The Routing Table: A Closer Look

Routing Protocols and Concepts – Chapter 8

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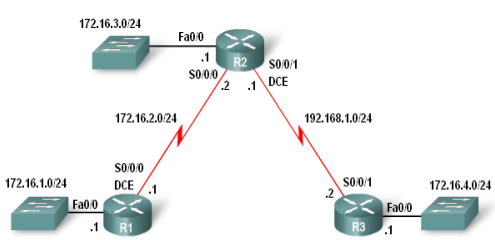
Objectives

- 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
- In this chapter, we will take a closer look at the routing table.
- The first part of the chapter focuses on the structure of Cisco's IP routing table.
- We will examine the format of the routing table and learn about level 1 and level 2 routes.
- The second part of the chapter analyzes the lookup process of the routing table. We will discuss classful routing behavior, as well as classless routing behavior, which uses the no ip classless and ip classless commands.

Topology Example



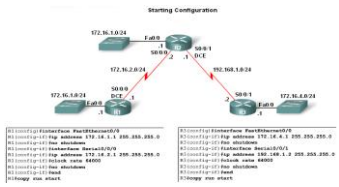
Routing Table Structure

- 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 discontiguous, from the 172.16.0.0 network that R1 and R2 share.



Routing Table Structure

- Routing table entries come from the following sources

  -Directly connected networks

  -Static routes

  -Dynamic routing protocols

Sample Routing Table

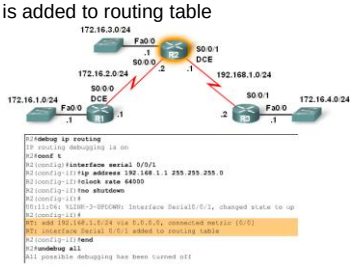
```
Router#show ip route
Codes: C - connected, S - static, I - IGRP, R - RIP, M - mobile,
<output omitted>

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



Level 1 or Level 2?

- The Cisco IP routing table is not a flat database.
- The routing table is actually a hierarchical structure that is used to speed up the lookup process when locating routes and forwarding packets.
- Within this structure, the hierarchy includes several levels. For simplicity, we will discuss all routes as one of two levels: level 1 or level 2.
- **A level 1 route is a route with a subnet mask equal to or less than the classful mask of the network address**.
- 192.168.1.0/24 is a level 1 network route, because the subnet mask is equal to the network's classful mask. /24 is the classful mask for class C networks, such as the 192.168.1.0 network.

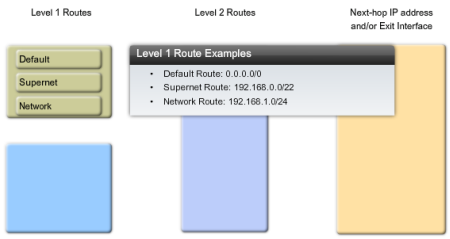
Level 1 Route

- A level 1 route can function as a:

1. Default route - A default route is a static route with the address 0.0.0.0/0.
2. Supernet route - A supernet route is a network address with a mask less than the classful mask.
3. Network route - A network route is a route that has a subnet mask equal to that of the classful mask. A network route can also be a parent route. Parent routes will be discussed in the next section.

Examples

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



Routing Table Structure

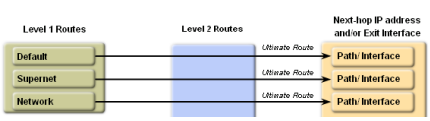
- Level 1 Routes
  - -Ultimate Route
    - Includes either:
      - -A next-hop address

      OR

      - -An exit interface

Routing Table: Level 1 Routes

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

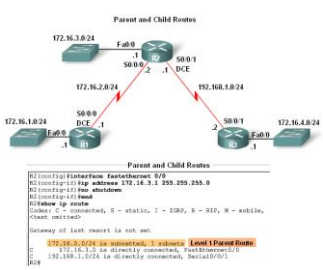


Routing Table Structure

- 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

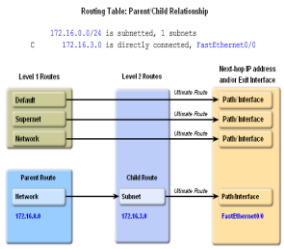


Parent Route

- A level 1 parent route is a network route that **does not** contain a **next-hop IP address** or exit interface for any network.
- A parent route is actually a heading that indicates the presence of level 2 routes, also known as child routes.
- A level 1 parent route is automatically created any time a subnet is added to the routing table.
- In other words, a parent route is created whenever a route with a mask greater than the classful mask is entered into the routing table.
- The subnet is the level 2 child route of the parent route. In this case, the level 1 parent route that was automatically created is: 172.16.0.0/24 is subnetted, 1 subnets

Routing Table Structure

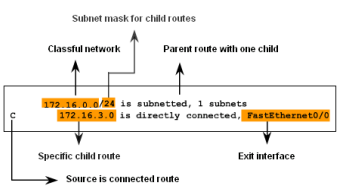
- Automatic creation of parent routes
  - -Occurs any time a subnet is added to the routing table
- Child routes
  - -Child routes are **level 2** routes
  - -Child routes are a **subnet** of a classful network address



Routing Table Structure

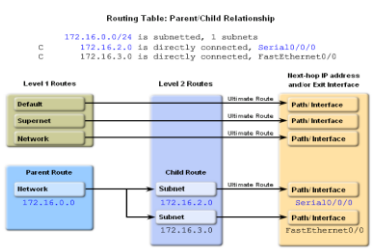
- Level 2 child routes contain route source & the network address of the route
- Level 2 **child routes are** also considered **ultimate routes**

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



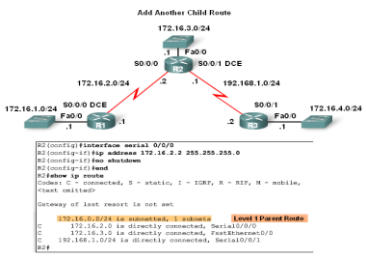
Routing Table Structure

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



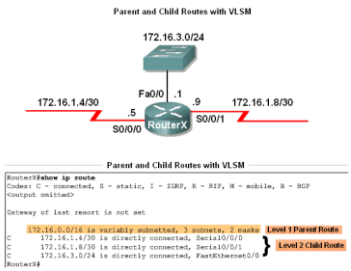
Routing Table Structure

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



Routing Table Structure

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



Classless Routes

- 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, which states that this **parent network is variably subnetted.**
- Although the parent/child relationship uses a classful structure to display networks and their subnets, this format can be used with both classful and classless addressing.
- **Regardless of the addressing scheme used by the network (classless or classful), the routing table will use a classful scheme.**

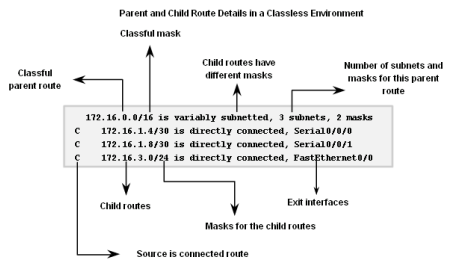
Routing Table Structure

- Parent & Child Routes: Classless Networks

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

Routing Table Structure

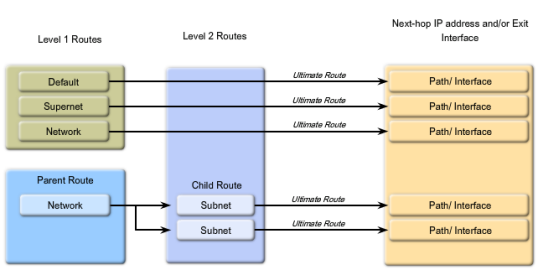
- Parent & Child Routes: Classless Networks



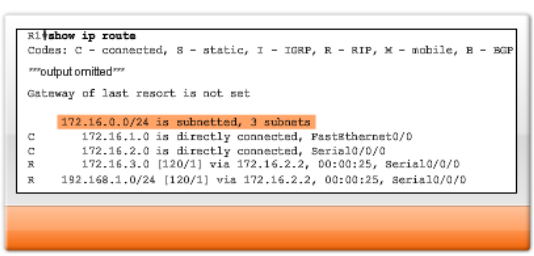
Route Lookup Process

1. What happens when a router receives an IP packet, examines the IP destination address, and looks that address up in the routing table?
2. How does the router decide which route in the routing table is the best match?
3. What effect does the subnet mask have on the routing table lookup process?
4. How does the router decide whether or not to use a supernet or default route if a better match is not found?

Router Lookup Process



Routing Table



Routing Table Lookup Process

- **The Route Lookup Process**
  - **Examine level 1 routes**
    -If best match at 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

Longest Match

- First of all, what is a match? 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 **left-most 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 left-most bits that must match. (Remember, an IP packet only contains the IP address and not the subnet mask.)
- The best match or longest match is the route in the routing table that has the most number of left-most matching bits with the destination IP address of the packet.
- **The route with the most number of equivalent left-most bits, or the longest match, is always the preferred route**.

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

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

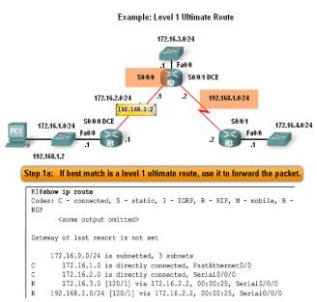
Longest Match to IP Packet Destination

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 between192.168.1.2 & 192.168.1.0 / 24
- –Router forwards packets out s0/0/0

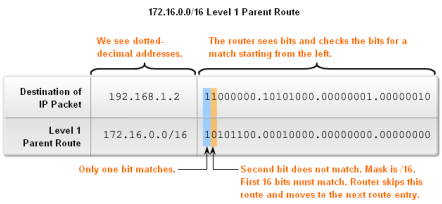


Routing Table Lookup Process

- The process of matching

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

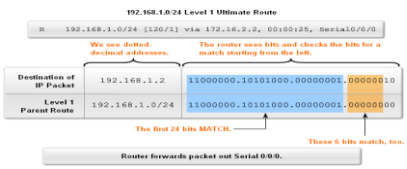
  -If a match is made then an attempt at finding a match between the destination IP and the child route is made.



Routing Table Lookup Process

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

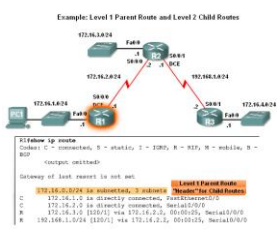
  -The figure shows a match between the destination IP of 192.168.1.0 and the level one IP of 192.168.1.0 / 24 then packet forwarded out s0/0/0



Routing Table Lookup Process

- Level 1 Parent & Level 2 Child Routes
- Before level 2 child routes are examined

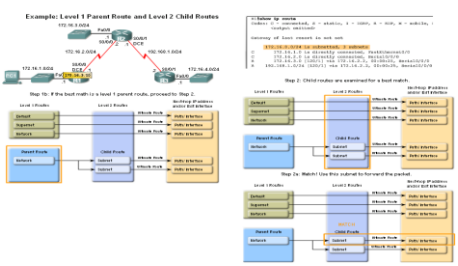
  -There must be a match between classful level one parent route and destination IP address.



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



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

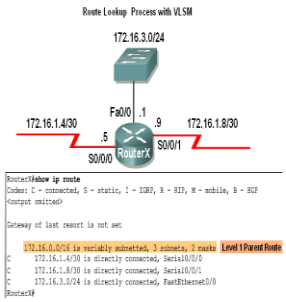
Example: Level 1 Parent Route and Level 2 Child Routes

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



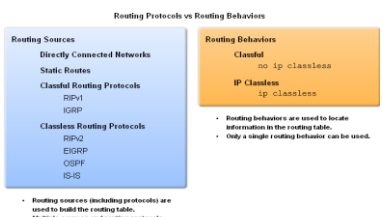
Routing Behavior

- 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 Behaviours

- **Classless** and **classful** routing behaviours are not the same as classless and classful routing protocols. Classful and classless routing protocols affect how the routing table is populated.
- **Classful and classless routing behaviours determine how the routing table is searched after it is populated**.
- The routing behaviour, specified by the **ip classless** or **no ip classless** commands, determines how the route lookup process will proceed at Step 3.
- As you can see, routing protocols and routing behaviours are **completely independent of each other**.
- The routing table could be populated with routes from a classless routing protocol like RIPv2 yet implement classful routing behaviour because the no ip classless command is configured.

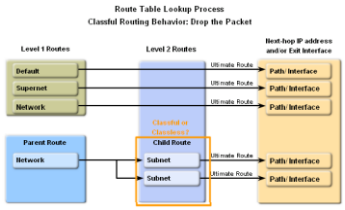
Routing Behavior

- 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

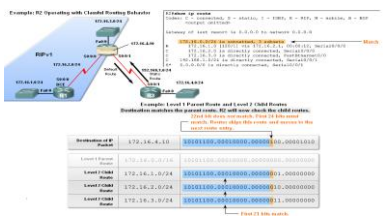
    -Lookup process is terminated and packet is dropped



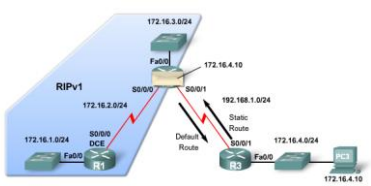
Routing Behavior

- 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



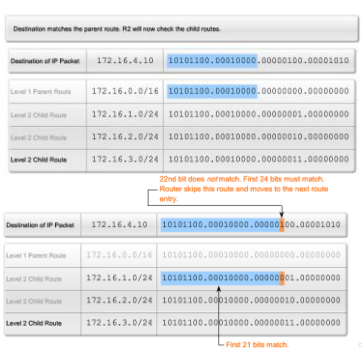
Examples

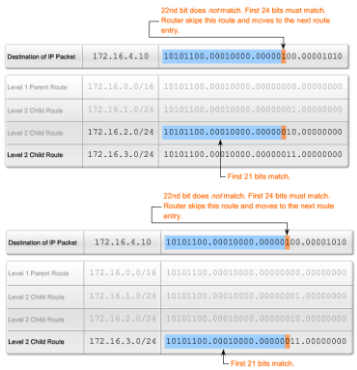



```
R2#show ip route
Codes: C - connected, S - static, I - IGRP, R - RIP, M - mobile, B - BGP
***output omitted***
Gateway of last resort is 0.0.0.0 to network 0.0.0.0

     172.16.0.0/24 is subnetted, 3 subnets          <-- Match
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
```


Matching the Packets





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

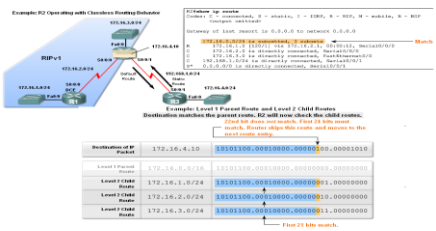
Routing Behavior

- 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

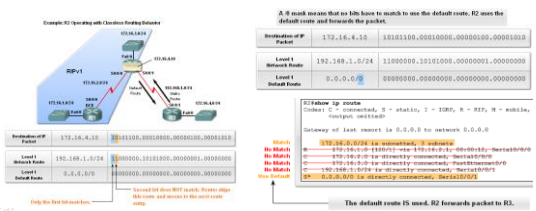
  After finding the above mentioned match, then there is a search of the child route



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



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