Static Routing & Dynamic Routing Protocol

Jirasak Sittigorn
Internetworking Standards & Technologies
Department of Computer Engineering, Faculty of Engineering
King Mongkut's Institute of Technology Ladkrabang

Cisco Networking Academy®
Mind Wide Open™

Routing Concepts

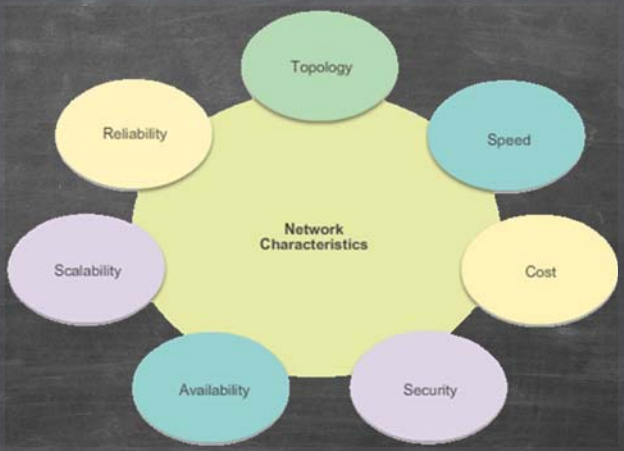
- Functions of a Router
- Connect Devices
- Initial Configuration of a Router
- Routing Decisions
- Routing Operation
- The Routing Table

Static Routing

- Static Routing Implementation
- Configure Static and Default Routes
- Review of CIDR and VLSM
- Summary and Floating Static Routes
- Troubleshoot Static and Default Route Issues

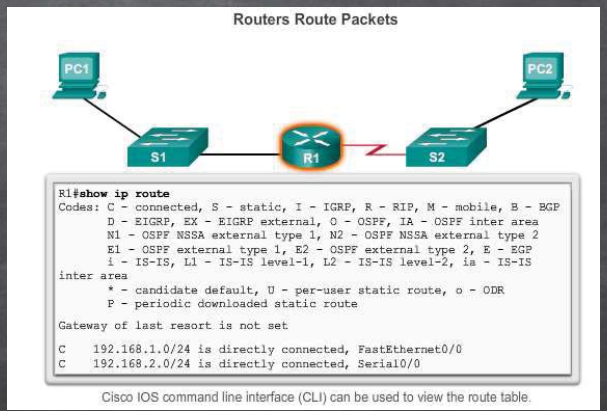
Functions of a Router

- Characteristics of a Network



Functions of a Router

- Why Routing?
  - The router is responsible for the routing of traffic between networks.



Cisco IOS command line interface (CLI) can be used to view the route table.

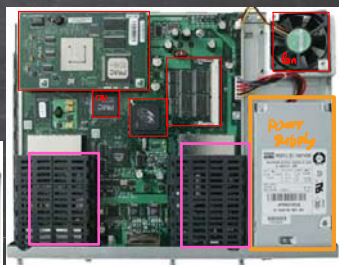
Functions of a Router

- Routers are Computers
  - Routers are specialized computers containing the following required components to operate:
    - Central processing unit (CPU)
    - Operating system (OS) - Routers use Cisco IOS
    - Memory and storage (RAM, ROM, NVRAM, Flash, hard drive)
  - Routers utilize the following memory:

Memory	Volatile / Non-Volatile	Stores
RAM	Volatile	• Running IOS • Running configuration file • IP routing and ARP tables • Packet buffer
ROM	Non-Volatile	• Bootup instructions • Basic diagnostic software • Limited IOS
NVRAM	Non-Volatile	• Startup configuration file
Flash	Non-Volatile	• IOS • Other system files

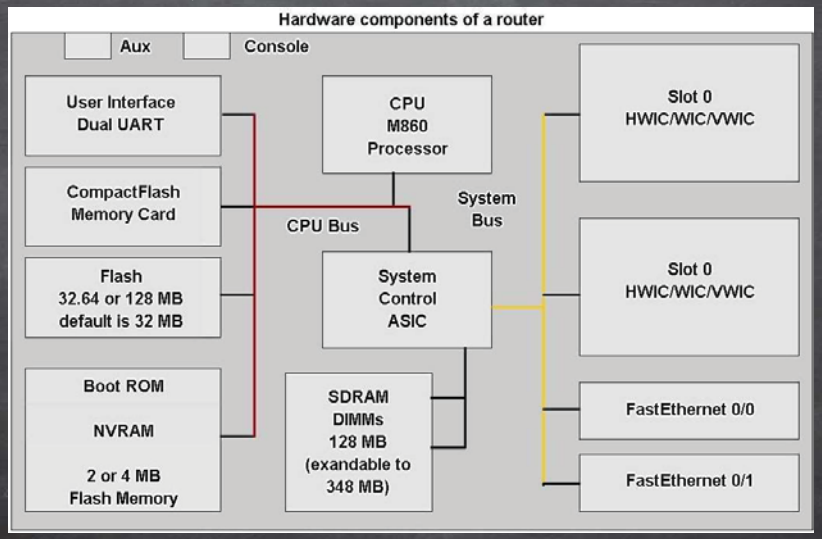
Functions of a Router

- Router components and their functions"
  - CPU - Executes operating system instructions
  - Random access memory (RAM) - Contains the running copy of configuration file. Stores routing table. RAM contents lost when power is off
  - Read-only memory (ROM) - Holds diagnostic software used when router is powered up. Stores the router's bootstrap program.
  - Non-volatile RAM (NVRAM) - Stores startup configuration. This may include IP addresses (Routing protocol, Hostname of router)
  - Flash memory - Contains the operating system (Cisco IOS)
  - Interfaces - There exist multiple physical interfaces that are used to connect network. Examples of interface types:
    - Ethernet / fast Ethernet interfaces
    - Serial interfaces
    - Management interfaces



Functions of a Router

- Router components



Functions of a Router

- Router as a Computer
- Major phases to the router boot-up process
  - Test router hardware
    - Power-On Self Test (POST)
    - Execute bootstrap loader
  - Locate & load Cisco IOS software
    - Locate IOS
    - Load IOS
  - Locate & load startup configuration file or enter setup mode
    - Bootstrap program looks for configuration file

1.	ROM	POST	Perform POST
2.	ROM	Boostrap	Load Bootstrap
3.	Flash	Cisco Internetwork Operation System	Locate and load Operating system
4.	TFTP Server		
5.	NVRAM	Configuration	Locate and load configuration file or enter setup mode
6.	TFTP Server		
7.	Console		

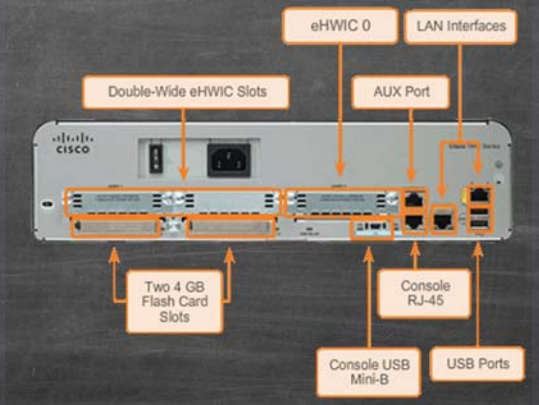
Functions of a Router

IOS version
Bootstrap version
Model and CPU
Amount of RAM
Number and type of interfaces
Amount of NVRAM
Amount of Flash

```
Router#show version
Cisco Internetwork Operating System Software
IOS (tm) C2600 Software (C2600-I-M), Version 12.2(28), RELEASE SOFTWARE (fc5)

Technical Support: http://www.cisco.com/techsupport
Copyright (c) 1986-2005 by cisco Systems, Inc.
Compiled Wed 27-Apr-04 19:01 by miwang
Image text-base: 0x8000808C, data-base: 0x80A1FECC

ROM: System Bootstrap, Version 12.1(3r)T2, RELEASE SOFTWARE (fc1)

CDATA[Copyright (c) 2000 by cisco Systems, Inc.
ROM: C2600 Software (C2600-I-M), Version 12.2(28), RELEASE SOFTWARE (fc5)
System returned to ROM by reload
System image file is "flash:c2600-i-mz.122-28.bin"

cisco 2621 (MPC860) processor (revision 0x200) with 60416K/5120K bytes of memory.

Processor board ID JAD05190MTZ (4292891495)
M860 processor: part number 0, mask 49
Bridging software.
X.25 software, Version 3.0.0.

2 FastEthernet/IEEE 802.3 interface(s)
2 Low-speed serial(sync/async) network interface(s)

32K bytes of non-volatile configuration memory.

16384K bytes of processor board System flash (Read/Write)

Configuration register is 0x2102
Router#
```

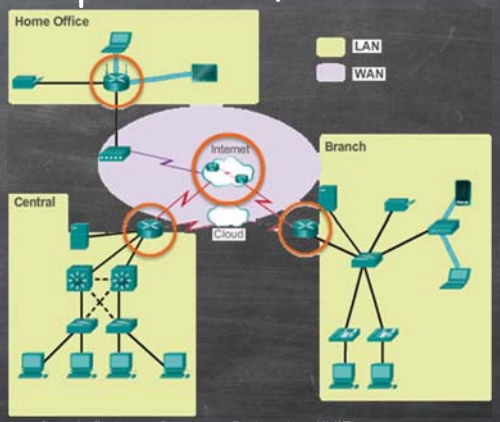

Functions of a Router

- Routers are Computers
  - Routers use specialized ports and network interface cards to interconnect to other networks



Functions of a Router

- Routers Interconnect Networks
  - Routers can connect multiple networks.
  - Routers have multiple interfaces, each on a different IP network.

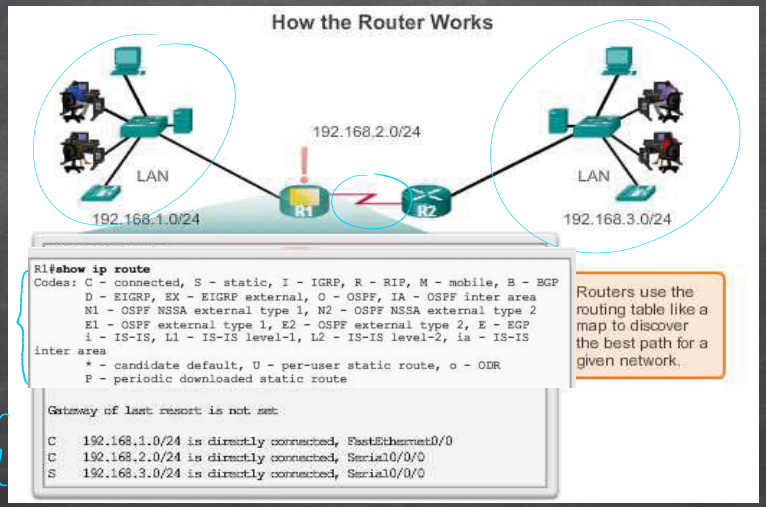


Functions of a Router

- Routers Choose Best Paths
  - Determine the best path to send packets
    - Uses its routing table to determine path
  - Forward packets toward their destination
    - Forwards packet to interface indicated in routing table.
    - Encapsulates the packet and forwards out toward destination.
  - Routers use static routes and dynamic routing protocols to learn about remote networks and build their routing tables.

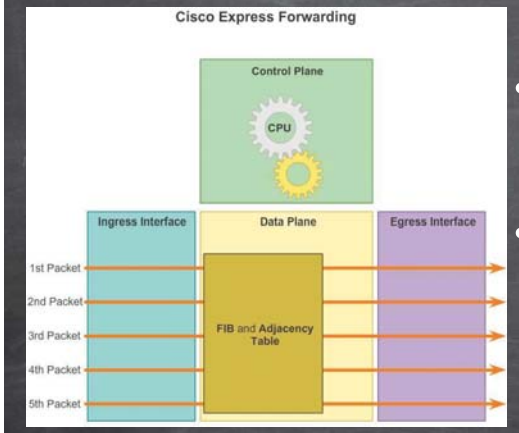
Functions of a Router

- Routers Choose Best Paths



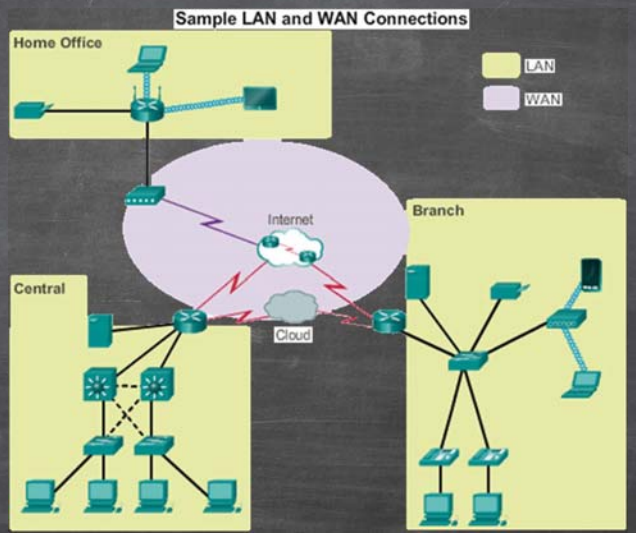
Functions of a Router

- Packet Forwarding Methods



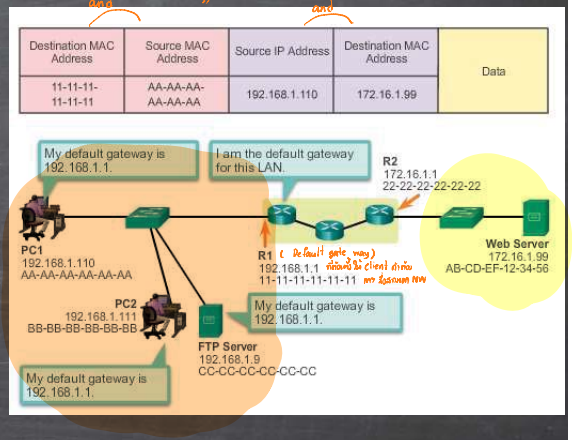
- **Process switching** - An older packet forwarding mechanism still available for Cisco routers.
- **Fast switching** - A common packet forwarding mechanism which uses a fast-switching cache to store next hop information.
- **Cisco Express Forwarding (CEF)** - The most recent, fastest, and preferred Cisco IOS packet-forwarding mechanism. Table entries are not packet-triggered like fast switching but change-triggered.

Connect Devices



Connect Devices

- Default Gateways
- To enable network access devices must be configured with the following IP address information
  - IP address - Identifies a unique host on a local network.
  - Subnet mask - Identifies the host's network subnet.
  - Default gateway - Identifies the router a packet is sent to to when the destination is not on the same local network subnet.

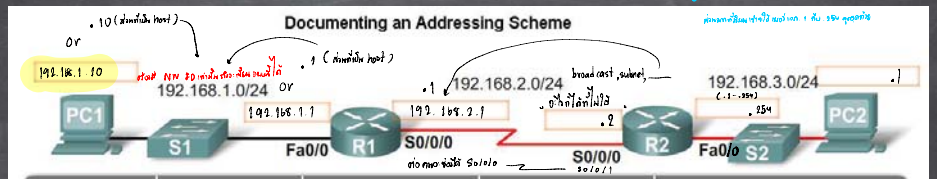


Connect Devices

- Document Network Addressing
  - Network Documentation should include at least the following in a topology diagram and addressing table:
    - Device names
    - Interfaces
    - IP addresses and subnet mask
    - Default gateways

Connect Devices

- Document Network Addressing



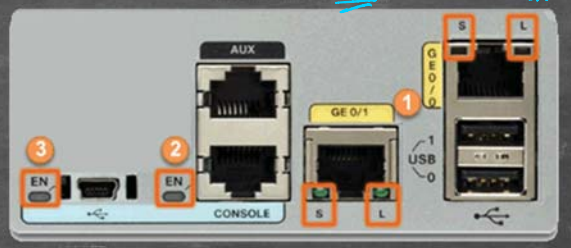
Device	Interface	IP Address	Subnet Mask	Default Gateway
R1	Fa0/0	192.168.1.1	255.255.255.0	N/A
	S0/0/0	192.168.2.1	255.255.255.0	N/A
R2	Fa0/0	192.168.3.254	255.255.255.0	N/A
	S0/0/0	192.168.3.2	255.255.255.0	N/A
PC1	N/A	192.168.1.10	255.255.255.0	192.168.1.1
PC2	N/A	192.168.3.1	255.255.255.0	192.168.3.254

Connect Devices

- Enable IP on a Host
  - ① Statically Assigned IP address - host is manually assigned the IP address, subnet mask and default gateway. DNS server IP address can also be assigned.
    - Used to identify specific network resources such as network servers and printers
    - Can be used in very small networks with few hosts.
  - ② Dynamically Assigned IP Address - IP Address information is dynamically assigned by a server using Dynamic Host Configuration Protocol (DHCP)
    - Most hosts acquire their IP address information through DHCP
    - DHCP services can be provided by Cisco routers

Connect Devices

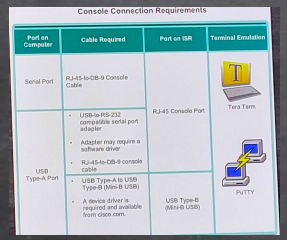
- Device LEDs

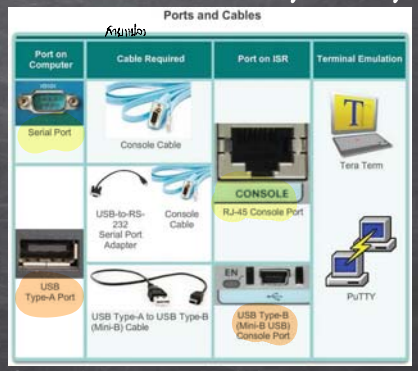


#	Port	LED	Color	Description
1	GE0/0 and GE0/1	S (Speed)	1 blink + pause	Port operating at 10 Mb/s
			2 blink + pause	Port operating at 100 Mb/s
			3 blink + pause	Port operating at 1000 Mb/s
		L (Link)	Green	Link is active
			Off	Link is inactive
2	Console	EN	Green	Port is active
			Off	Port is inactive
3	USB	EN	Green	Port is active
			Off	Port is inactive

Connect Devices

- Console Access
  - Console access requires:
    - Console cable - RJ-45-to-DB-9 console cable
    - Terminal emulation software - Tera Term, PuTTY, HyperTerminal





Basic Settings on a Router

- Configure Basic Router Settings
  - Name the device : `hostname name`
  - Secure management access : `enable secret password`
  - Configure a banner : `banner motd # text #`
  - Configured an Interface : `interface type slot/port`
    - address and subnet mask : `ip address x.x.x.x y.y.y.y`
    - Activated : `no shutdown`
    - serial cable end labeled DCE : `clock rate 56000`
  - Configure a Loopback Interface →

```
interface loopback number
ip address x.x.x.x y.y.y.y
```


Verify Connectivity of Directly Connected Networks

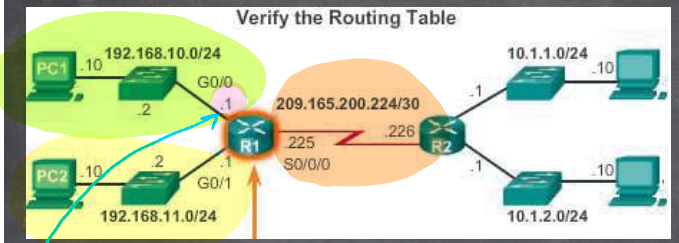
- Verify Interface Settings
  - Show commands to verify operation and configuration of interface.

```
show ip interface brief
show ip route
show running-config
```

  - Show commands to gather more detailed interface information.

```
show interfaces
show ip interface
```


Verify Connectivity of Directly Connected Networks




```
Gateway of last resort is not set

      192.168.10.0/24 is variably subnetted, 2 subnets, 2 masks
C        192.168.10.0/24 is directly connected, GigabitEthernet0/0
L        192.168.10.1/32 is directly connected, GigabitEthernet0/0
      192.168.11.0/24 is variably subnetted, 2 subnets, 2 masks
C        192.168.11.0/24 is directly connected, GigabitEthernet0/1
L        192.168.11.1/32 is directly connected, GigabitEthernet0/1
      209.165.200.0/24 is variably subnetted, 2 subnets, 2 masks
C        209.165.200.224/30 is directly connected, Serial0/0/0
L        209.165.200.225/32 is directly connected, Serial0/0/0
Router#
```

```
Gateway of last resort is not set

C    192.168.10.0/24 is directly connected, FastEthernet0/0
C    192.168.11.0/24 is directly connected, FastEthernet0/1
     209.165.200.0/30 is subnetted, 1 subnets
C       209.165.200.224 is directly connected, Serial0/0
Router#
```

```
interface GigabitEthernet0/0
 ip address 192.168.10.1 255.255.255.0
 duplex auto
 speed auto
!
interface GigabitEthernet0/1
 ip address 192.168.11.1 255.255.255.0
 duplex auto
 speed auto
!
interface GigabitEthernet0/2
 no ip address
 duplex auto
 speed auto
 shutdown
!
interface Serial0/0/0
 ip address 209.165.200.225 255.255.255.252
!
interface Serial0/0/1
 no ip address
 clock rate 2000000
 shutdown
!
```

```
Router#sh ip int brief
Interface              IP-Address      OK? Method Status                Protocol
GigabitEthernet0/0     192.168.10.1    YES manual up                    up
GigabitEthernet0/1     192.168.11.1    YES manual up                    up
GigabitEthernet0/2     unassigned      YES unset  administratively down down
Serial0/0/0            209.165.200.226 YES manual up                    up
Serial0/0/1            unassigned      YES unset  administratively down down
Vlan1                  unassigned      YES unset  administratively down down
Router#
```

Verify Connectivity of Directly Connected Networks

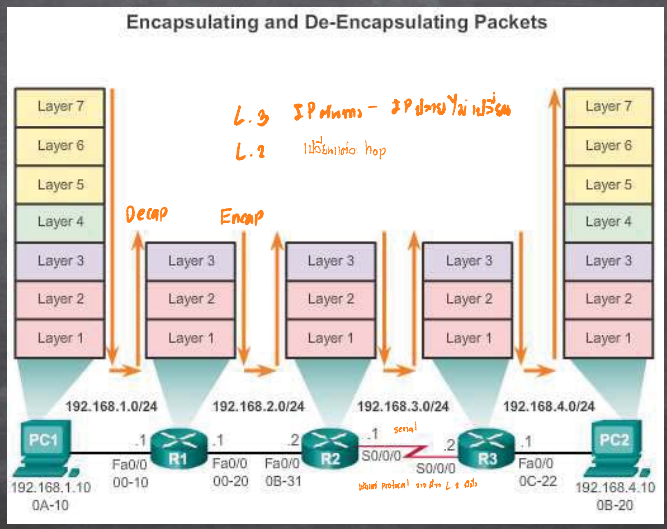
- Filter Show Command Output
  - Use the terminal lengthnumbercommand to specify the number of lines to be displayed. A value of 0 (zero) prevents the router from pausing between screens of output.
  - To filter specific output of commands use the (|)pipe character after show command. Parameters that can be used after pipe include:
    - section, include, exclude, begin

```
R1#show ip interface brief
Interface                  IP-Address      OK? Method Status
Embedded-Service-Engine0/0 unassigned      YES unset  admin
GigabitEthernet0/0         192.168.10.1    YES manual up
GigabitEthernet0/1         192.168.11.1    YES manual up
Serial0/0/0                209.165.200.225 YES manual up
Serial0/0/1                unassigned      YES unset  admin

R1#show ip interface brief | exclude unassigned
Interface                  IP-Address      OK? Method Status
GigabitEthernet0/0         192.168.10.1    YES manual up
GigabitEthernet0/1         192.168.11.1    YES manual up
Serial0/0/0                209.165.200.225 YES manual up
```

```
R1#show ip interface brief
Interface                  IP-Address      OK? Method Status
Embedded-Service-Engine0/0 unassigned      YES unset  administ
GigabitEthernet0/0         192.168.10.1    YES manual up
GigabitEthernet0/1         192.168.11.1    YES manual up
Serial0/0/0                209.165.200.225 YES manual up
Serial0/0/1                unassigned      YES unset  administ
R1#
R1#show ip interface brief | include up
GigabitEthernet0/0         192.168.10.1    YES manual up
GigabitEthernet0/1         192.168.11.1    YES manual up
Serial0/0/0                209.165.200.225 YES manual up
R1#
```

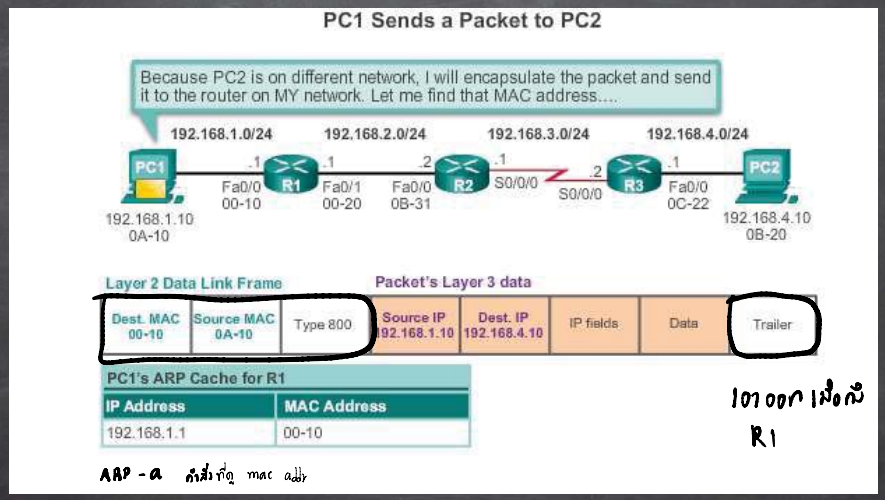

Switching Packets between Networks

- Router Switching Functions



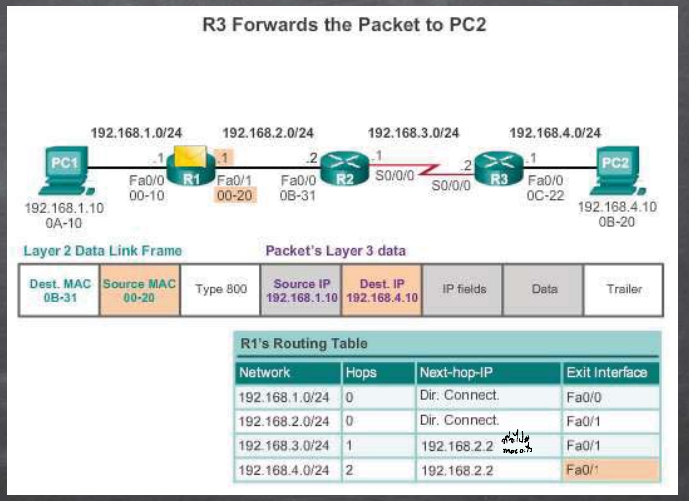
Switching Packets between Networks

- Send a Packet



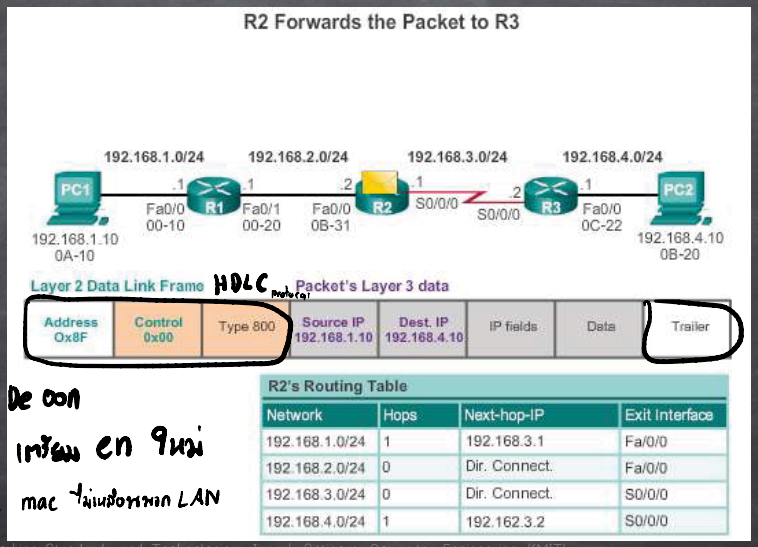
Switching Packets between Networks

- Forward to the Next Hop



Switching Packets between Networks

- Packet Routing



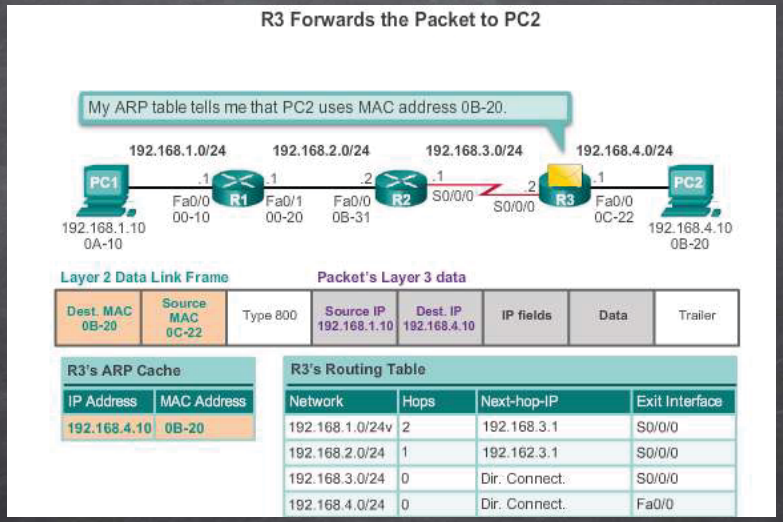
1. De con
2. เทียบ en ขาออก
3. mac ไม่เหมือนจาก LAN

R2's Routing Table

Network	Hops	Next-hop-IP	Exit Interface
192.168.1.0/24	1	192.168.3.1	Fa/0/0
192.168.2.0/24	0	Dir. Connect.	Fa/0/0
192.168.3.0/24	0	Dir. Connect.	S0/0/0
192.168.4.0/24	1	192.162.3.2	S0/0/0

Switching Packets between Networks

- Reach the Destination



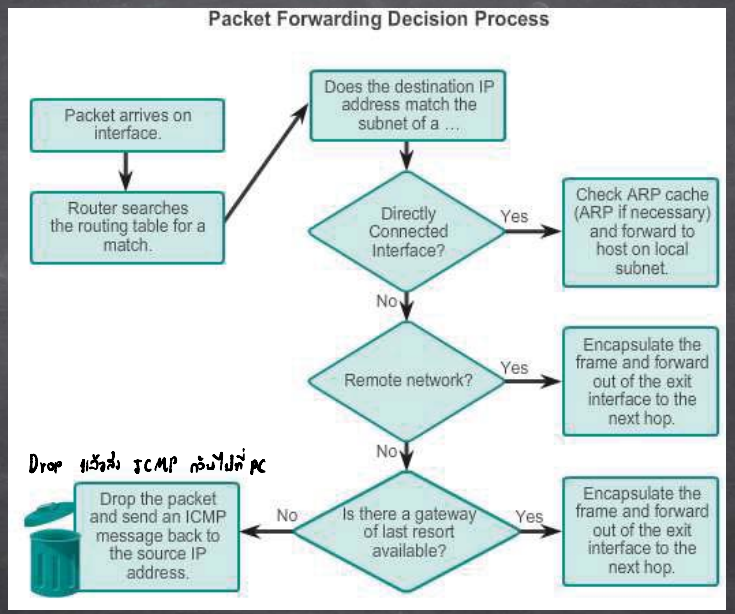
R3's ARP Cache

IP Address	MAC Address
192.168.4.10	0B-20

R3's Routing Table

Network	Hops	Next-hop-IP	Exit Interface
192.168.1.0/24v	2	192.168.3.1	S0/0/0
192.168.2.0/24	1	192.162.3.1	S0/0/0
192.168.3.0/24	0	Dir. Connect.	S0/0/0
192.168.4.0/24	0	Dir. Connect.	Fa0/0

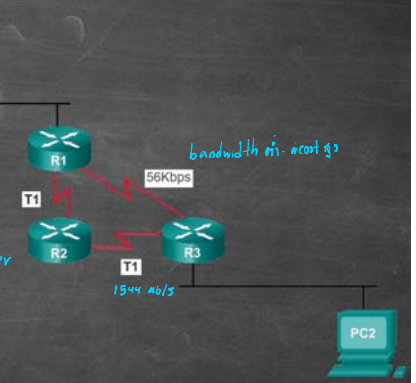
Path Determination



Drop แล้วส่ง ICMP กลับไปที่ PC

Path Determination

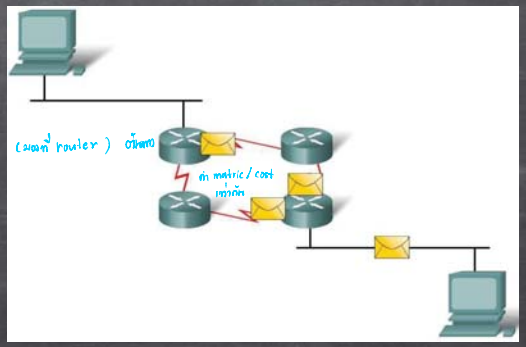
- Best Path : lowest metric
  - Dynamic routing protocols use their own rules and metrics
    - Routing Information Protocol (RIP) - Hop count
    - Open Shortest Path First (OSPF) - Cost based on cumulative bandwidth from source to destination
    - Enhanced Interior Gateway Routing Protocol (EIGRP) - Bandwidth, delay, load, reliability



Path Determination

ค่า matric / cost เท่ากัน ⇒ ทำ

- "Load Balancing"
  - When a router has two or more paths to a destination with equal cost metrics, then the router forwards the packets using both paths equally.



Path Determination

ระยะห่าง/ทางไกล จาก admin

- Administrative Distance (AD) : "trustworthiness"

ใช้บอกความน่าเชื่อถือ

Default Administrative Distances

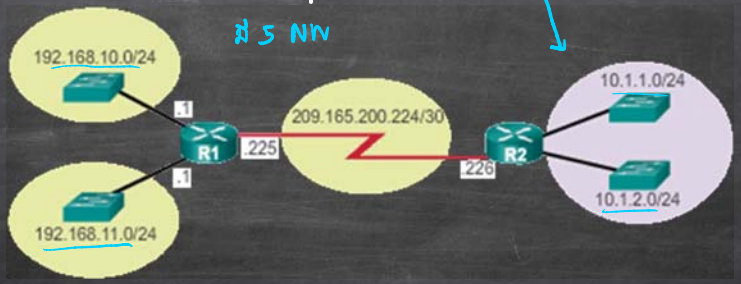
Route Source	Administrative Distance
Connected	0 ใกล้มาก
Static	1
EIGRP summary route	5
External BGP	20
Internal EIGRP	90
IGRP	100
OSPF	110
IS-IS	115
External EIGRP	170
Internal BGP	200

RIP 120

The Routing Table

- Routing Table is a file stored in RAM that contains information about เทียบกับ RI
  - Directly Connected Routes สายเชื่อม
  - Remote Routes ที่ไม่ใช่เส้นทางตรง
  - Network or Next hop Associations

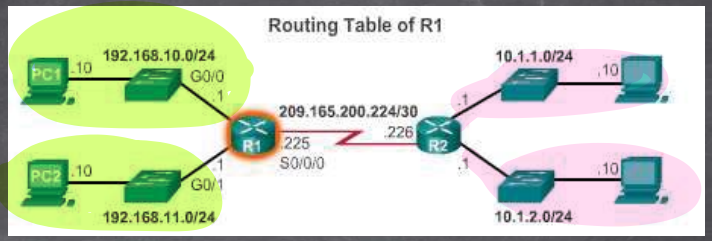
มี 5 NW



The Routing Table

- Routing Table Sources
  - Show ip route command is used to display the contents of the routing table
    - Link local Interfaces -Added to the routing table when an interface is configured. (displayed in IOS 15 or newer) ล่าสุด
    - Directly connected interfaces -Added to the routing table when an interface is configured and active.
    - Static routes - Added when a route is manually configured and the exit interface is active.
    - Dynamic routing protocol - Added when EIGRP or OSPF are implemented and networks are identified.

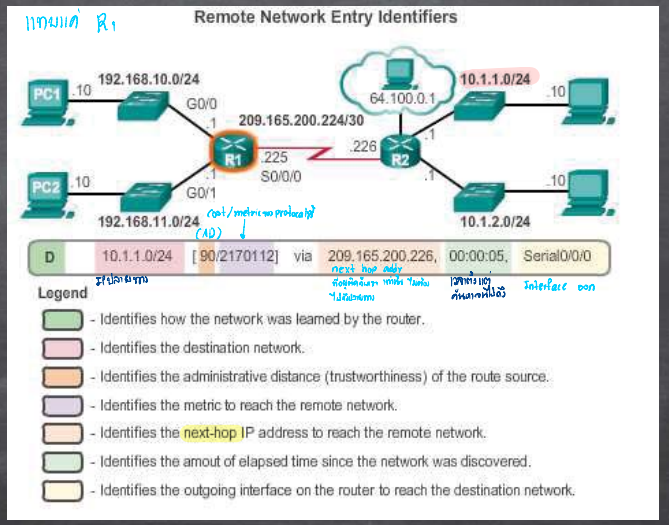
The Routing Table




```
Router#sh ip ro
Codes: L - local, C - connected, S - static, 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

      10.0.0.0/24 is subnetted, 2 subnets
D        10.1.1.0/24 [90/2172416] via 209.165.200.226, 00:01:51, Serial0/0/0
D        10.1.2.0/24 [90/2172416] via 209.165.200.226, 00:01:51, Serial0/0/0
      192.168.10.0/24 is variably subnetted, 2 subnets, 2 masks
C        192.168.10.0/24 is directly connected, GigabitEthernet0/0
L        192.168.10.1/32 is directly connected, GigabitEthernet0/0
      192.168.11.0/24 is variably subnetted, 2 subnets, 2 masks
C        192.168.11.0/24 is directly connected, GigabitEthernet0/1
L        192.168.11.1/32 is directly connected, GigabitEthernet0/1
      209.165.200.0/24 is variably subnetted, 2 subnets, 2 masks
C        209.165.200.224/30 is directly connected, Serial0/0/0
L        209.165.200.225/32 is directly connected, Serial0/0/0
Router#
```

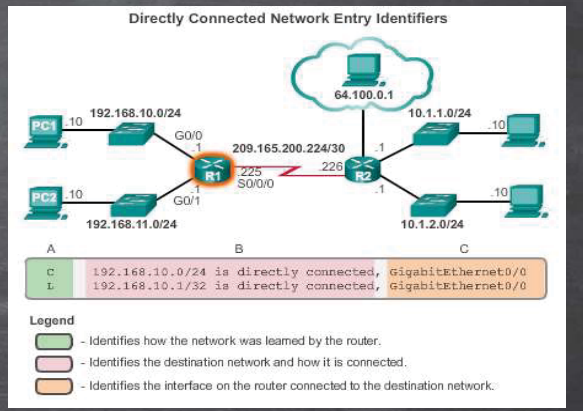

The Routing Table

- Remote Network Routing Entries



Directly Connected Routes

- A newly deployed router, without any configured interfaces, has an empty routing table.
- An active, configured directly connected interface creates two routing table entries
  - Link Local (L)
  - Directly Connected (C)



Routing

- Reach Remote Networks
  - A router can learn about remote networks in one of two ways:
    - Manually - Remote networks are manually entered into the route table using static routes.
    - Dynamically - Remote routes are automatically learned using a dynamic routing protocol.

Routing

- Static Routing
- Dynamic Routing Protocols
  - Exterior Routing Protocols
    - BGP
  - Interior Gateway Routing Protocols
    - RIP - Routing Information Protocol
    - OSPF - Open Shortest Path First
    - EIGRP - Enhanced Interior Gateway Routing Protocol
    - IS-IS - Intermediate System-to-Intermediate System

Static Routing

- Advantages

1 ใช้ทรัพยากร น้อย
2 ปลอดภัย

- Disadvantages

1 config มาก
2 ต้องรู้ทางไป NW อย่างดี

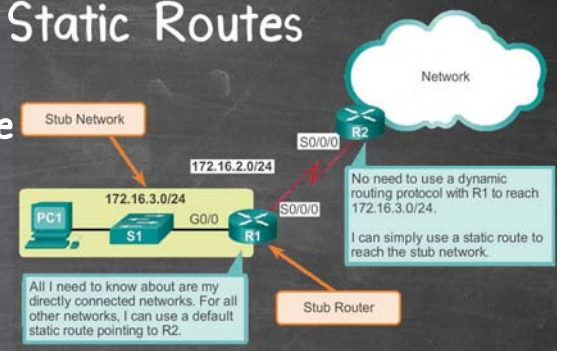
- When to Use Static Routes
  - NW ทางออกทางเดียว
  - NW เล็กๆ

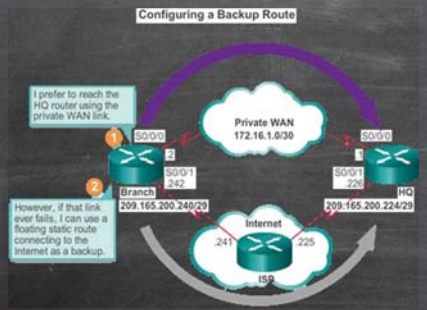
Types of Static Routes

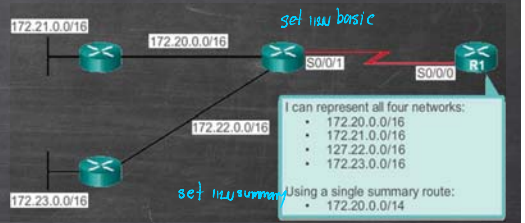
- Static Route Applications
  - Static Routes are often used to:
    - Connect to a specific network
      - Provide a Gateway of Last Resort for a stub network
      - Reduce the number of routes advertised by summarizing several contiguous networks as one static route (ลดจำนวน route)
      - Create a backup route in case a primary route link fails

Types of Static Routes

- Standard Static Route
- Default Static Route (ออกนอก ออกทางเดียว ไปไหนใช้ออกหมด)
- Summary Static Route (เขา standard ยาวๆ command รวมกัน)
- Floating Static Route (Back up route)







Configure IPv4 Static Routes

ip route Command Syntax

```
Router(config)#ip route network-address subnet-mask
{ip-address | exit-intf}
```

(Dest, subnet ของ Dest, next hop)

Parameter	Description
network-address	Destination network address of the remote network to be added to the routing table.
subnet-mask	• Subnet mask of the remote network to be added to the routing table. • The subnet mask can be modified to summarize a group of networks.
ip-address	• Commonly referred to as the next-hop router's IP address. • Typically used when connecting to a broadcast media (i.e., Ethernet). • Commonly creates a recursive lookup.
exit-intf	• Use the outgoing interface to forward packets to the destination network. • Also referred to as a directly attached static route. • Typically used when connecting in a point-to-point configuration.

2 แบบ

Configure IPv4 Static Routes

- Next-Hop Options : The next hop can be identified by an IP address, exit interface, or both. How the destination is specified creates one of the three following route types:
  - Next-hop route - Only the next-hop IP address is specified.
  - Directly connected static route - Only the router exit interface is specified.
  - Fully specified static route - The next-hop IP address and exit interface are specified.

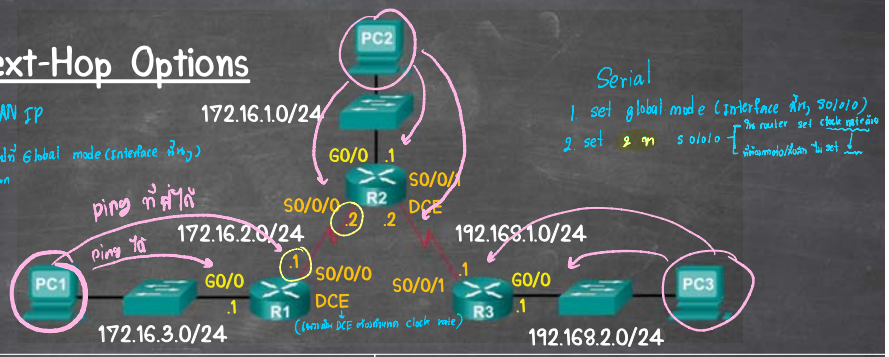
Configure IPv4 Static Routes basic

- Next-Hop Options

LAN IP
1. set IP ให้กับ Global mode (interface ตัวไหน)
2. no shut down

Serial
1. set global mode (interface ตัวไหน, s0/0/0)
2. set IP ตาม s0/0/0 (ถ้า router set clock rate ต้องเลือกข้างที่ set)

ping ทำที่ตัวไหน




```
R1#show ip route | begin Gateway
Gateway of last resort is not set
   172.16.0.0/16 is varibly subnet, 4 subnets, 2 masks
C     172.16.2.0/24 is directly connected, Serial0/0/0
L     172.16.2.1/32 is directly connected, Serial0/0/0
C     172.16.3.0/24 is directly connected, GigabitEthernet0/0
L     172.16.3.1/32 is directly connected, GigabitEthernet0/0
```

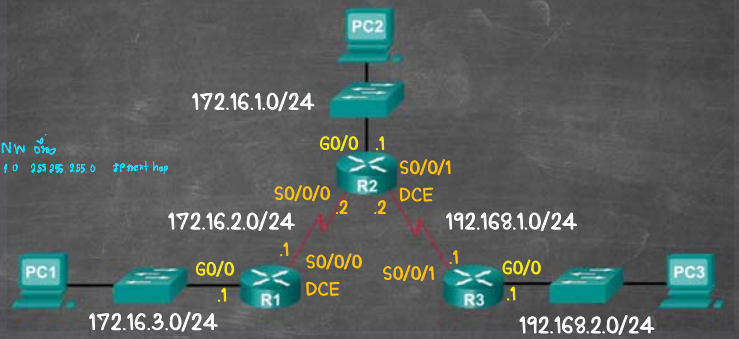
```
R2#show ip route | begin Gateway
Gateway of last resort is not set
   172.16.0.0/16 is varibly subnet, 4 subnets, 2 masks
C     172.16.1.0/24 is directly connected, GigabitEthernet0/0
L     172.16.1.1/32 is directly connected, GigabitEthernet0/0
C     172.16.2.0/24 is directly connected, Serial0/0/0
L     172.16.2.2/32 is directly connected, Serial0/0/0
   192.168.1.0/24 is varibly subnet, 2 subnets, 2 masks
C     192.168.1.0/24 is directly connected, Serial0/0/1
L     192.168.1.2/32 is directly connected, Serial0/0/1
```

```
R3#show ip route | begin Gateway
Gateway of last resort is not set
   192.168.1.0/24 is varibly subnet, 4 subnets, 2 masks
C     192.168.1.0/24 is directly connected, Serial0/0/1
L     192.168.1.1/32 is directly connected, Serial0/0/1
   192.168.2.0/24 is varibly subnet, 4 subnets, 2 masks
C     192.168.2.0/24 is directly connected, GigabitEthernet0/0
L     192.168.2.1/32 is directly connected, GigabitEthernet0/0
```

```
R3#show ip route | include C
Code:L - local, C - connected, S - static, R - RIP, . . .
C  192.168.1.0/24 is directly connected, Serial0/0/1
C  192.168.2.0/24 is directly connected, GigabitEthernet0/0
```


Configure IPv4 Static Routes

config ที่ตัวไหน NW อื่นๆ
IP route 172.16.1.0 255.255.255.0 ip next hop
ต้องเป็น S (static)



ตัวไหน

Configure a Next-Hop Static Route

```
R1(config)#ip route 172.16.1.0 255.255.255.0 172.16.2.2
R1(config)#ip route 192.168.1.0 255.255.255.0 172.16.2.2
R1(config)#ip route 192.168.2.0 255.255.255.0 172.16.2.2
```

Configure a Directly Connected Static Route

```
R1(config)#ip route 172.16.1.0 255.255.255.0 s0/0/0
R1(config)#ip route 192.168.1.0 255.255.255.0 s0/0/0   } next hop
R1(config)#ip route 192.168.2.0 255.255.255.0 s0/0/0
```

Configure a Fully Specified Static Route

```
R1(config)#ip route 172.16.1.0 255.255.255.0 172.16.2.2 Ge0/1
R1(config)#ip route 192.168.1.0 255.255.255.0 172.16.2.2 Ge0/1
R1(config)#ip route 192.168.2.0 255.255.255.0 172.16.2.2 Ge0/1
```

```
R1#show ip route | begin Gateway
Gateway of last resort is not set
   172.16.0.0/16 is varibly subnet, 5 subnets, 2 masks
S     172.16.1.0/24 [1/0] via 172.16.2.2
C     172.16.2.0/24 is directly connected, Serial0/0/0
L     172.16.2.1/32 is directly connected, Serial0/0/0
C     172.16.3.0/24 is directly connected, GigabitEthernet0/0
L     172.16.3.1/32 is directly connected, GigabitEthernet0/0
S  192.168.1.0/24 [1/0] via 172.16.2.2
S  192.168.2.0/24 [1/0] via 172.16.2.2
```

Configure IPv4 Static Routes

- Verify a Static Route
  - Along with ping and traceroute, useful commands to verify static routes include:

```
show ip route
show ip route static
show ip route network
Show running-config
```

```
R1# show ip route static | begin Gateway
Gateway of last resort is not set

      172.16.0.0/16 is variably subnetted, 5 subnets, 2 masks
S        172.16.1.0/24 [1/0] via 172.16.2.2
S     192.168.1.0/24 [1/0] via 172.16.2.2
S     192.168.2.0/24 [1/0] via 172.16.2.2
R1#
```

```
R1# show running-config | section ip route
ip route 172.16.1.0 255.255.255.0 172.16.2.2
ip route 192.168.1.0 255.255.255.0 172.16.2.2
ip route 192.168.2.0 255.255.255.0 172.16.2.2
```

```
R1# show ip route 192.168.2.1
Routing entry for 192.168.2.0/24
  Known via "static", distance 1, metric 0
  Routing Descriptor Blocks:
  * 172.16.2.2
      Route metric is 0, traffic share count is 1
R1#
```


Configure IPv4 Static Routes

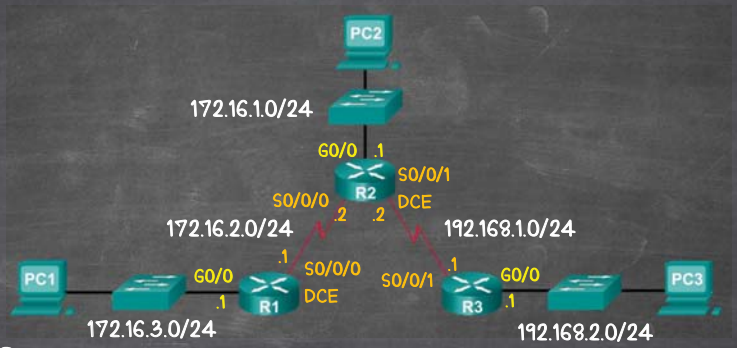
Default Static Route Syntax

next hop

```
Router(config)#ip route 0.0.0.0 0.0.0.0 {ip-address | exit-intf}
```

Parameter	Description
0.0.0.0	Matches any network address.
0.0.0.0	Matches any subnet mask.
ip-address	• Commonly referred to as the next-hop router's IP address. • Typically used when connecting to a broadcast media (i.e., Ethernet). • Commonly creates a recursive lookup.
exit-intf	• Use the outgoing interface to forward packets to the destination network. • Also referred to as a directly attached static route. • Typically used when connecting in a point-to-point configuration.

Configure IPv4 Static Routes



Default Static Route

```
R3(config)#ip route 0.0.0.0 0.0.0.0 172.16.2.2
```

```
R1#show ip route | begin Gateway
Gateway of last resort is not set
S* 0.0.0.0/0 [1/0] via 172.16.2.2
   172.16.0.0/16 is varibly subnet, 5 subnets, 2 masks
C       172.16.2.0/24 is directly connected, Serial0/0/0
L       172.16.2.1/32 is directly connected, Serial0/0/0
C       172.16.3.0/24 is directly connected, GigabitEthernet0/0
L       172.16.3.1/32 is directly connected, GigabitEthernet0/0
```

```
R1#show ip route static
Gateway of last resort is 172.16.2.2 to network 0.0.0.0

S* 0.0.0.0/0 [1/0] via 172.16.2.2
```

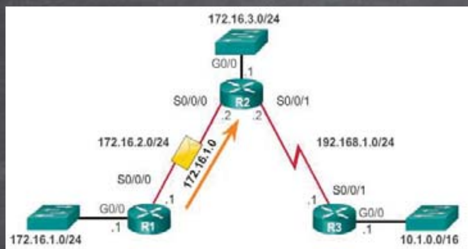

Classful Addressing

- Classful Network Addressing

Class	High Order Bits	Start	End
Class A	0xxxxxxx	0.0.0.0	127.255.255.255
Class B	10xxxxxx	128.0.0.0	191.255.255.255
Class C	110xxxxx	192.0.0.0	223.255.255.255
Multicast	1110xxxx	224.0.0.0	239.255.255.255
Reserved	1111xxxx	240.0.0.0	255.255.255.255

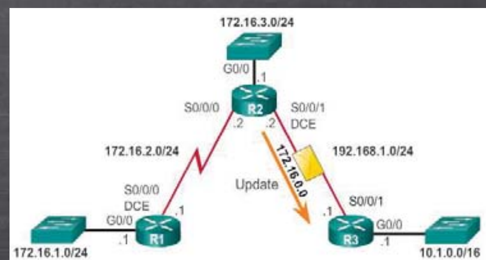
Classful Addressing

- Classful Routing Protocol Example



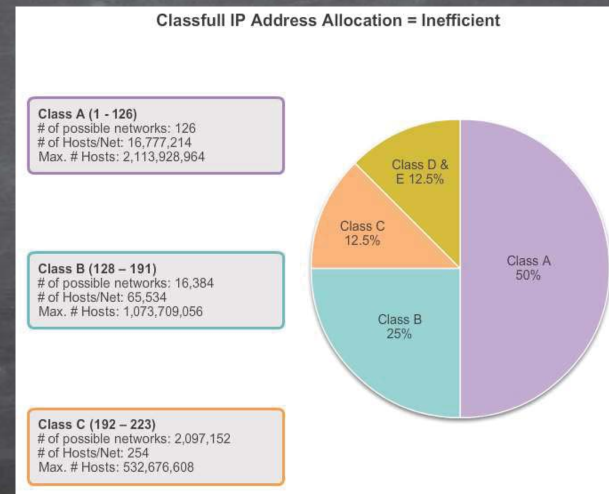
Router subnet

Class less subnet



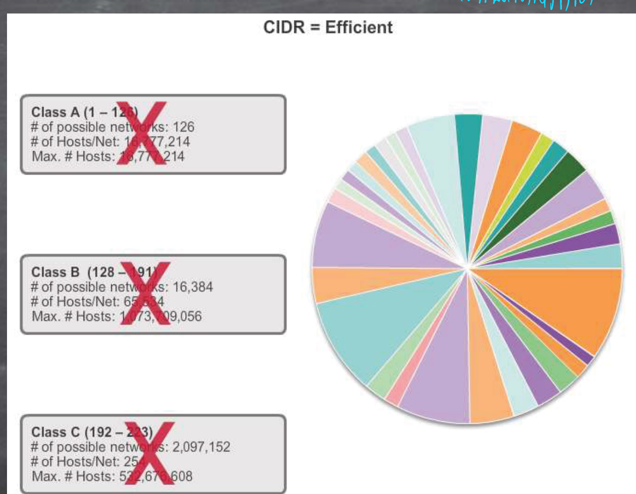
Classful Addressing

- Classful Addressing Waste


Classfull IP Address Allocation = Inefficient
Class A (1 - 126)
# of possible networks: 126
# of Hosts/Net: 16,777,214
Max. # Hosts: 2,113,928,964
Class B (128 – 191)
# of possible networks: 16,384
# of Hosts/Net: 65,534
Max. # Hosts: 1,073,709,056
Class C (192 – 223)
# of possible networks: 2,097,152
# of Hosts/Net: 254
Max. # Hosts: 532,676,608
Class D & E 12.5%
Class C 12.5%
Class B 25%
Class A 50%

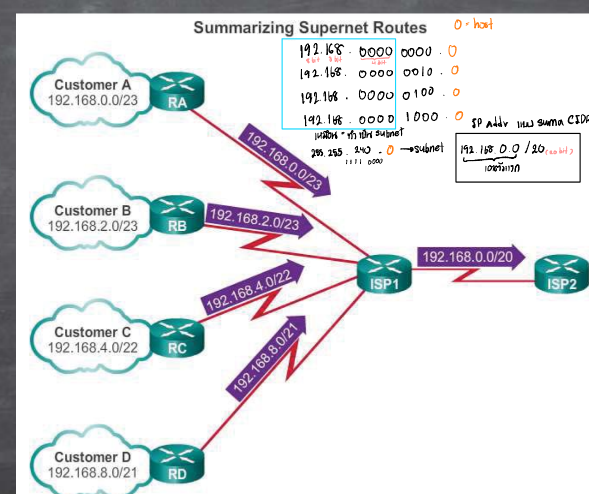
CIDR

- Classless Inter-Domain Routing



CIDR

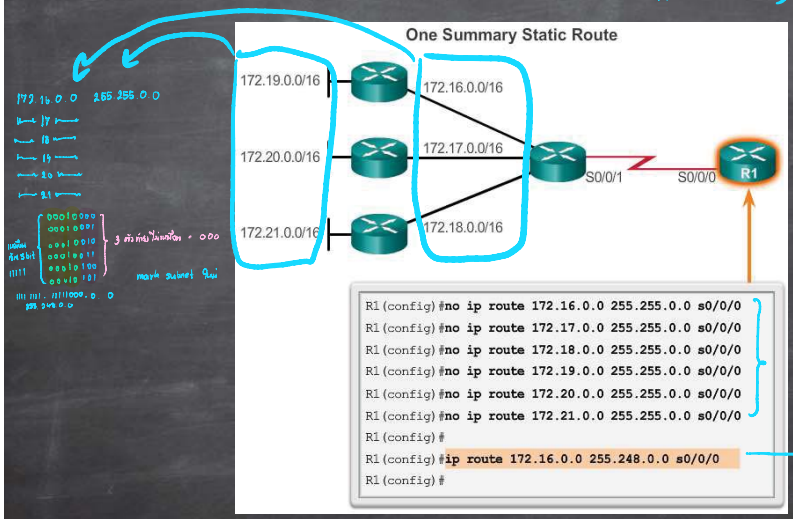
- CIDR and Route Summarization


Summarizing Supernet Routes
0 = host
192.168 . 0000 0000 . 0
192.168 . 0000 0010 . 0
192.168 . 0000 0100 . 0
192.168 . 0000 1000 . 0
255.255 . 240 . 0 → subnet
192.168.0.0 /20
Customer A 192.168.0.0/23
Customer B 192.168.2.0/23
Customer C 192.168.4.0/22
Customer D 192.168.8.0/21
RA
RB
RC
RD
192.168.0.0/23
192.168.2.0/23
192.168.4.0/22
192.168.8.0/21
ISP1
192.168.0.0/20
ISP2

CIDR

- Static Routing CIDR Example

ทำ summary route ได้

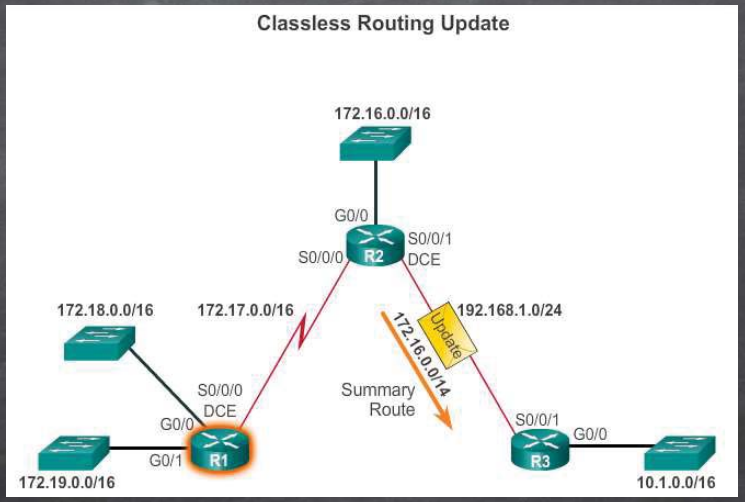


ยกเลิกไป ทั้งหมด

รวมเป็น route อันเดียว

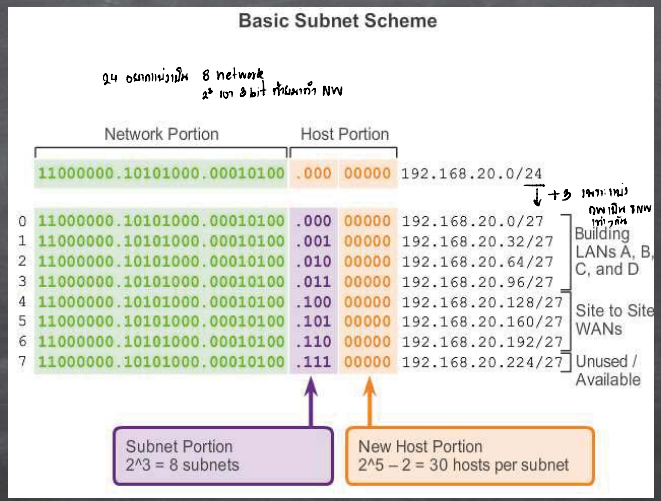
CIDR

- Classless Routing Protocol Example



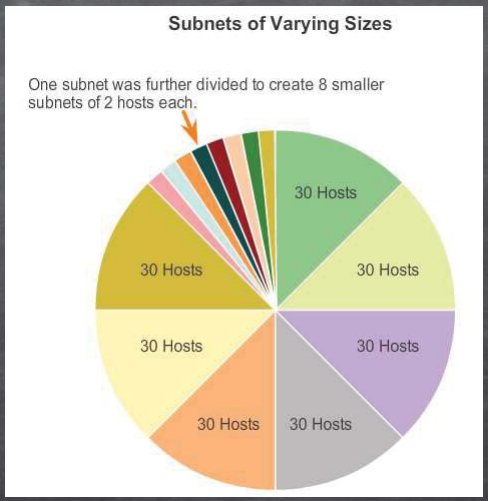
VLSM

- Fixed Length Subnet Masking



VLSM

- Variable Length Subnet Masking

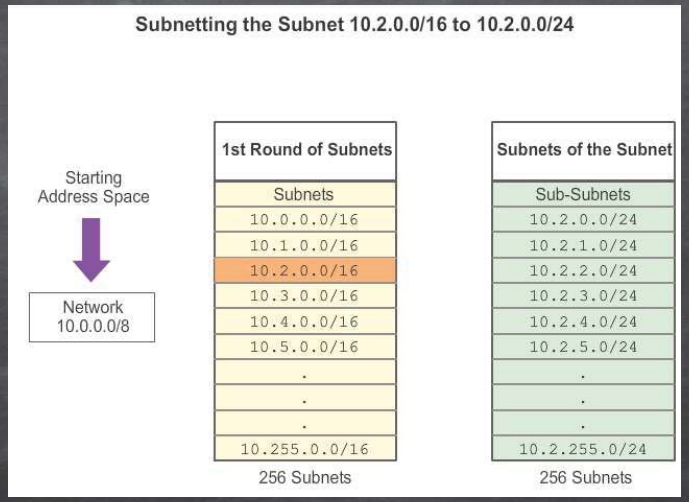


VLSM

- VLSM in Action
  - VLSM allows the use of different masks for each subnet.
  - After a network address is subnetted, those subnets can be further subnetted.
  - VLSM is simply subnetting a subnet. VLSM can be thought of as sub-subnetting.
  - Individual host addresses are assigned from the addresses of "sub-subnets".

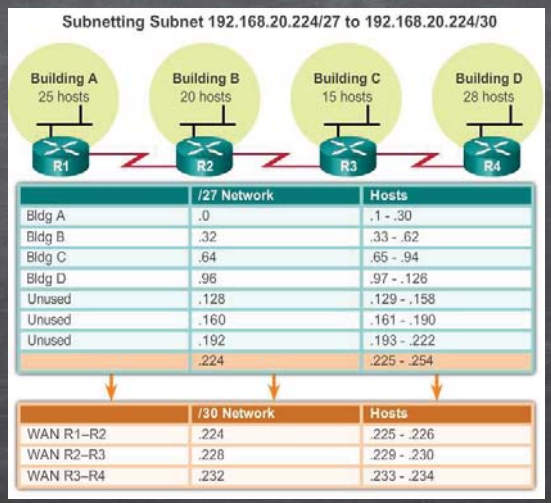
VLSM

- Subnetting Subnets



VLSM

- VLSM Example



Configure IPv4 Summary Routes

- Route summarization, also known as route aggregation, is the process of advertising a contiguous set of addresses as a single address with a less-specific, shorter subnet mask.
- CIDR is a form of route summarization and is synonymous with the term supernetting.
- CIDR ignores the limitation of classful boundaries, and allows summarization with masks that are smaller than that of the default classful mask.
- This type of summarization helps reduce the number of entries in routing updates and lowers the number of entries in local routing tables.

Configure IPv4 Summary Routes

- Calculate a Summary Route

Calculating a Route Summary

Step 1: List networks in binary format.

172.20.0.0	10101100 . 00010100 . 00000000 . 00000000
172.21.0.0	10101100 . 00010101 . 00000000 . 00000000
172.22.0.0	10101100 . 00010110 . 00000000 . 00000000
172.23.0.0	10101100 . 00010111 . 00000000 . 00000000

Step 2: Count the number of far-left matching bits to determine the mask.

Answer: 14 matching bits = /14 or 255.252.0.0

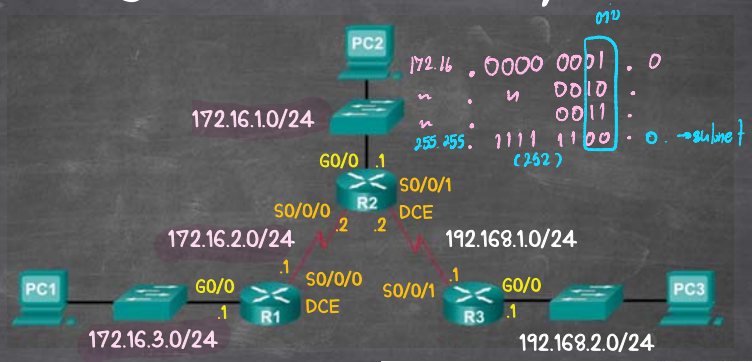
Step 3: Copy the matching bits and add zero bits to determine the network address.

10101100 . 00010100 . 00000000 . 00000000

Copy — Add zero bits

Answer: 172.20.0.0

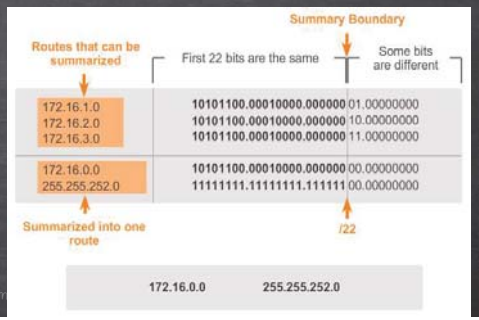
Configure IPv4 Summary Routes




```
R3#show ip route static | begin Gateway
Gateway of last resort is not set
     172.16.0.0/24 is subnet, 3 subnets
S       172.16.1.0/24 [1/0] via 192.168.1.2
S       172.16.2.0/24 [1/0] via 192.168.1.2
S       172.16.3.0/24 [1/0] via 192.168.1.2
```

```
R3(config)#no ip route 172.16.1.0 255.255.255.0 192.168.1.2
R3(config)#no ip route 172.16.2.0 255.255.255.0 192.168.1.2
R3(config)#no ip route 172.16.3.0 255.255.255.0 192.168.1.2
R3(config)#ip route 172.16.0.0 255.255.252.0 192.168.1.2
```

```
R3#show ip route static | begin Gateway
Gateway of last resort is not set
     172.16.0.0/22 is subnet, 1 subnets
S       172.16.1.0 [1/0] via 192.168.1.2
```



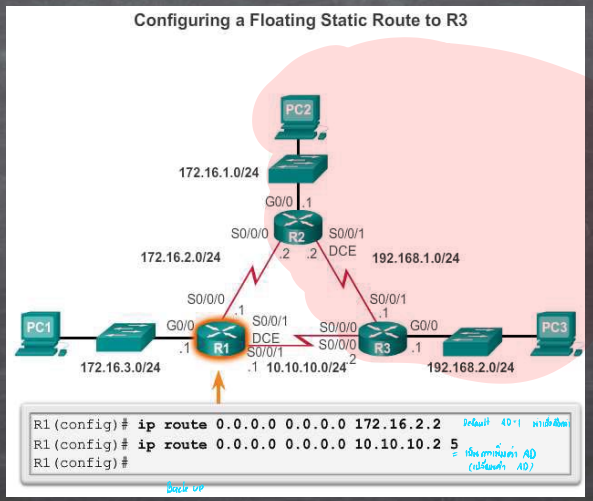
Configure Floating Static Routes

- Floating static routes are static routes that have an administrative distance greater than the administrative distance of another static route or dynamic routes.
- The administrative distance of a static route can be increased to make the route less desirable than that of another static route or a route learned through a dynamic routing protocol.
- In this way, the static route "floats" and is not used when the route with the better administrative distance is active.
- However, if the preferred route is lost, the floating static route can take over, and traffic can be sent through this alternate route.

Configure Floating Static Routes

- Configure a Floating Static Route

Configuring a Floating Static Route to R3



Configure Floating Static Routes

- Test the Floating Static Route
  - Use a show ip route command to verify that the routing table is using the default static route.
  - Use a traceroute command to follow the traffic flow out the primary route.
  - Disconnect the primary link or shutdown the primary exit interface.
  - Use a show ip route command to verify that the routing table is using the floating static route.
  - Use a traceroute command to follow the traffic flow out the backup route.

Troubleshoot IPv4 Static and Default Route Configuration

- Troubleshoot a Missing Route

```
ping
traceroute
show ip route
show ip interface brief
show cdp neighbors detail
```


Questions and Answers