



# The Routing Table: A Closer Look



## Routing Protocols and Concepts – Chapter 8

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# Objectives

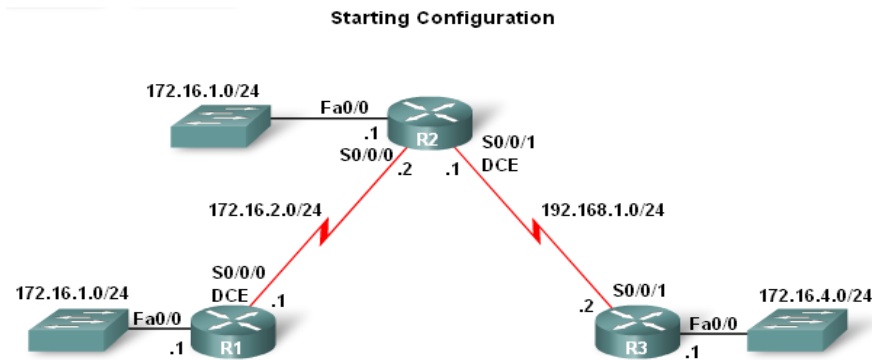
- Describe the various route types found in the routing table structure
- Describe the routing table lookup process.
- Describe routing behavior in routed networks.

# Introduction

- Chapter Focus
  - Structure of the routing table
  - Lookup process of the routing table
  - Classless and classful routing behaviors

# Routing Table Structure

- Lab Topology
- 3 router setup
  - R1 and R2 share a common 172.16.0.0/16 network with 172.16.0.0/24 subnets.
  - R2 and R3 are connected by the 192.168.1.0/24 network.
  - R3 also has a 172.16.4.0/24 subnet, which is disconnected, or discontinuous, from the 172.16.0.0 network that R1 and R2 share.



```
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
R1(config-if)#end
R1#copy run start
```

```
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)#clock rate 64000
R3(config-if)#no shutdown
R3(config-if)#end
R3#copy run start
```

# Routing Table Structure

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

Sample Routing Table

```

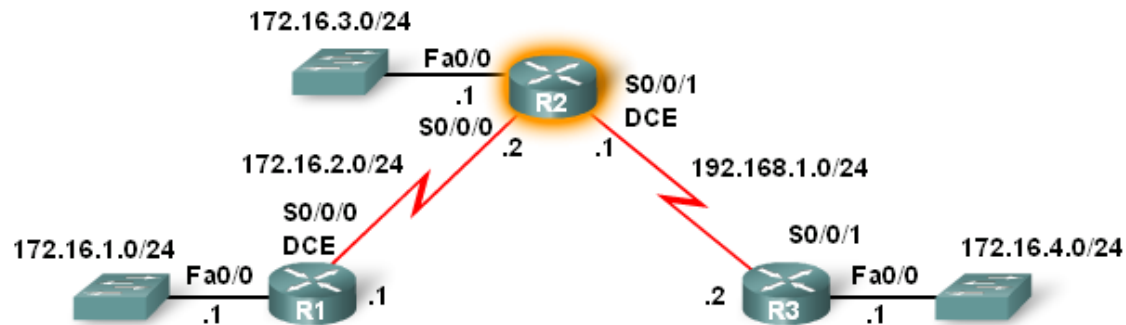
Router#show ip route
Codes: C - connected, S - static, I - IGRP, R - RIP, M - mobile,
<output omitted>

Gateway of last resort is not set

 172.16.0.0/24 is subnetted, 4 subnets
S       172.16.4.0 is directly connected, Serial0/0/1
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
 10.0.0.0/16 is subnetted, 1 subnets
S       10.1.0.0 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
Router#
  
```

# Routing Table Structure

- Level 1 Routes
- As soon as the no shutdown command is issued the route is added to routing table



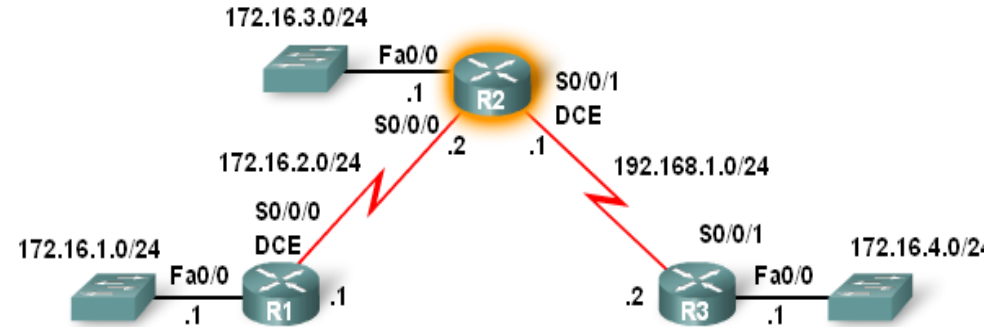
```

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 Serial 0/0/1 added to routing table
R2(config-if)#end
R2#undebug all
All possible debugging has been turned off
    
```

# Routing Table Structure

- Cisco IP routing table is a hierarchical structure

-The reason for this is to speed up lookup process



Routing Table



```
R2#show ip route
```

```
Codes: C - connected, S - static, I - IGRP, R - RIP, M - mobile, B - BGP
       D - EIGRP, EX - EIGRP external, O - OSPF, IA - OSPF inter area
       N1 - OSPF NSSA external type 1, N2 - OSPF NSSA external type 2
       E1 - OSPF external type 1, E2 - OSPF external type 2, E - EGP
       i - IS-IS, L1 - IS-IS level-1, L2 - IS-IS level-2, ia - IS-IS inter area
       * - candidate default, U - per-user static route, o - ODR
       P - periodic downloaded static route
```

```
Gateway of last resort is not set
```

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

# Routing Table Structure

- Level 1 Routes

- Have a subnet mask equal to or less than the classful mask of the network address.

- Level 1 route can function as

- Default route

- Supernet route

- Network route

## Routing Table: Level 1 Routes

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

### Level 1 Route Examples

- Default Route: 0.0.0.0/0
- Supernet Route: 192.168.0.0/22
- Network Route: 192.168.1.0/24



# Routing Table Structure

- Level 1 Routes
  - Ultimate Route
    - Includes either:
      - A next-hop address
      - OR**
      - An exit interface

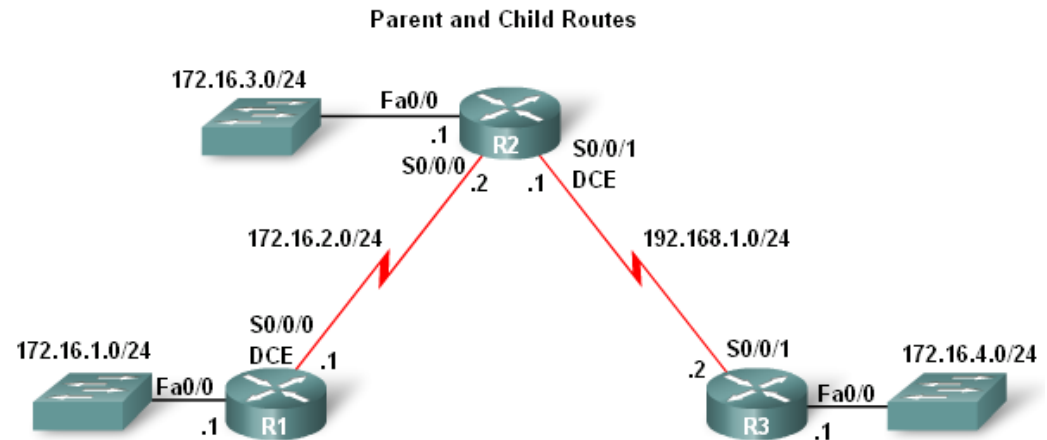
Routing Table: Level 1 Routes

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



# Routing Table Structure

- Parent and Child Routes
  - A **parent route** is a **level 1** route
  - A **parent route does not contain** any next-hop IP address or exit interface information



Parent and Child Routes

```

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
Codes: C - connected, S - static, I - IGRP, R - RIP, M - mobile,
<text omitted>

Gateway of last resort is not set

    172.16.0.0/24 is subnetted, 1 subnets  Level 1 Parent Route
C       172.16.3.0 is directly connected, FastEthernet0/0
C       192.168.1.0/24 is directly connected, Serial0/0/1
R2#
    
```

# Routing Table Structure

- Automatic creation of parent routes

-Occurs any time a subnet is added to the routing table

- Child routes

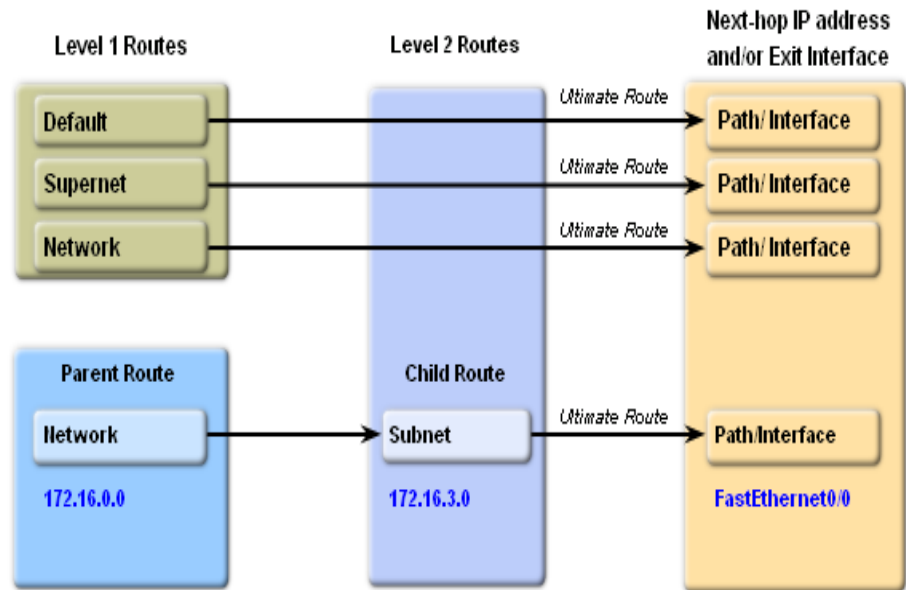
-Child routes are **level 2** routes

-Child routes are a **subnet** of a classful network address

Routing Table: Parent/Child Relationship

```

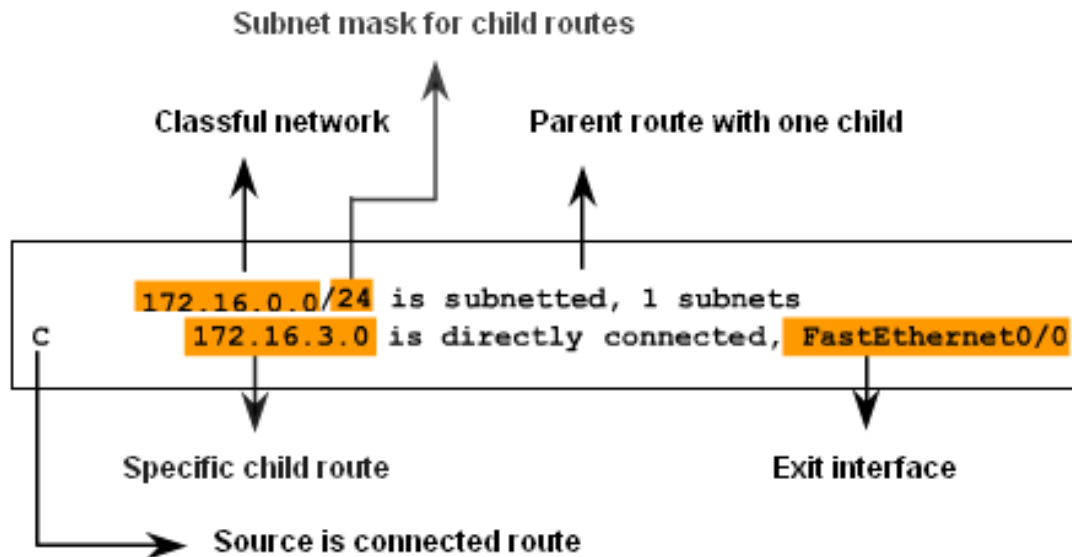
172.16.0.0/24 is subnetted, 1 subnets
C      172.16.3.0 is directly connected, FastEthernet0/0
    
```



# Routing Table Structure

- Level 2 child routes contain route source & the network address of the route
- Level 2 **child routes** are also considered **ultimate routes**

*Reason:* they contain the next hop address &/or exit interface



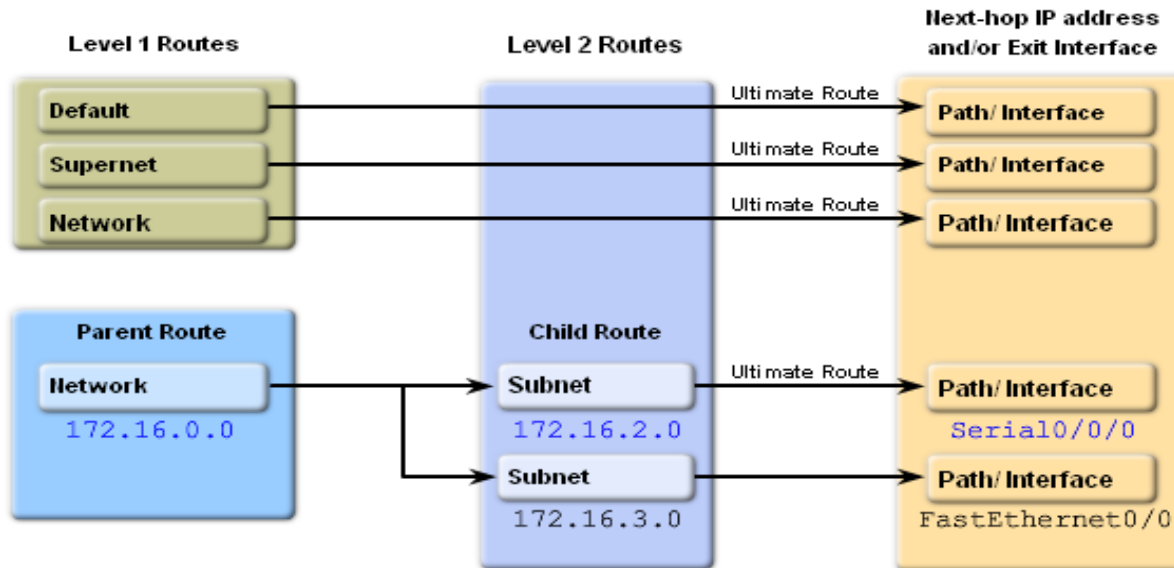
# Routing Table Structure

- Both child routes have the same subnet mask
  - This means the parent route maintains the /24 mask

Routing Table: Parent/Child Relationship

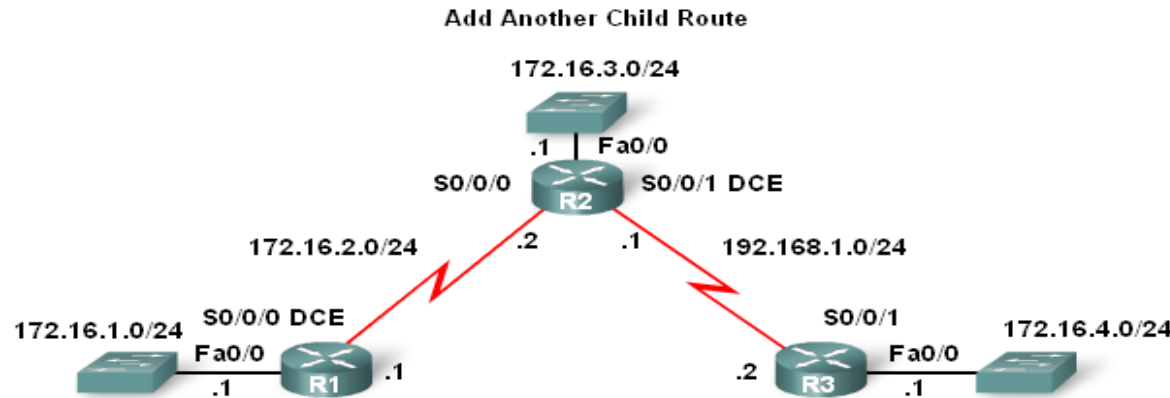
```

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



# Routing Table Structure

- Diagram illustrates 2 child networks belonging to the parent route 172.16.0.0 / 24



```

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
Codes: C - connected, S - static, I - IGRP, R - RIP, M - mobile,
<text omitted>

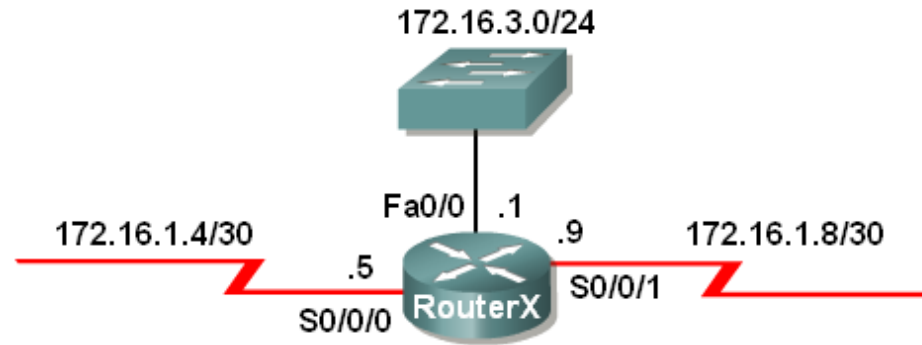
Gateway of last resort is not set

    172.16.0.0/24 is subnetted, 1 subnets      Level 1 Parent Route
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
R2#
    
```

# Routing Table Structure

- In classless networks, child routes do not have to share the same subnet mask

Parent and Child Routes with VLSM



Parent and Child Routes with VLSM

```

RouterX#show ip route
Codes: C - connected, S - static, I - IGRP, R - RIP, M - mobile, B - BGP
<output omitted>

Gateway of last resort is not set

    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
RouterX#
    
```

**Level 1 Parent Route** (highlighted in orange)

**Level 2 Child Route** (highlighted in orange)

# Routing Table Structure

- Parent & Child Routes: Classless Networks

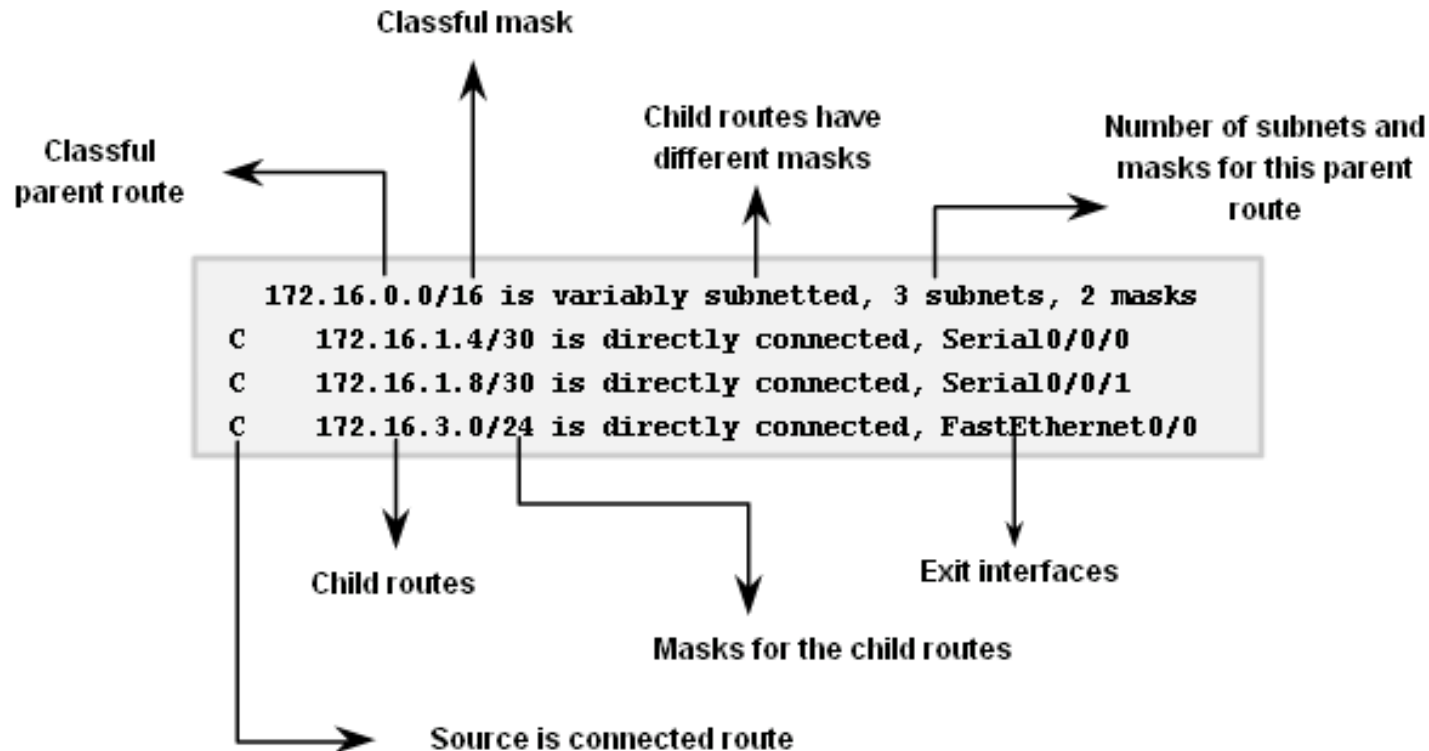
Network Type	Parent route's Classful mask is Displayed	Term <b>variably subnetted</b> is seen in parent route in routing table	Includes the # of different masks of child routes	Subnet mask included with each child route entry
<b>Classful</b>	No	No	No	No
<b>Classless</b>	Yes	Yes	Yes	Yes



# Routing Table Structure

- Parent & Child Routes: Classless Networks

Parent and Child Route Details in a Classless Environment



# Routing Table Lookup Process

## ■ The Route Lookup Process

### ■ Examine level 1 routes

-If best match a level 1 ultimate route and is not a parent route this route is used to forward packet

### ■ Router examines level 2 (child) routes

-If there is a match with level 2 child route then that subnet is used to forward packet

-If no match then determine routing behavior type

### ■ Router determines classful or classless routing behavior

-If classful then packet is dropped

-If classless then router searches level one supernet and default routes

-If there exists a level 1 supernet or default route match then Packet is forwarded. If not packet is dropped

# Routing Table Lookup Process

- Longest Match: Level 1 Network Routes
  - Best match is also known as the longest match
  - The **best match** is the one that has the most number of left most bits matching between the destination IP address and the route in the routing table.

Longest Match is the Preferred Route

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

Longest Match to IP Packet Destination



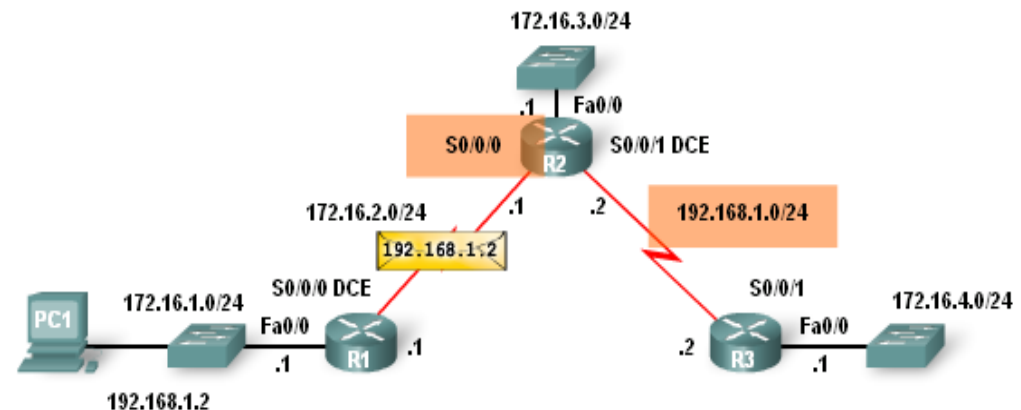
# Routing Table Lookup Process

- Finding the subnet mask used to determine the longest match

Scenario:

- PC1 pings 192.168.1.2
- Router examines level 1 route for best match
- There exist a match between 192.168.1.2 & 192.168.1.0 / 24
- Router forwards packets out s0/0/0

Example: Level 1 Ultimate Route



**Step 1a: If best match is a level 1 ultimate route, use it to forward the packet.**

```
R1#show ip route
Codes: C - connected, S - static, I - IGRP, R - RIP, M - mobile, B -
BGP
      <some output omitted>

Gateway of last resort is not set

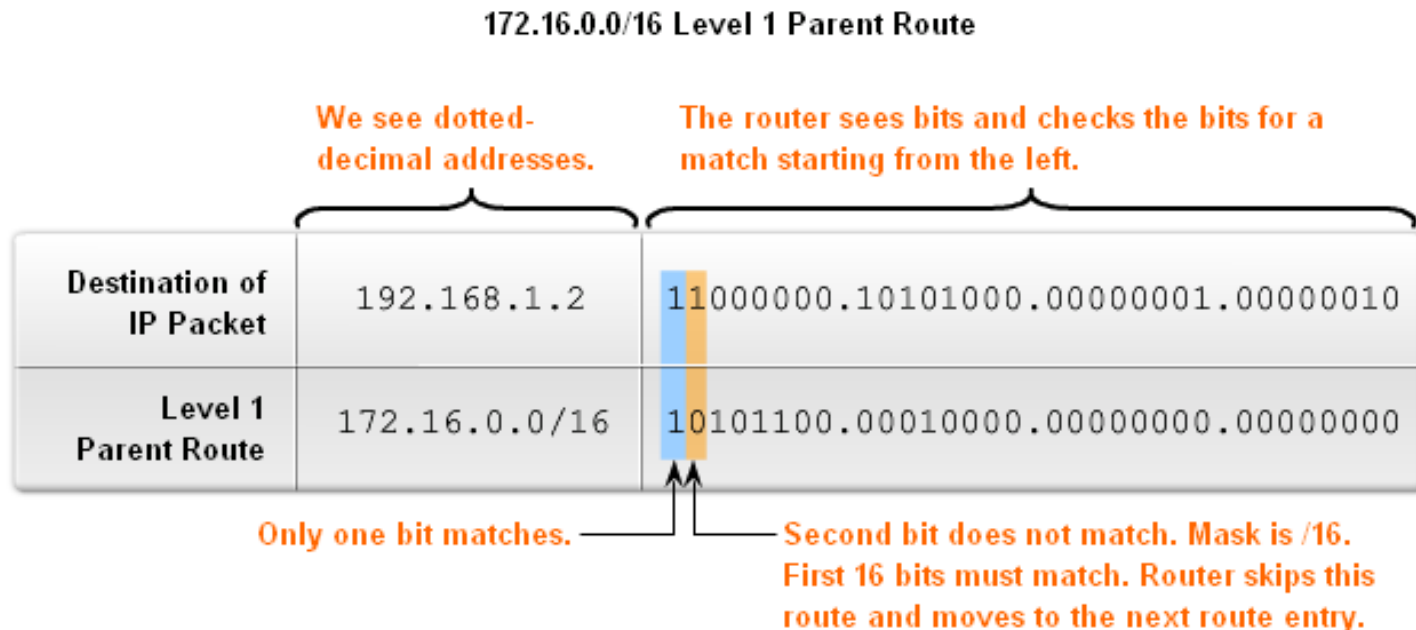
    172.16.0.0/24 is subnetted, 3 subnets
C       172.16.1.0 is directly connected, FastEthernet0/0
C       172.16.2.0 is directly connected, Serial0/0/0
R       172.16.3.0 [120/1] via 172.16.2.2, 00:00:25, Serial0/0/0
R       192.168.1.0/24 [120/1] via 172.16.2.2, 00:00:25, Serial0/0/0
```

# Routing Table Lookup Process

- The process of matching

-1st there must be a match made between the parent route & destination IP

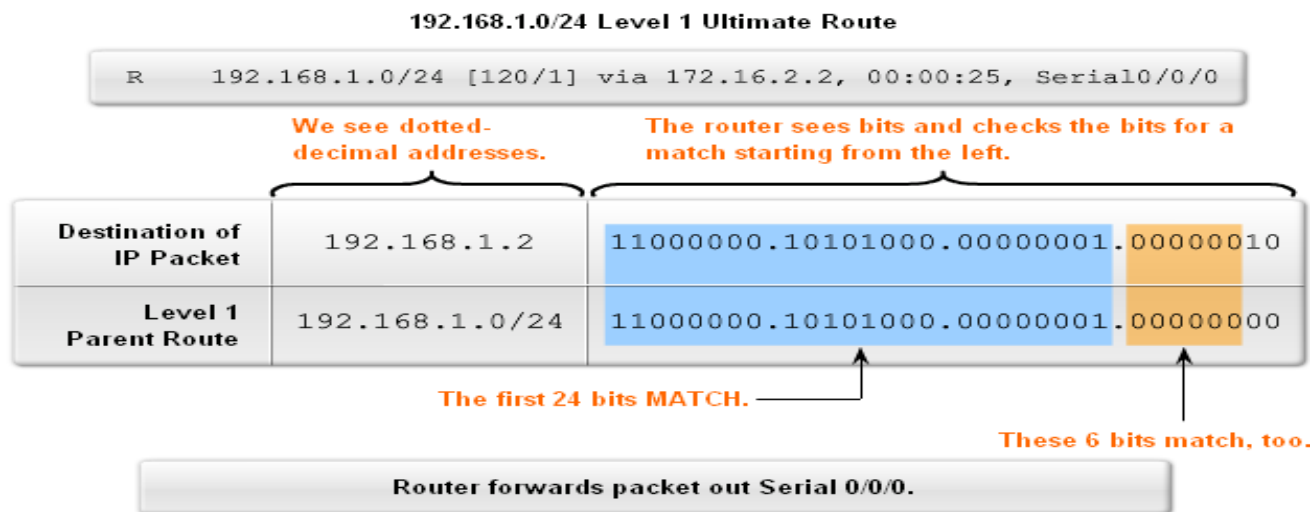
-If a match is made then an attempt at finding a match between the destination IP and the child route is made.



# Routing Table Lookup Process

- Finding a match between packet's destination IP address and the next route in the routing table

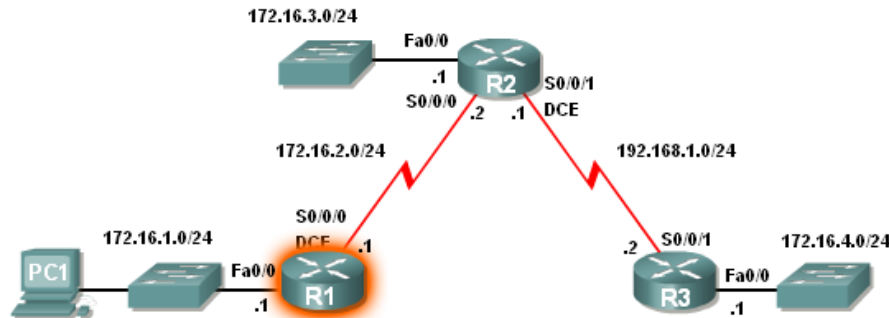
-The figure shows a match between the destination IP of 192.168.1.0 and the level one IP of 192.168.1.0 / 24 then packet forwarded out s0/0/0



# Routing Table Lookup Process

- Level 1 Parent & Level 2 Child Routes
- Before level 2 child routes are examined
  - There must be a match between classful level one parent route and destination IP address.

Example: Level 1 Parent Route and Level 2 Child Routes



```

R1#show ip route
Codes: C - connected, S - static, I - IGRP, R - RIP, M - mobile, B -
BGP
      <output omitted>

Gateway of last resort is not set

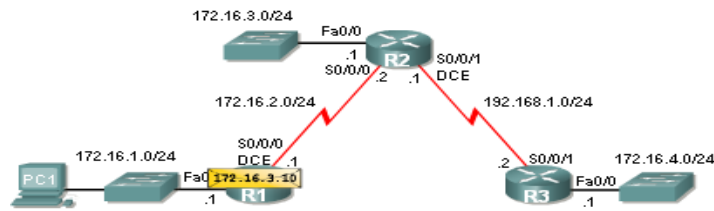
172.16.0.0/24 is subnetted, 3 subnets
  C    172.16.1.0 is directly connected, FastEthernet0/0
  C    172.16.2.0 is directly connected, Serial0/0/0
  R    172.16.3.0 [120/1] via 172.16.2.2, 00:00:25, Serial0/0/0
  R    192.168.1.0/24 [120/1] via 172.16.2.2, 00:00:25, Serial0/0/0
    
```

# Routing Table Lookup Process

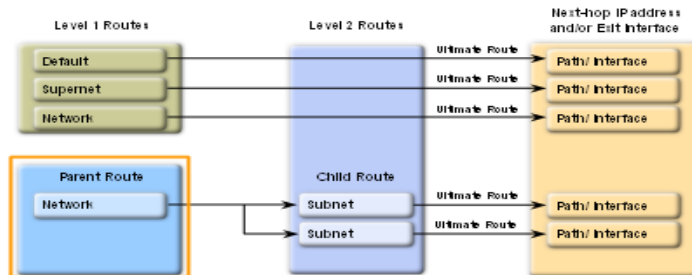
- After the match with parent route has been made Level 2 child routes will be examined for a match

-Route lookup process searches for child routes with a match with destination IP

Example: Level 1 Parent Route and Level 2 Child Routes



Step 1b: If the best math is a level 1 parent route, proceed to Step 2.



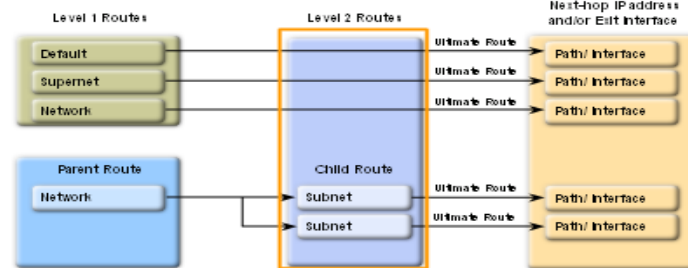
```

R1#show ip route
Codes: C - connected, S - static, I - IGRP, R - RIP, X - mobile, l
       <output omitted>

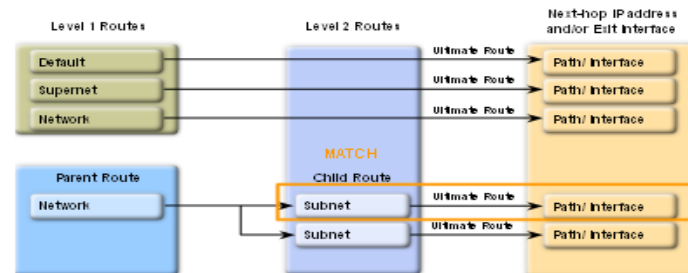
Gateway of last resort is not set

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
    
```

Step 2: Child routes are examined for a best match.



Step 2a: Match! Use this subnet to forward the packet.





# Routing Table Lookup Process

- How a router finds a match with one of the level 2 child routes
  - First router examines parent routes for a match
  - If a match exists then:
    - Child routes are examined
    - Child route chosen is the one with the longest match

Example: Level 1 Parent Route and Level 2 Child Routes

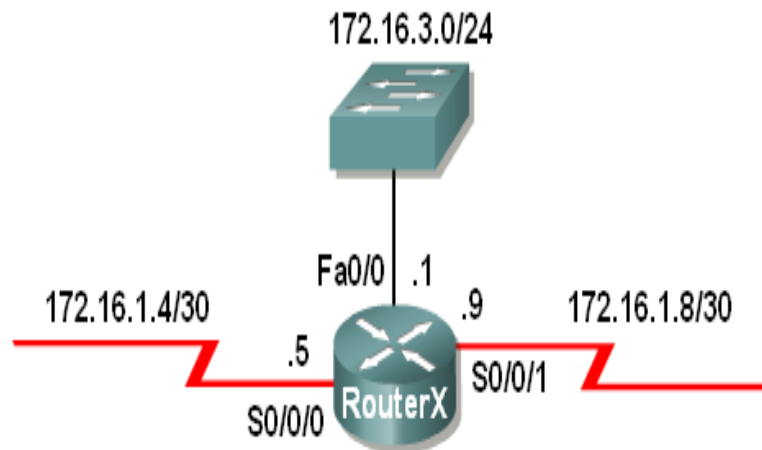
Destination of IP Packet	172.16.3.10	10101100 00010000 00000011 00001010
Level 1 Parent Route	172.16.0.0/16	10101100 00010000 00000000 00000000
Level 2 Child Route	172.16.1.0/24	10101100 00010000 00000001 00000000
Level 2 Child Route	172.16.2.0/24	10101100 00010000 00000010 00000000
Level 2 Child Route	172.16.3.0/24	10101100 00010000 00000011 00000000

First 24 bits match.

# Routing Table Lookup Process

- Example: Route Lookup Process with VLSM
  - The use of VLSM does not change the lookup process
  - If there is a match between destination IP address and the level 1 parent route then
  - Level 2 child routes will be searched

Route Lookup Process with VLSM



```

RouterX#show ip route
Codes: C - connected, S - static, I - IGRP, R - RIP, M - mobile, B - BGP
<output omitted>

Gateway of last resort is not set

172.16.0.0/16 is variably subnetted, 3 subnets, 2 masks Level 1 Parent Route
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
RouterX#
    
```

# Routing Behavior

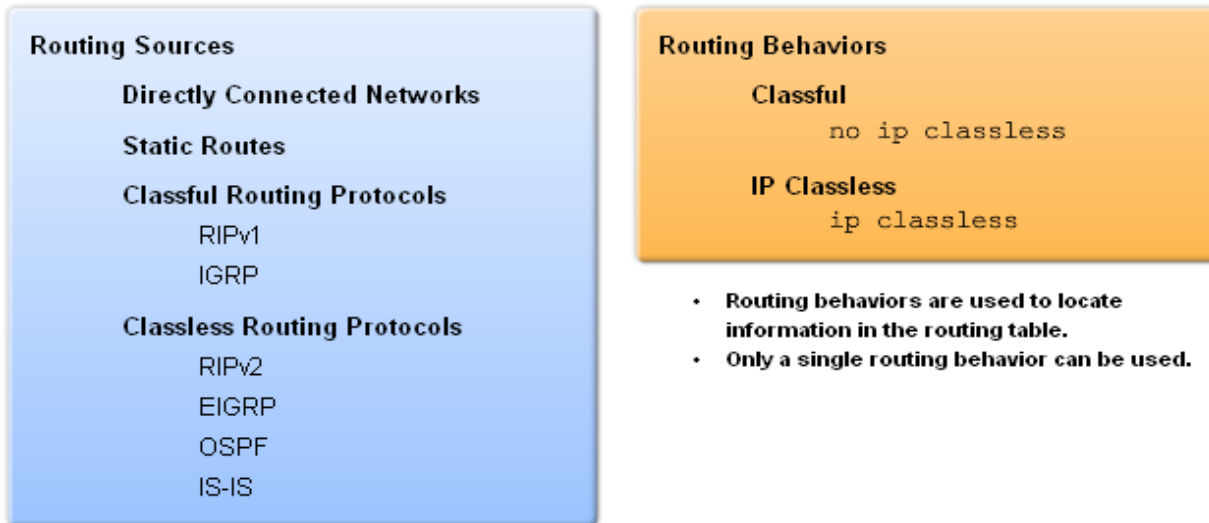
- Classful & classless **routing protocols**

Influence how routing table is **populated**

- Classful & classless **routing behaviors**

Determines how routing table is **searched** after it is filled

Routing Protocols vs Routing Behaviors



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

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

# Routing Behavior

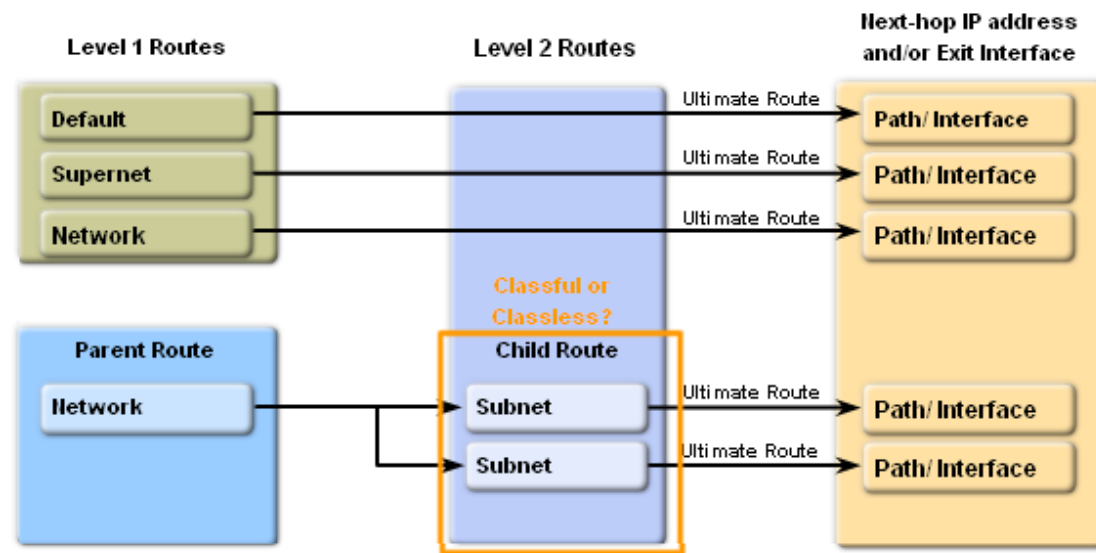
- Classful Routing Behavior: no ip classless
- What happens if there is **not a match** with any level 2 child routes of the parent?

-Router must determine if the routing behavior is classless or classful

-If router is utilizing **classful routing behavior** then

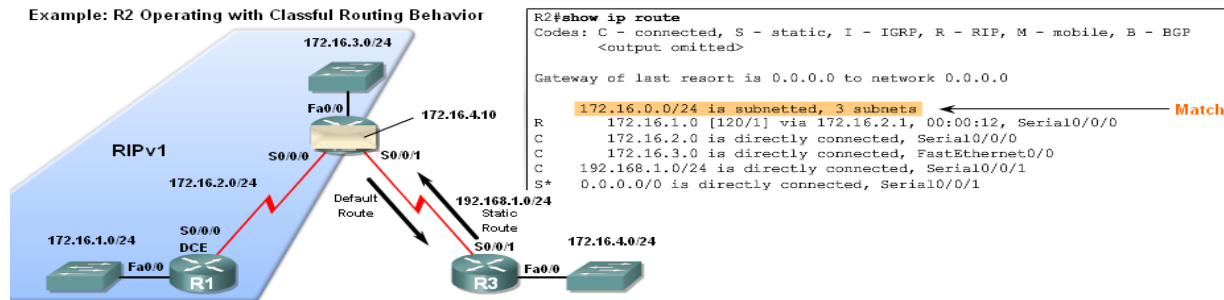
-Lookup process is terminated and **packet is dropped**

Route Table Lookup Process  
Classful Routing Behavior: Drop the Packet



# Routing Behavior

- Classful Routing Behavior – Search Process
- An example of when classful routing behavior is in effect and why the router drops the Packet
  - The destination's subnet mask is a /24 and none of the child routes left most bits match the first 24 bits. This means packet is dropped



**Example: Level 1 Parent Route and Level 2 Child Routes**  
 Destination matches the parent route. R2 will now check the child routes.

22nd bit does not match. First 24 bits must match. Router skips this route and moves to the next route entry.

Destination of IP Packet	Binary Representation
Destination of IP Packet	172.16.4.10 → 10101100.00010000.00000100.00001010
Level 1 Parent Route	172.16.0.0/16 → 10101100.00010000.00000000.00000000
Level 2 Child Route	172.16.1.0/24 → 10101100.00010000.00000001.00000000
Level 2 Child Route	172.16.2.0/24 → 10101100.00010000.00000010.00000000
Level 2 Child Route	172.16.3.0/24 → 10101100.00010000.00000011.00000000

First 21 bits match.

# Routing Behavior

- Classful Routing Behavior – Search Process
- The reason why the router will not search beyond the child routes
  - Originally networks were all classful
  - This meant an organization could subnet a major network address and “enlighten” all the organization’s routers about the subnetting
  - Therefore, if the subnet was not in the routing table, the subnet did not exist and packet was dropped

# Routing Behavior

- ip Classless
- **Beginning with IOS 11.3**, ip classless was configured by default
- **Classless routing behavior** works for
  - Discontiguous networks
  - And
  - CIDR supernets

# Routing Behavior

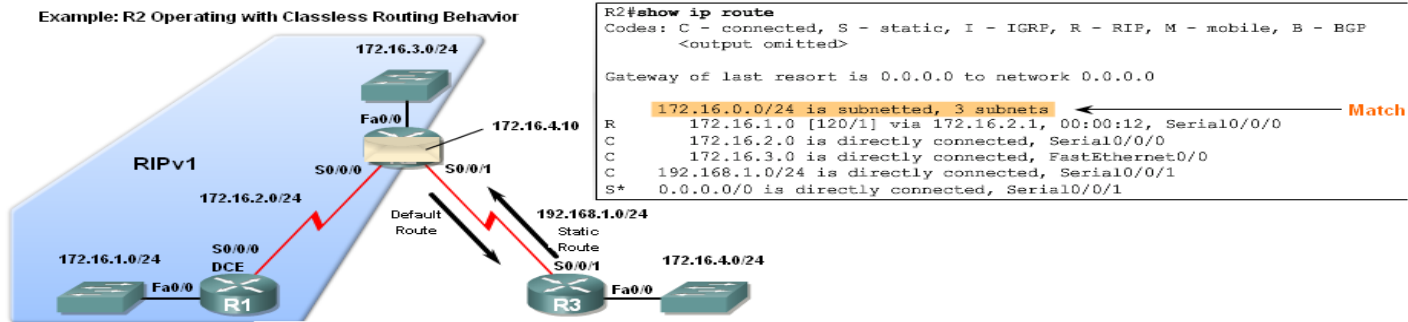
- Classless Routing Behavior: ip classless
  - Route lookup process when ip classless is in use
    - If **classless routing behavior** in effect then
      - Search level 1 routes
      - Supernet routes Checked first
    - If a match exists then forward packet
      - Default routes Checked second
- If there is no match or no default route then the
- Packet is dropped



# Routing Behavior

- Classless Routing Behavior – Search Process
- Router begins search process by finding a match between destination IP and parent route

After finding the above mentioned match, then there is a search of the child route



**Example: Level 1 Parent Route and Level 2 Child Routes**  
 Destination matches the parent route. R2 will now check the child routes.

22nd bit does not match. First 24 bits must match. Router skips this route and moves to the next route entry.

Destination of IP Packet	172.16.4.10	10101100.00010000.000000100.00001010
Level 1 Parent Route	172.16.0.0/16	10101100.00010000.00000000.00000000
Level 2 Child Route	172.16.1.0/24	10101100.00010000.00000001.00000000
Level 2 Child Route	172.16.2.0/24	10101100.00010000.00000010.00000000
Level 2 Child Route	172.16.3.0/24	10101100.00010000.00000011.00000000

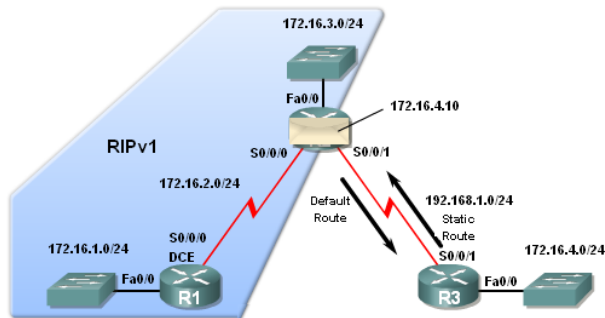
First 21 bits match.

# Routing Behavior

- Classless Routing Behavior – Search Process
- If **no match** is found in child routes of previous slide then

Router continues to search the routing table for a match that may have fewer bits in the match

Example: R2 Operating with Classless Routing Behavior



Destination of IP Packet	172.16.4.10	101011100.00010000.000001100.00001010
Level 1 Network Route	192.168.1.0/24	110000000.10101000.00000001.00000000
Level 1 Default Route	0.0.0.0/0	00000000.00000000.00000000.00000000

Only the first bit matches.

Second bit does NOT match. Router skips this route and moves to the next route entry.

A /0 mask means that no bits have to match to use the default route. R2 uses the default route and forwards the packet.

Destination of IP Packet	172.16.4.10	101011100.00010000.000001100.00001010
Level 1 Network Route	192.168.1.0/24	110000000.10101000.00000001.00000000
Level 1 Default Route	0.0.0.0/0	00000000.00000000.00000000.00000000

R2#show ip route

Codes: C - connected, S - static, I - IGRP, R - RIP, M - mobile, <output omitted>

Gateway of last resort is 0.0.0.0 to network 0.0.0.0

Match  
 No Match  
 No Match  
 No Match  
 No Match  
 Use Default

```

172.16.0.0/24 is subnetted, 3 subnets
R 172.16.1.0 [120/1] via 172.16.2.1, 00:00:12, 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
    
```

The default route IS used. R2 forwards packet to R3.

# Routing Behavior

- **Classful vs. Classless Routing Behavior**

- It is recommended to use classless routing behavior

- Reason: so supernet and default routes can be used whenever needed

# Summary

## Content/structure of a routing table

- **Routing table entries**

- Directly connected networks
- Static route
- Dynamic routing protocols

- **Routing tables are hierarchical**

- Level 1 route

Have a subnet mask that is less than or equal to classful subnet mask for the network address

- Level 2 route

These are subnets of a network address

# Summary

## Routing table lookup process

- **Begins with examining level 1 routes** for best match with packet's destination IP
  - If the best match = an ultimate route then
    - Packet is forwarded -Else-
    - Parent route is examined
      - If parent route & destination IP match then Level 2 (child) routes are examined

### Level 2 route examination

- If a match between destination IP and child route found then Packet forwarded -Else
- If Router is using classful routing behavior then Packet is dropped -Else
- If router is using classless routing behavior then Router searches **Level 1 supernet & default routes** for a match
- If a match is found then Packet if forwarded -Else
- Packet is dropped

# Summary

- **Routing behaviors**

- This refers to how a routing table is searched

- **Classful routing behavior**

- Indicated by the use of the no ip classless command

- Router **will not look** beyond child routes for a lesser match

- **Classless routing behavior**

- Indicated by the use of the ip classless command

- Router will look beyond child routes for a lesser match

