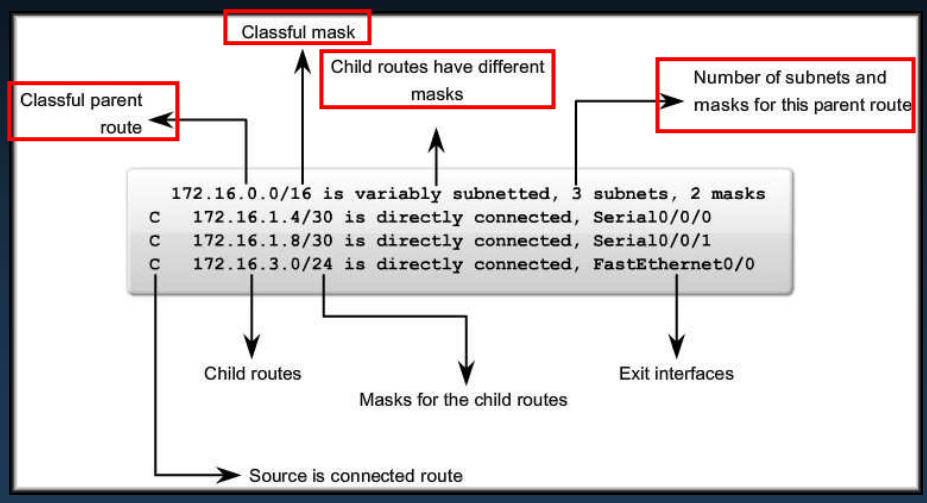
Parent and Child Routes: Classless Networks

```
RouterX# show ip route
<output omitted>

     172.16.0.0/16 is variably subnetted, 3 subnets, 2 masks
C       172.16.1.4/30 is directly connected, Serial0/0/0
C       172.16.1.8/30 is directly connected, Serial0/0/1
C       172.16.3.0/24 is directly connected, FastEthernet0/0
```

- All three subnets belong to the classful network 172.16.0.0/16 and are level 2 child routes.
  - The child routes do not share the same subnet mask because the network addressing scheme used VLSM.
- Whenever there are two or more child routes with different subnet masks belonging to the same classful network, the routing table presents a slightly different view.
  - This parent network is variably subnetted.

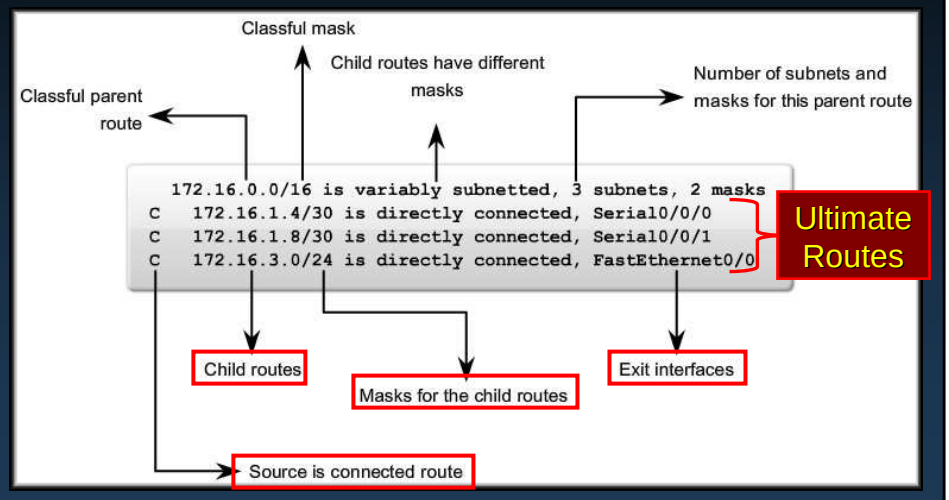
Parent and Child Routes: Classless Networks

Parent Route: A Closer Look



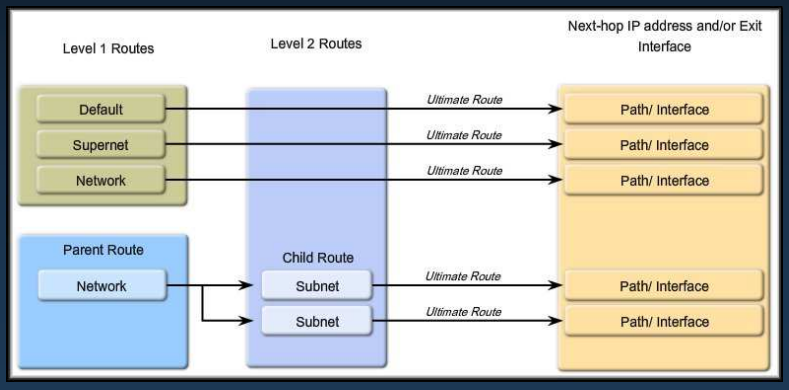
Parent and Child Routes: Classless Networks

Child Route: A Closer Look



The Routing Table: A Closer Look

The Routing Table Lookup Process



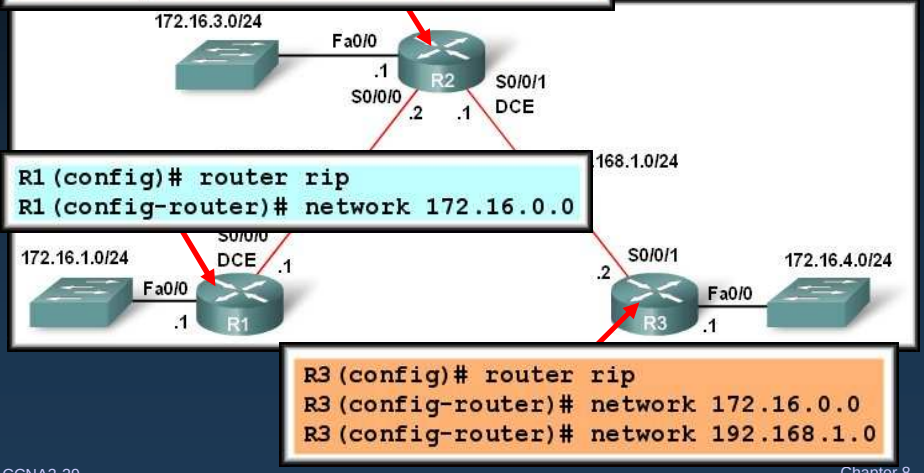
Routing Table Lookup Process


```
ot set
ed, 1 subnets
S       10.1.0.0 is directly connected, Serial0/0/1
    172.16.0.0/24 is subnetted, 4 subnets
R       172.16.1.0 [120/1] via 172.16.2.1, 00:00:08, Serial0/0/0
C       172.16.2.0 is directly connected, Serial0/0/0
C       172.16.3.0 is directly connected, FastEthernet0/0
S       172.16.4.0 is directly connected, Serial0/0/1
C    192.168.1.0/24 is directly connected, Serial0/0/1
S    192.168.100.0/24 is directly connected, Serial0/0/1
```

- *When a router receives a frame on one of its interfaces*:
  - The routing table lookup process compares the destination IP address of the incoming packet with the entries in the routing table.
  - The best match between the packet's destination IP address and the route in the routing table is used to determine the interface used to forward the packet.

Routing Table Lookup Process

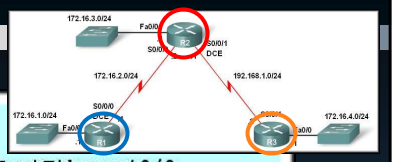
```
R2(config)# router rip
R2(config-router)# network 172.16.0.0
R2(config-router)# network 192.168.1.0
```




```
R1(config)# router rip
R1(config-router)# network 172.16.0.0
```

```
R3(config)# router rip
R3(config-router)# network 172.16.0.0
R3(config-router)# network 192.168.1.0
```


Routing Table Lookup Process



```
R1# show ip route
     172.16.0.0/24 is subnetted, 3 subnets
C       172.16.1.0 is directly connected, FastEthernet0/0
C       172.16.2.0 is directly connected, Serial0/0/0
R       172.16.3.0 [120/1] via 172.16.2.2, 00:00:25, Serial0/0/0
R    192.168.1.0/24 [120/1] via 172.16.2.2, 00:00:25, Serial0/0/0
```

```
R2# show ip route
     172.16.0.0/24 is subnetted, 3 subnets
R       172.16.1.0 [120/1] via 172.16.2.1, 00:00:07, Serial0/0/0
C       172.16.2.0 is directly connected, Serial0/0/0
C       172.16.3.0 is directly connected, FastEthernet0/0
C    192.168.1.0/24 is directly connected, Serial0/0/1
```

```
R3# show ip route
     172.16.0.0/24 is subnetted, 1 subnets
C       172.16.4.0 is directly connected, FastEthernet0/0
C    192.168.1.0/24 is directly connected, Serial0/0/1
```

Routing Table Lookup Process

As you would expect, there are reachability problems.

```
R1# show ip route
     172.16.0.0/24 is subnetted, 3 subnets
C       172.16.1.0 is directly connected, FastEthernet0/0
C       172.16.2.0 is directly connected, Serial0/0/0
R       172.16.3.0 [120/1] via 172.16.2.2, 00:00:25, Serial0/0/0
R    192.168.1.0/24 [120/1] via 172.16.2.2, 00:00:25, Serial0/0/0
```

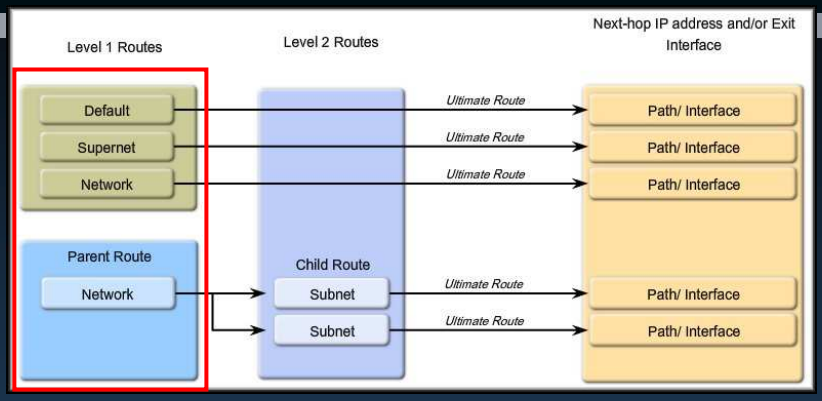
```
R2# show ip route
     172.16.0.0/24 is subnetted, 3 subnets
R       172.16.1.0 [120/1] via 172.16.2.1, 00:00:07, Serial0/0/0
C       172.16.2.0 is directly connected, Serial0/0/0
C       172.16.3.0 is directly connected, FastEthernet0/0
C    192.168.1.0/24 is directly connected, Serial0/0/1
```

```
R3# show ip route
     172.16.0.0/24 is subnetted, 1 subnets
C       172.16.4.0 is directly connected, FastEthe
C    192.168.1.0/24 is directly connected, Serial0
```

No route to 172.16.4.0

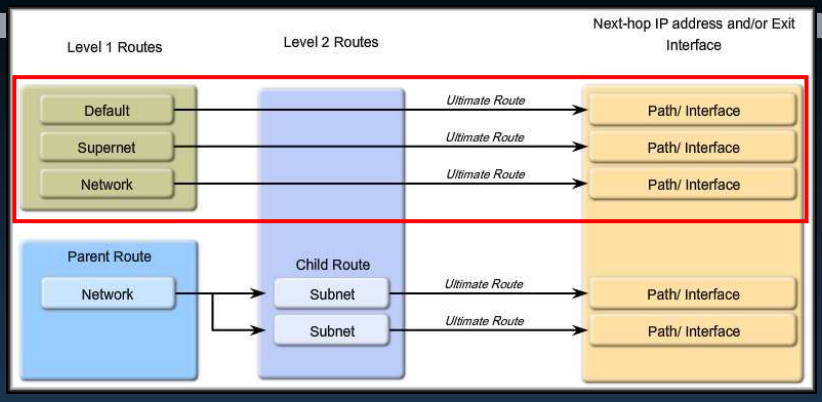
No route to 172.16.1.0 172.16.2.0 172.16.3.0

Steps in the Routing Table Lookup Process



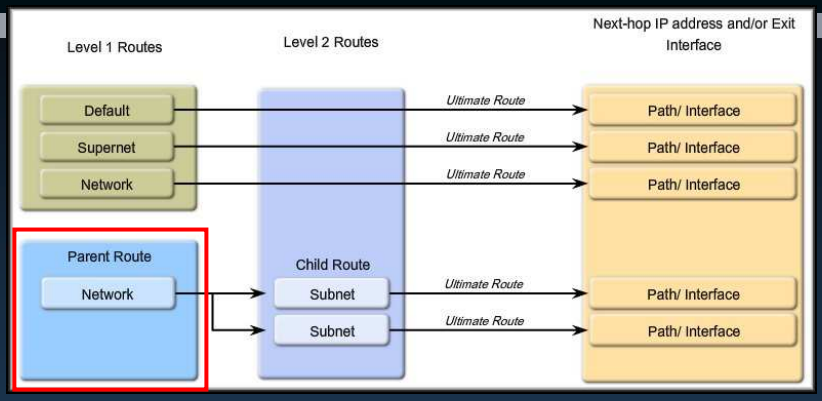
- Step 1:
  - The router examines level 1 routes, including network routes and supernet routes, for the best match with the destination address of the IP packet.

Steps in the Routing Table Lookup Process



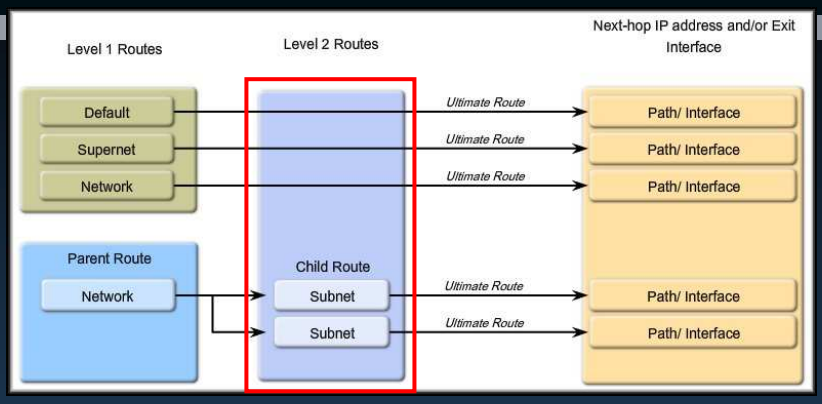
- Step 1a:
  - If the best match is a level 1 ultimate route (a classful network, supernet, or default route) use this route to forward the packet.

Steps in the Routing Table Lookup Process



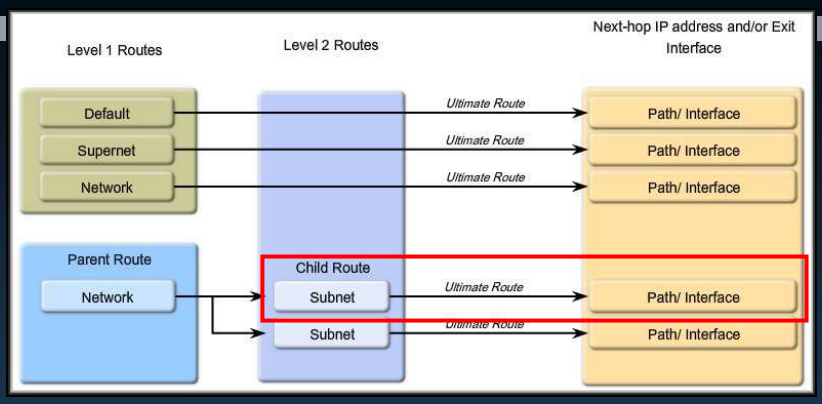
- Step 1b:
  - If the best match is a level 1 parent route, examine the child routes.

Steps in the Routing Table Lookup Process



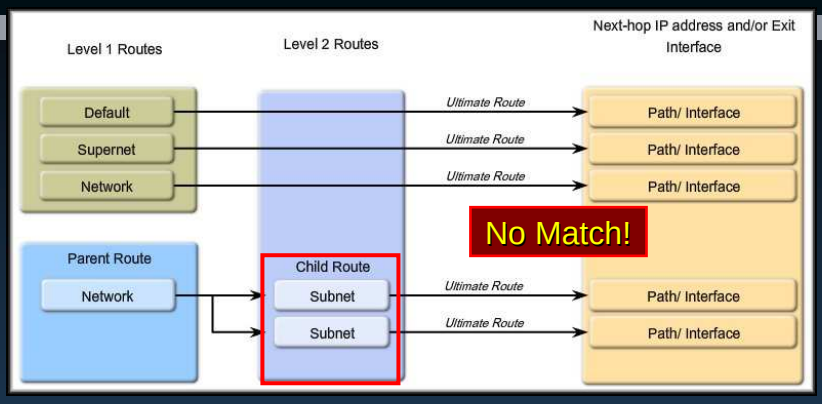
- Step 2:
  - The router examines child routes (the subnet routes) of the parent route for a best match.

Steps in the Routing Table Lookup Process



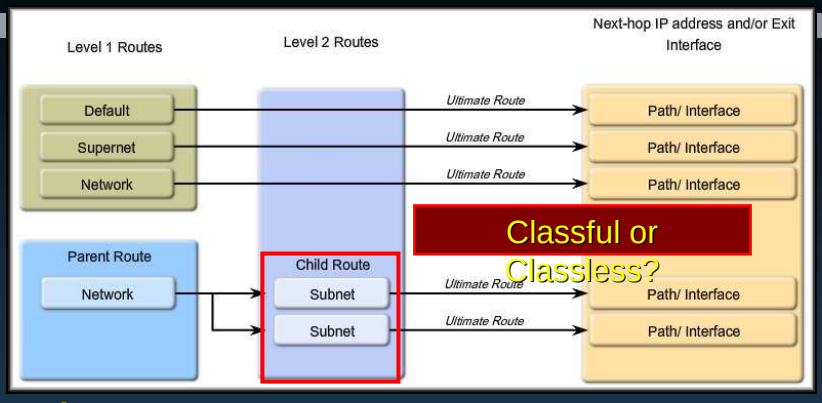
- Step 2a:
  - If there is a match with a level 2 child route, that subnet is used to forward the packet.

Steps in the Routing Table Lookup Process



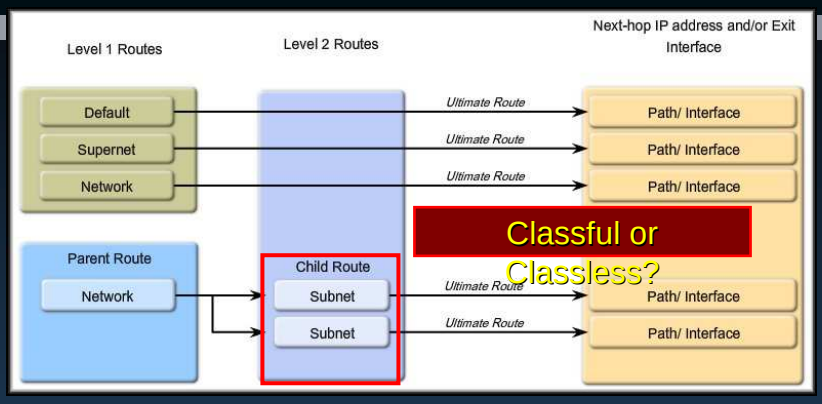
- Step 2b:
  - If there is not a match with any of the level 2 child routes, check the routing behaviour.

Steps in the Routing Table Lookup Process



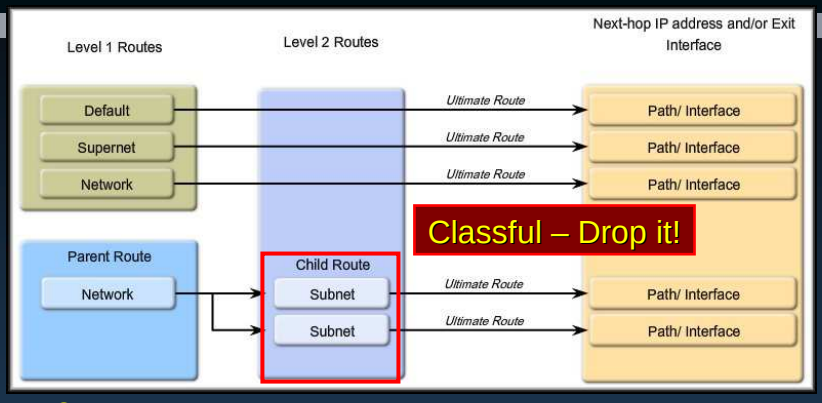
- Step 3:
  - Is the router implementing **classful or classless** routing behavior?
    - *We'll get into **Routing Behaviour** in a moment!*

Steps in the Routing Table Lookup Process



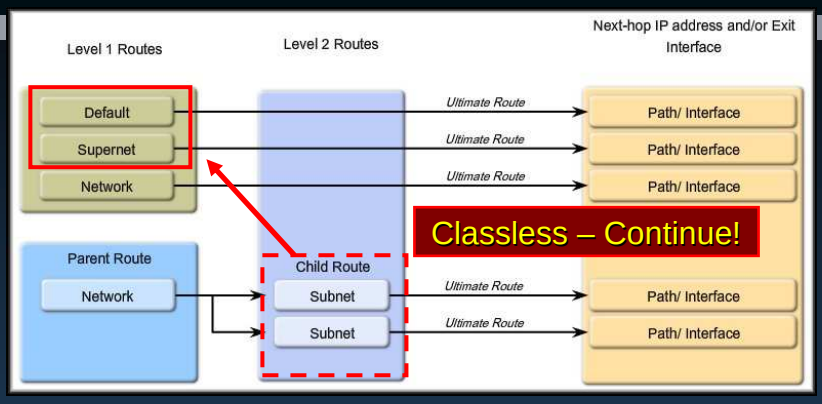
- Step 3a:
  - If **classful routing behavior** is in effect, terminate the lookup process and drop the packet.
    - *We'll get into Routing Behaviour in a moment!*

Steps in the Routing Table Lookup Process



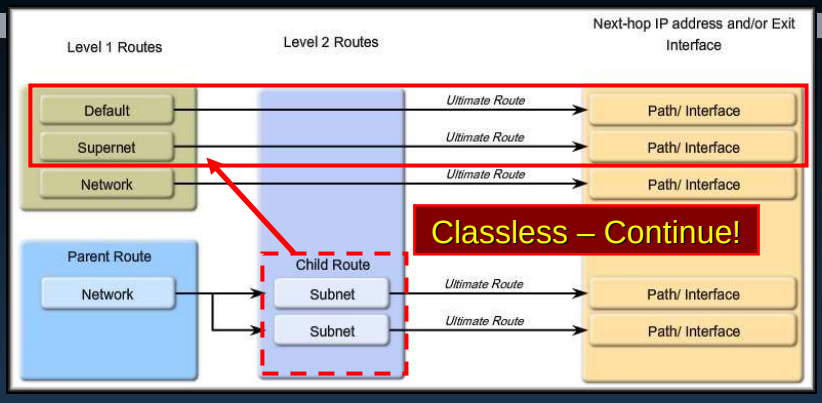
- Step 3a:
  - If **classful routing behavior** is in effect, terminate the lookup process and drop the packet.
    - *We'll get into Routing Behaviour in a moment!*

Steps in the Routing Table Lookup Process



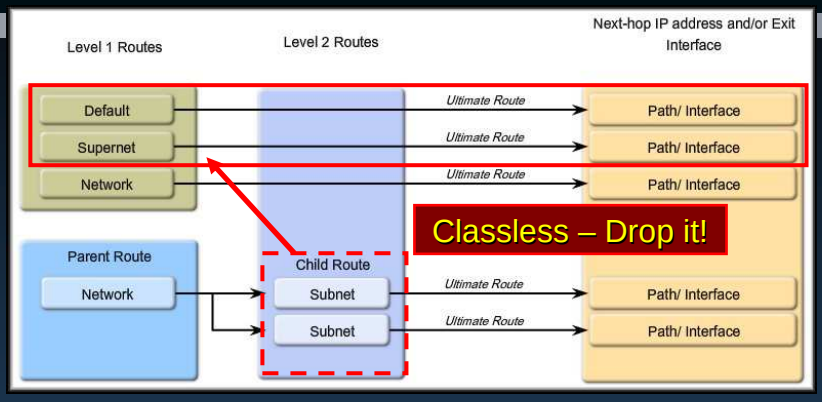
- Step 3b:
  - If classless routing behavior is in effect, continue searching level 1 supernet routes in the routing table for a match, including the default route, if there is one.

Steps in the Routing Table Lookup Process



- Step 4:
  - If there is now a lesser match with a level 1 supernet or default routes, the router uses that route to forward the packet.

Steps in the Routing Table Lookup Process



- Step 5:
  - If there is not a match with any route in the routing table, the router drops the packet.

Longest Match: Level 1 Network Routes

IP Packet Destination	172.16.0.10	10101100.00010000.00000000.00001010
Route 1	172.16.0.0/12	10101100.00010000.00000000.00000000
Route 2	172.16.0.0/18	10101100.00010000.00000000.00000000
Route 3	172.16.0.0/26	10101100.00010000.00000000.00000000

- For there to be a match between the destination IP address of a packet and a route in the routing table, a minimum number of leftmost bits must match between the IP address of the packet and the route in the routing table.
  - *The subnet mask of the route in the routing table is used to determine the minimum number of leftmost bits that must match.*

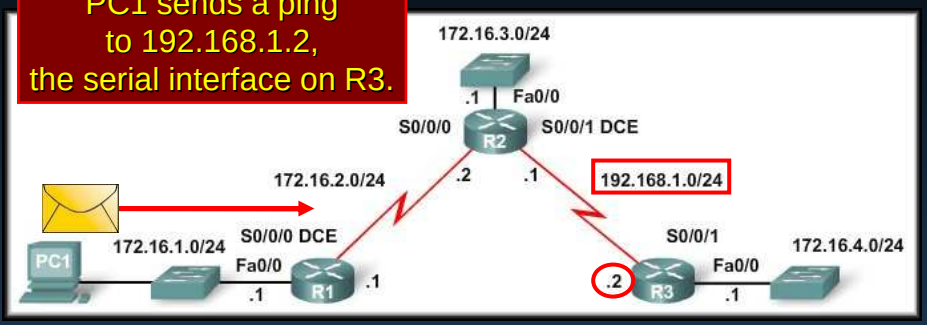
Longest Match: Level 1 Network Routes

IP Packet Destination	172.16.0.10	10101100.00010000.00000000.00001010
Route 1	172.16.0.0/12	10101100.00010000.00000000.00000000
Route 2	172.16.0.0/18	10101100.00010000.00000000.00000000
Route 3	172.16.0.0/26	10101100.00010000.00000000.00000000

- The **best match or longest match** is the route in the routing table that has the **greatest number of leftmost** matching bits with the destination IP address of the packet.
- **Preferred Route:**
  - The route with the greatest number of equivalent leftmost bits, or the longest match.

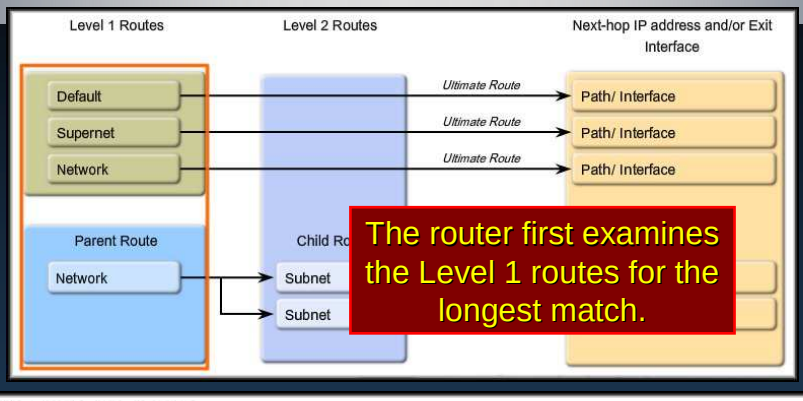
Example: Level 1 Ultimate Routes

PC1 sends a ping to 192.168.1.2, the serial interface on R3.



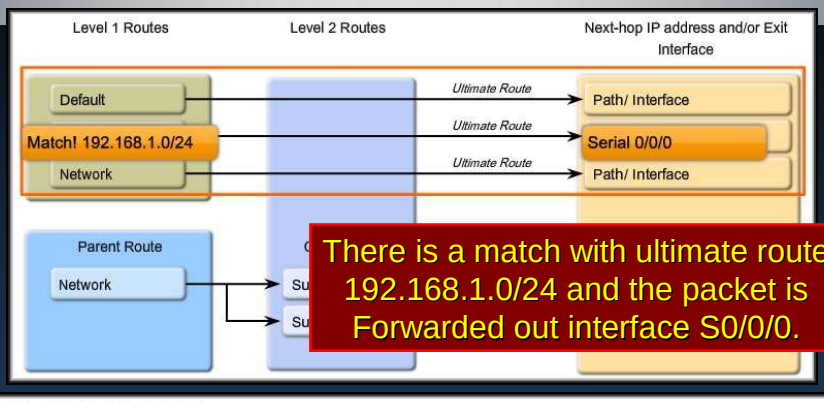

```
R1# show ip route
     172.16.0.0/24 is subnetted, 3 subnets
C       172.16.1.0 is directly connected, FastEthernet0/0
C       172.16.2.0 is directly connected, Serial0/0/0
R       172.16.3.0 [120/1] via 172.16.2.2, 00:00:25, Serial0/0/0
R    192.168.1.0/24 [120/1] via 172.16.2.2, 00:00:25, Serial0/0/0
```

Example: Level 1 Ultimate Routes




```
R1# show ip route
     172.16.0.0/24 is subnetted, 3 subnets
C       172.16.1.0 is directly connected, FastEthernet0/0
C       172.16.2.0 is directly connected, Serial0/0/0
R       172.16.3.0 [120/1] via 172.16.2.2, 00:00:25, Serial0/0/0
R    192.168.1.0/24 [120/1] via 172.16.2.2, 00:00:25, Serial0/0/0
```


Example: Level 1 Ultimate Routes




```
R1# show ip route
     172.16.0.0/24 is subnetted, 3 subnets
C       172.16.1.0 is directly connected, FastEthernet0/0
C       172.16.2.0 is directly connected, Serial0/0/0
R       172.16.3.0 [120/1] via 172.16.2.2, 00:00:25, Serial0/0/0
R    192.168.1.0/24 [120/1] via 172.16.2.2, 00:00:25, Serial0/0/0
```

Example: Level 1 Ultimate Routes

- *Why didn't it find a match in one of the other subnets?*

```
R1# show ip route
    172.16.0.0/24 is subnetted, 3 subnets
C       172.16.1.0 is directly connected, FastEthernet0/0
C       172.16.2.0 is directly connected, Serial0/0/0
R       172.16.3.0 [120/1] via 172.16.2.2, 00:00:25, Serial0/0/0
R    192.168.1.0/24 [120/1] via 172.16.2.2, 00:00:25, Serial0/0/0
```

Destination IP	192.168.1.2	11000000.10101000.00000001.00000010
Level 1 Parent	172.16.0.0	10101100.00010000.00000000.00000000

172.16.0.0/16 is a Parent Route and there must be a match to the first 16 bits before any Child Routes are checked.

Example: Level 1 Ultimate Routes

- *Why did it find a match to the ultimate route 192.168.1.0/24?*

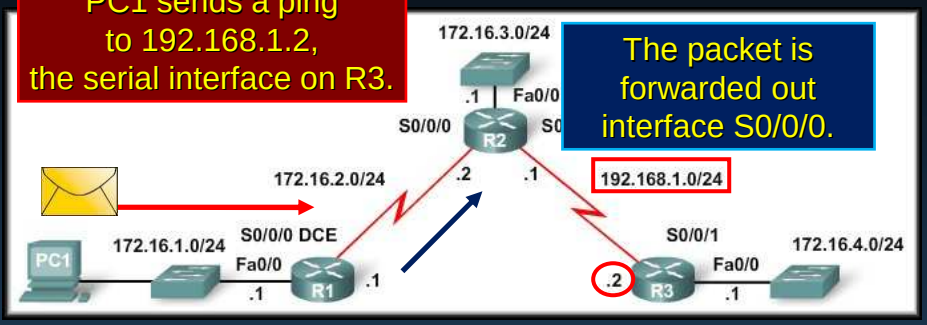
```
R1# show ip route
     172.16.0.0/24 is subnetted, 3 subnets
C       172.16.1.0 is directly connected, FastEthernet0/0
C       172.16.2.0 is directly connected, Serial0/0/0
R       172.16.3.0 [120/1] via 172.16.2.2, 00:00:25, Serial0/0/0
R    192.168.1.0/24 [120/1] via 172.16.2.2, 00:00:25, Serial0/0/0
```

Destination IP	192.168.1.2	11000000.10101000.00000001.00000010
Level 1 Parent	192.168.1.0	11000000.10101000.00000001.00000000

The first 24 bits of the ultimate route match. In fact, the first 30 bits match. *There is no longer, more specific match.*

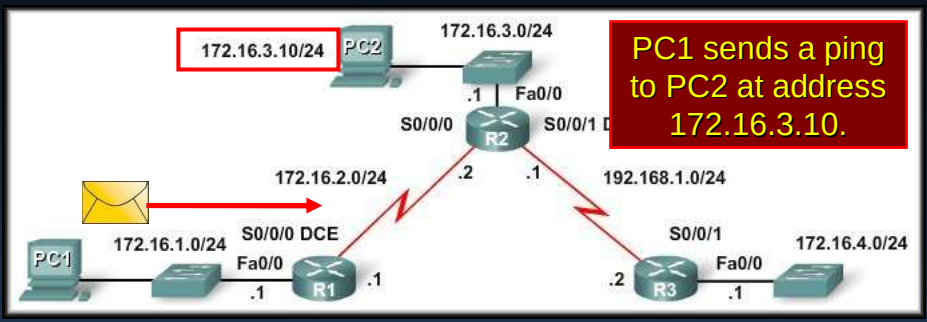
Example: Level 1 Ultimate Routes

PC1 sends a ping to 192.168.1.2, the serial interface on R3.



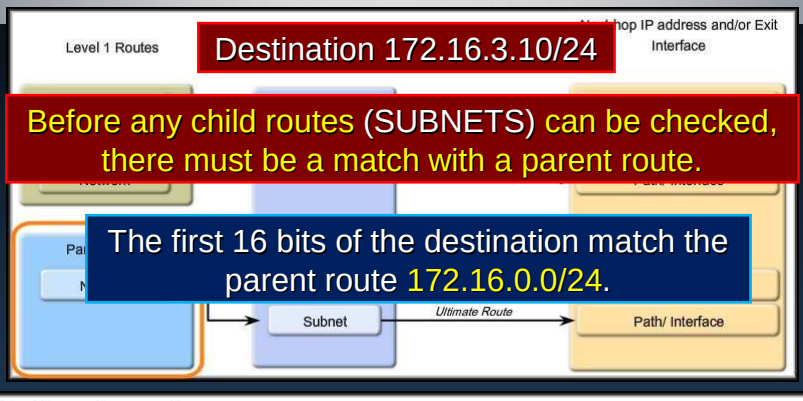

```
R1# show ip route
     172.16.0.0/24 is subnetted, 3 subnets
C       172.16.1.0 is directly connected, FastEthernet0/0
C       172.16.2.0 is directly connected, Serial0/0/0
R       172.16.3.0 [120/1] via 172.16.2.2, 00:00:25, Serial0/0/0
R    192.168.1.0/24 [120/1] via 172.16.2.2, 00:00:25, Serial0/0/0
```


Longest Match: Level 1 Parent / Level 2 Child



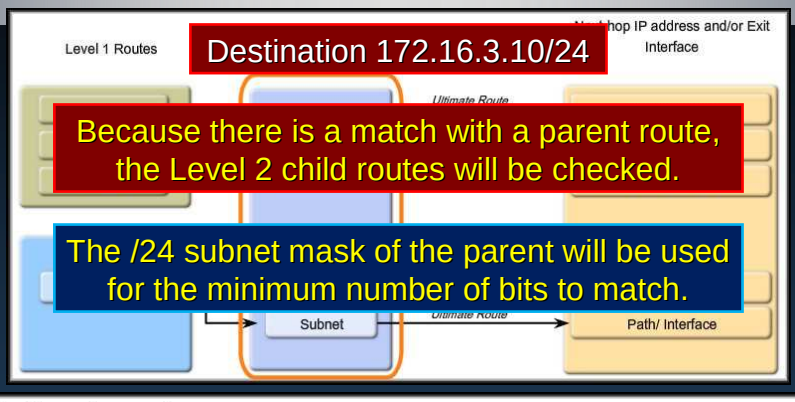

```
R1# show ip route
     172.16.0.0/24 is subnetted, 3 subnets
C       172.16.1.0 is directly connected, FastEthernet0/0
C       172.16.2.0 is directly connected, Serial0/0/0
R       172.16.3.0 [120/1] via 172.16.2.2, 00:00:25, Serial0/0/0
R    192.168.1.0/24 [120/1] via 172.16.2.2, 00:00:25, Serial0/0/0
```

Longest Match: Level 1 Parent / Level 2 Child



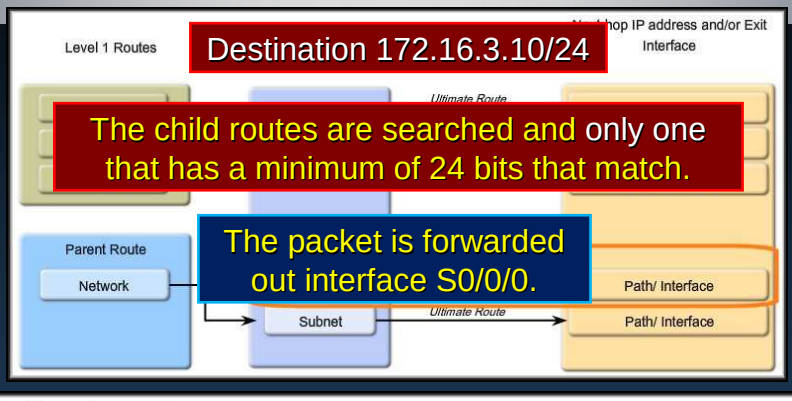

```
R1# show ip route
     172.16.0.0/24 is subnetted, 3 subnets
C       172.16.1.0 is directly connected, FastEthernet0/0
C       172.16.2.0 is directly connected, Serial0/0/0
R       172.16.3.0 [120/1] via 172.16.2.2, 00:00:25, Serial0/0/0
R    192.168.1.0/24 [120/1] via 172.16.2.2, 00:00:25, Serial0/0/0
```


Longest Match: Level 1 Parent / Level 2 Child




```
R1# show ip route
     172.16.0.0/24 is subnetted, 3 subnets
C       172.16.1.0 is directly connected, FastEthernet0/0
C       172.16.2.0 is directly connected, Serial0/0/0
R       172.16.3.0 [120/1] via 172.16.2.2, 00:00:25, Serial0/0/0
R    192.168.1.0/24 [120/1] via 172.16.2.2, 00:00:25, Serial0/0/0
```

Longest Match: Level 1 Parent / Level 2 Child




```
R1# show ip route
     172.16.0.0/24 is subnetted, 3 subnets
C       172.16.1.0 is directly connected, FastEthernet0/0
C       172.16.2.0 is directly connected, Serial0/0/0
R       172.16.3.0 [120/1] via 172.16.2.2, 00:00:25, Serial0/0/0
R    192.168.1.0/24 [120/1] via 172.16.2.2, 00:00:25, Serial0/0/0
```


Longest Match: Level 1 Parent / Level 2 Child

```
R1# show ip route
     172.16.0.0/24 is subnetted, 3 subnets
C       172.16.1.0 is directly connected, FastEthernet0/0
C       172.16.2.0 is directly connected, Serial0/0/0
R       172.16.3.0 [120/1] via 172.16.2.2, 00:00:25, Serial0/0/0
R    192.168.1.0/24 [120/1] via 172.16.2.2, 00:00:25, Serial0/0/0
```

Destination IP	172.16.3.10	10101100.00010000.00000011.00001010
Level 1 Parent	172.16.0.0	10101100.00010000.00000000.00000000
Level 2 Child	172.16.1.0	10101100.00010000.00000001.00000000
Level 2 Child	172.16.2.0	10101100.00010000.00000010.00000000
Level 2 Child	172.16.3.0	10101100.00010000.00000011.00000000

Longest Match: Level 1 Parent / Level 2 Child

```
R1# show ip route
     172.16.0.0/24 is subnetted, 3 subnets
C       172.16.1.0 is directly connected, FastEthernet0/0
C       172.16.2.0 is directly connected, Serial0/0/0
R       172.16.3.0 [120/1] via 172.16.2.2, 00:00:25, Serial0/0/0
R    192.168.1.0/24 [120/1] via 172.16.2.2, 00:00:25, Serial0/0/0
```

- Final Notes:
  - If this child route had a next-hop IP Address instead of an exit interface, the lookup process would start again.
  - This time the next-hop IP address would be resolved to an exit interface.
  - *What happens if the router does not have a route?*
    - In this scenario, it discards the packet.

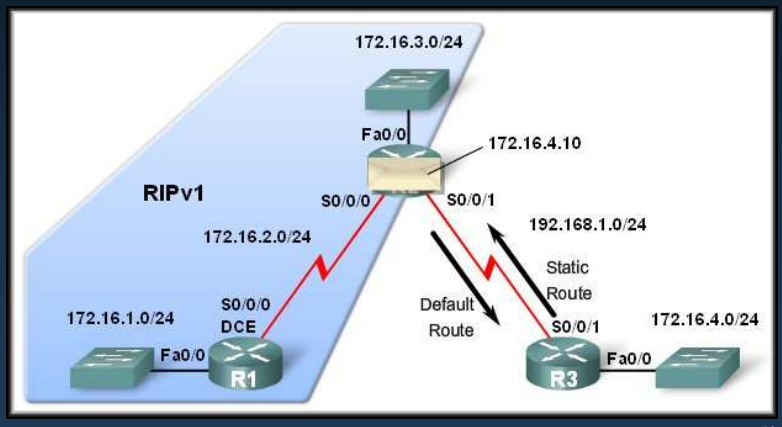
Route Lookup Process with VLSM

```
RouterX# show ip route

     172.16.0.0/16 is variably subnetted, 3 subnets, 2 masks
C       172.16.1.4/30 is directly connected, Serial0/0/0
C       172.16.1.8/30 is directly connected, Serial0/0/1
C       172.16.3.0/24 is directly connected, FastEthernet0/0
```

- Packet's destination IP Address: 172.16.1.5
  - *Using VSLM does not change the lookup process.*
  - The only difference with VLSM is that child routes display their own specific subnet masks.
  - 16 bits match the parent route, 172.16.0.0.
  - For there to be a match with the 172.16.1.4 child route, a minimum of 30 leftmost bits must match because the subnet mask is /30.

The Routing Table: A Closer Look

Routing Behaviour



Classful and Classless Routing Behaviour

- Classless and classful routing behaviours are not the same as classless and classful routing protocols.

Routing Protocols vs Routing Behaviors

Routing Sources
- Directly Connected Networks
- Static Routes
- Classful Routing Protocols
  - RIPv1
  - IGRP
- Classless Routing Protocols
  - RIPv2
  - EIGRP
  - OSPF
  - IS-IS

- Routing sources (including protocols) are used to build the routing table.
- Multiple sources and routing protocols can be used.

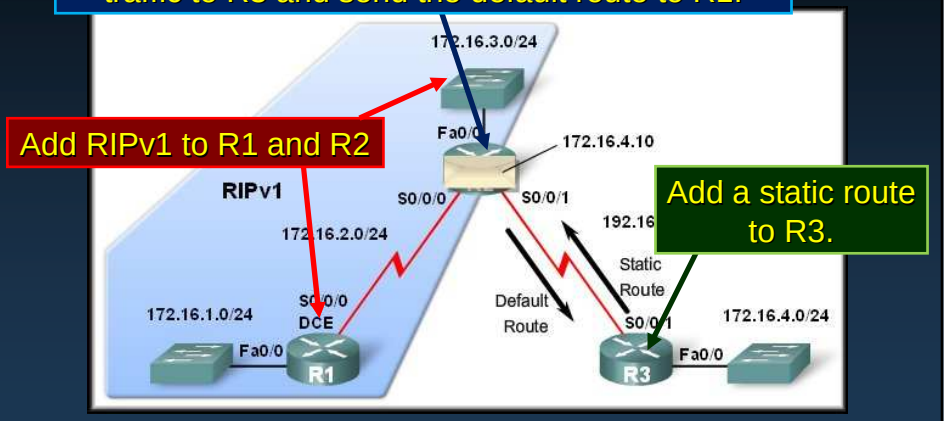
Routing Behaviors
- Classful
  - `no ip classless`
- IP Classless
  - `ip classless`

- Routing behaviors are used to locate information in the routing table.
- Only a single routing behavior can be used.

- **Classful and Classless Routing Protocols:**
  - Affect how the routing table is **populated**.
- **Classful and Classless Routing Behaviours:**
  - Determine how the routing table is **searched**.

Topology Changes

Add a “quad-zero” default route to R2 to send traffic to R3 and send the default route to R1.

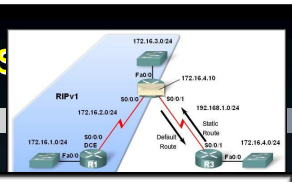


Add RIPv1 to R1 and R2

Add a static route to R3.

- **Classful** routing protocols such as RIPv1 do not support discontiguous networks.

Topology Changes



```
R2# show ip route

Gateway of last resort is 0.0.0.0 to network 0.0.0.0

    172.16.0.0/24 is subnetted, 3 subnets
R      172.16.1.0 [120/1] via 172.16.2.1, 00:00:00, Serial0/0/0
C      172.16.2.0 is directly connected, Serial0/0/0
C      172.16.3.0 is directly connected, FastEthernet0/0
C   192.168.1.0/24 is directly connected, Serial0/0/1
S*  0.0.0.0/0 is directly connected, Serial0/0/1
```

```
R3# show ip route

    172.16.0.0/16 is variably subnetted, 2 subnets, 2 masks
C      172.16.4.0/24 is directly connected, FastEthernet0/0
S      172.16.0.0/16 is directly connected, Serial0/0/1
C   192.168.1.0/24 is directly connected, Serial0/0/1
```

Classful and Classless Routing Behaviour

- Classful and classless routing behaviours can be controlled by commands.
- Global Configuration Mode:
  - **ip classless**
  - **no ip classless**
- The default is **ip classless.**

Classful Routing Behaviour: no ip classless

no ip classless = classful routing behaviour

Destination: 172.16.4.10

Is there a match?

```
R2# show ip route

Gateway of last resort is 0.0.0.0 to network 0.0.0.0

     172.16.0.0/24 is subnetted, 3 subnets
R       172.16.1.0 [120/1] via 172.16.2.1, 00:00:00, Serial0/0/0
C       172.16.2.0 is directly connected, Serial0/0/0
C       172.16.3.0 is directly connected, FastEthernet0/0
C    192.168.1.0/24 is directly connected, Serial0/0/1
S*   0.0.0.0/0 is directly connected, Serial0/0/1
```

NO! - Is routing behaviour classful or classless?

no ip classless (Classful) - DROP THE PACKET!
The default route is never used.

Classful Routing Behaviour: ip classless

ip classless = classless routing behaviour

Destination: 172.16.4.10

Is there a match?

```
R2# show ip route

Gateway of last resort is 0.0.0.0 to network 0.0.0.0

     172.16.0.0/24 is subnetted, 3 subnets
R       172.16.1.0 [120/1] via 172.16.2.1, 00:00:00, Serial0/0/0
C       172.16.2.0 is directly connected, Serial0/0/0
C       172.16.3.0 is directly connected, FastEthernet0/0
C    192.168.1.0/24 is directly connected, Serial0/0/1
S*   0.0.0.0/0 is directly connected, Serial0/0/1
```

NO! - Is routing behaviour classful or classless?

ip classless (Classless) USE THE DEFAULT ROUTE

Classful Routing Behaviour: R3

```
R3# show ip route

     172.16.0.0/16 is variably subnetted, 2 subnets, 2 masks
C       172.16.4.0/24 is directly connected, FastEthernet0/0
S       172.16.0.0/16 is directly connected, Serial0/0/1
C    192.168.1.0/24 is directly connected, Serial0/0/1
```

- When the static route was added to R3, it appears in the routing table as a **Child Route**.
  - Even though it is the same network as the parent route, there was already a child route (172.16.4.0/24) existing in the table for parent 172.16.0.0/16.
  - If there was no child route already existing, it would have been added as an ultimate route.

Classful Routing Behaviour: R3

```
R3# show ip route

     172.16.0.0/16 is variably subnetted, 2 subnets, 2 masks
C X     172.16.4.0/24 is directly connected, FastEthernet0/0
S       172.16.0.0/16 is directly connected, Serial0/0/1
C    192.168.1.0/24 is directly connected, Serial0/0/1
```

- Return traffic:
  - Finds a match on the Parent Route.
  - No match on the first Child Route.
  - Finds a match on the second child route and forwards the packet out interface S0/0/1.

Classful vs Classless – Real World

- *Remember that classful and classless routing behaviors are independent from classful and classless routing protocols.*
  - A router could be configured with classful routing behavior (no ip classless) and a classless routing protocol, such as RIPv2.
  - A router could also be configured with classless routing behavior (ip classless) and a classful routing protocol, such as RIPv1.
- In today's networks, it is recommended to use classless routing behavior so that supernet and default routes can be used whenever needed.