Network Layer: IPv4 Routing

Lecture 10 | CSE421 – Computer Networks

Department of Computer Science and Engineering
School of Data & Science

Objectives

Static Routing

- Standard static routing
  - Directly Attached / Connected
  - Next Hop / Recursive
- Default Routing

Learning About 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 networks are automatically learned using a dynamic routing protocol.

Static Route

- A static route is created, maintained, and updated by a network administrator, manually.
- A static route to every network must be configured on every router for full connectivity.

Learning About Networks

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Table of R1

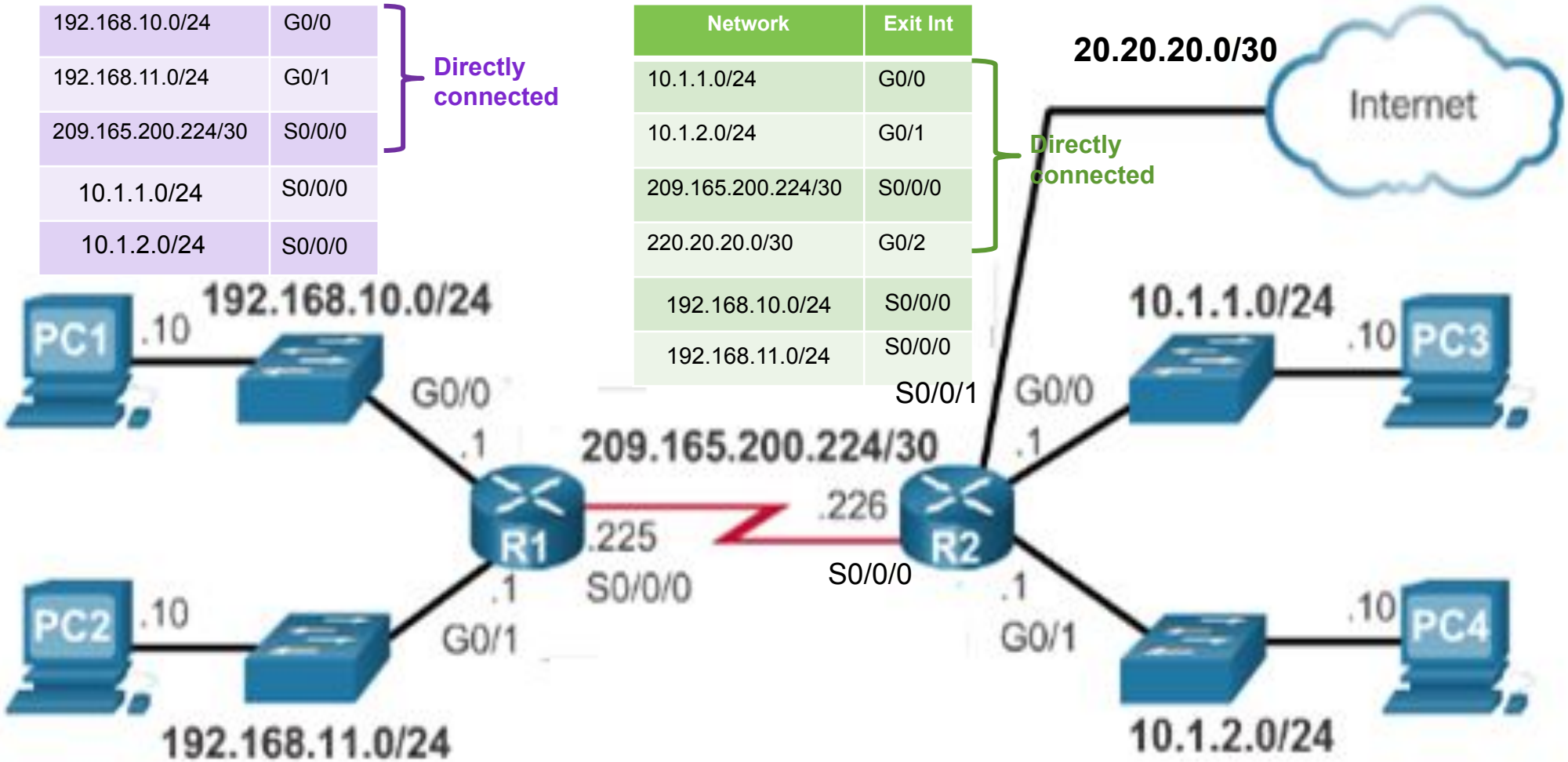
Network	Exit Int
192.168.10.0/24	G0/0
192.168.11.0/24	G0/1
209.165.200.224/30	S0/0/0
10.1.1.0/24	S0/0/0
10.1.2.0/24	S0/0/0

Directly connected

Table of R2

Network	Exit Int
10.1.1.0/24	G0/0
10.1.2.0/24	G0/1
209.165.200.224/30	S0/0/0
220.20.20.0/30	G0/2
192.168.10.0/24	S0/0/0
192.168.11.0/24	S0/0/0

Directly connected



Static Route Advantages

Static routing provides some advantages over dynamic routing, including:

- Static routes are not advertised over the network, resulting in better security.
- Routers not share static routes with each other, thus reducing CPU/RAM overhead and saving bandwidth.

Static Route Disadvantages

Static routing has the following disadvantages:

- Initial configuration and maintenance is time-consuming.
- Configuration is error-prone, especially in large networks.
- Administrator intervention is required to maintain changing route information.
- Does not scale well with growing networks; maintenance becomes cumbersome.
- Requires complete knowledge of the whole network for proper implementation.

Comparison

	Dynamic Routing	Static Routing
Configuration Complexity	Generally independent of the network size	Increases with network size
Topology Changes	Automatically adapts to topology changes	Administrator intervention required
Scaling	Suitable for simple and complex topologies	Suitable for simple topologies
Security	Less secure	More secure
Resource Usage	Uses CPU, memory, link bandwith	No extra resources needed
Predictability	Route depends on the current topology	Route to destination is always the same

Static Route Applications : Types

Static Routes are often used to:

1. Connect to a specific network
2. Provide a Gateway of Last Resort for a stub network – Default Gateway
3. Summarize routing table entries
4. Create a backup route in case a primary route link fails

Standard Static Route

Types of Static Routes

Static Route Applications

Static Routes are often used to:

1. Connect to a specific network
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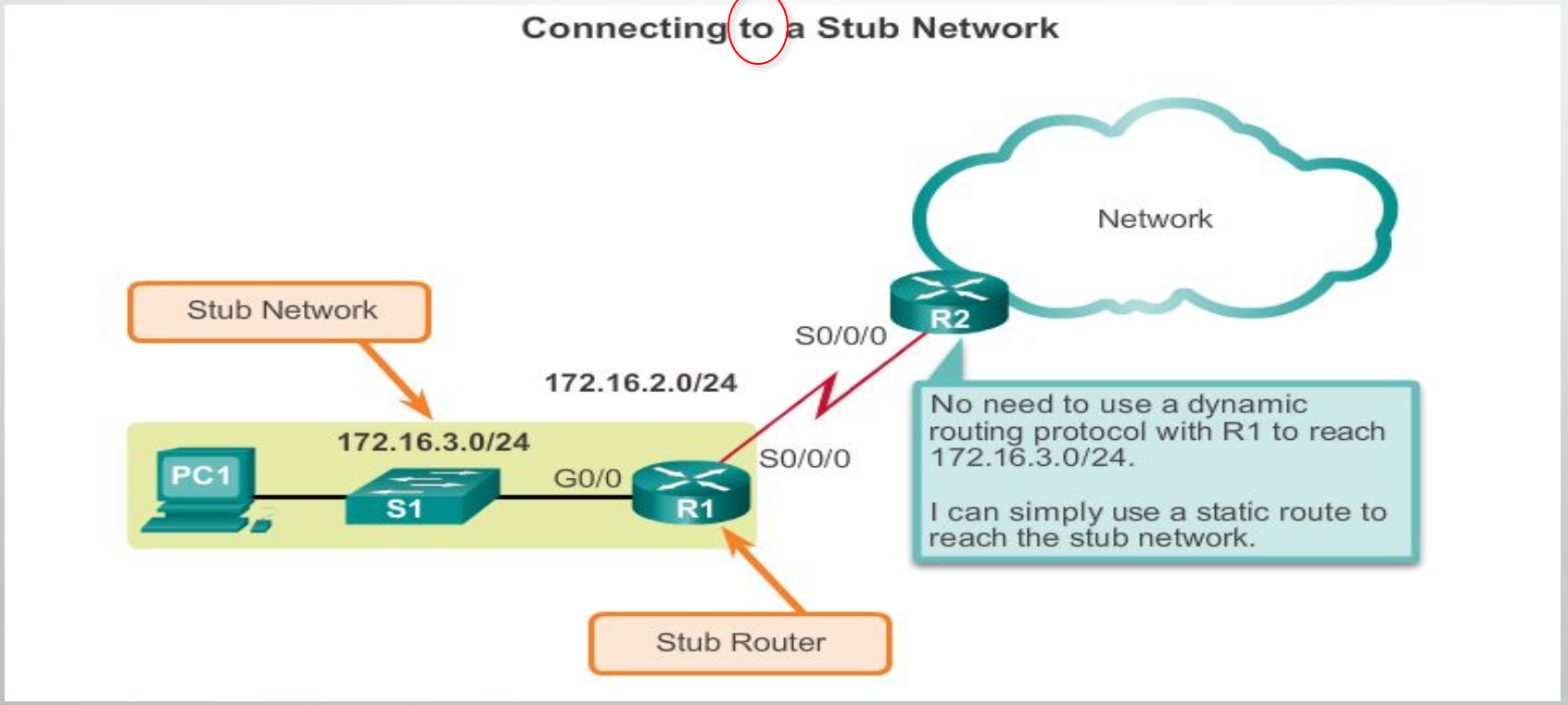
Static route can be used to connect to a specific network (like for example a stub network)



ip route Command

ip route Command Syntax

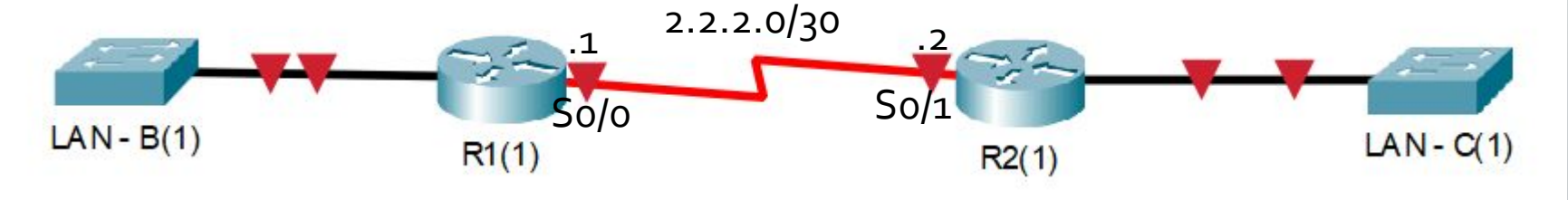
```
Router(config)#ip route network-address subnet-mask
{ip-address | exit-intf}
```

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.

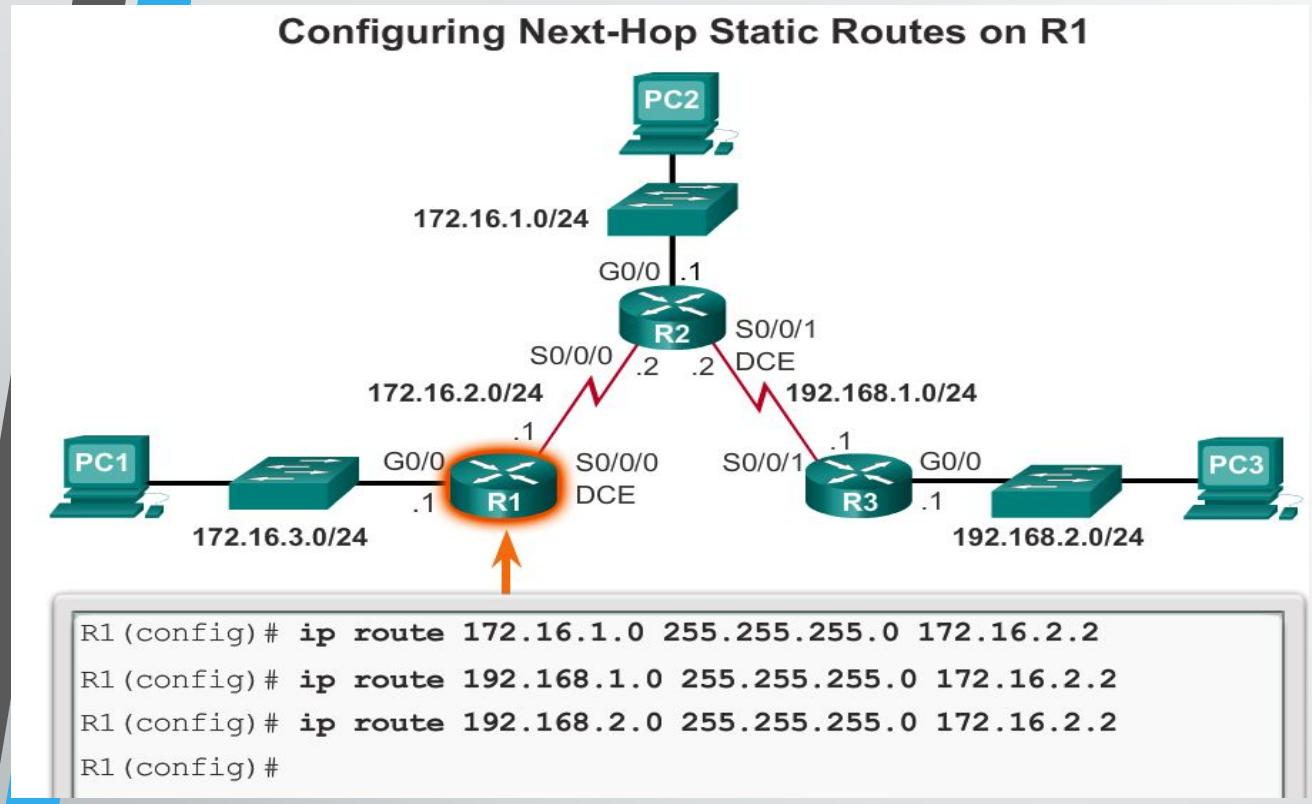
Next Hop Options

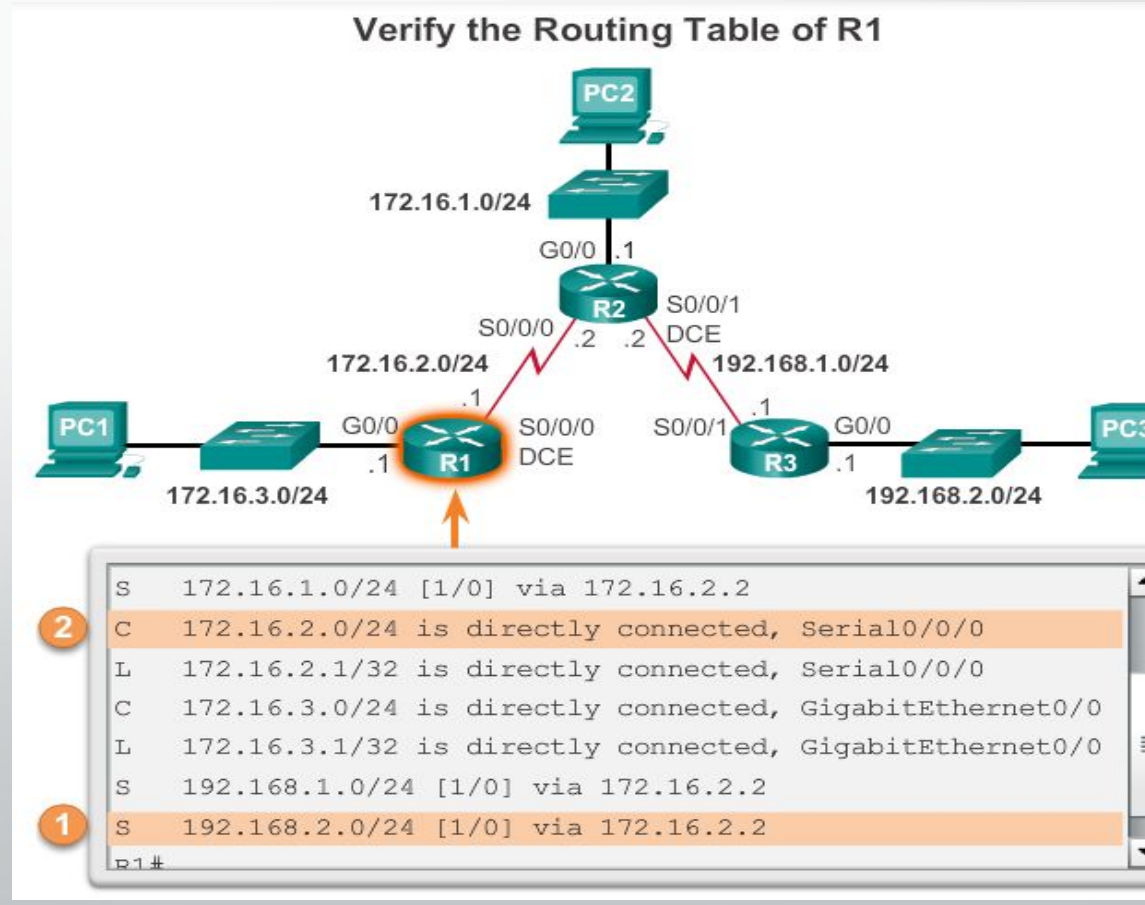
- **Directly attached/connected static route**
  - Only the router **exit interface**/port name (i.e. so/o) is specified.
- **Next-hop/Recursive lookup static route**
  - Only the next-hop IP address (i.e. 2.2.2.2) is specified.
- ****Note: Port labels:**
  - Each port has a name (so/o or fo/o or go/o or etc.) and an IP address (1.2.3.4 or etc.)



**Configuring R1(1) towards LAN – C
***All settings are done from R1(1)'s perspective

Standard Static Route using next hop IP address

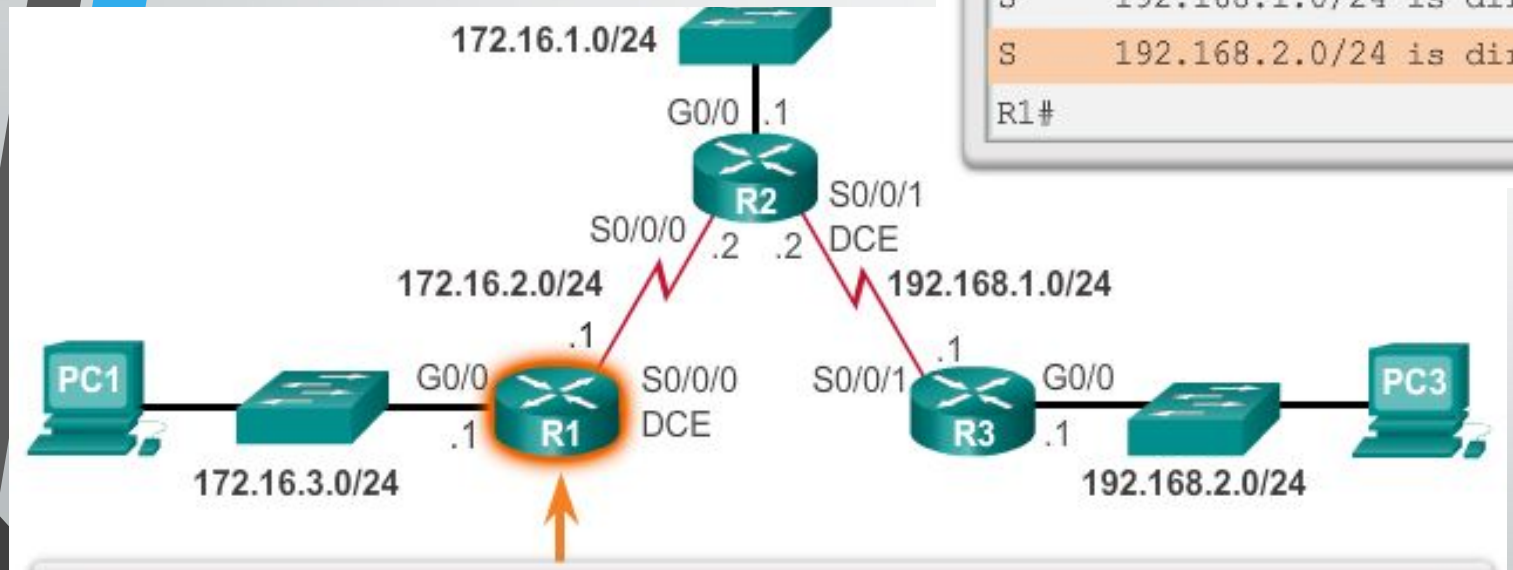




Recursive Lookup

Standard Static Route using Exit Interface

```
S        172.16.1.0/24 is directly connected, Serial0/0/0
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 is directly connected, Serial0/0/0
S     192.168.2.0/24 is directly connected, Serial0/0/0
R1#
```




```
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
R1(config)#ip route 192.168.2.0 255.255.255.0 s0/0/0
R1(config)#
```

Static Route : The line and AD explained

```
R1#show ip route
Codes: C - connected, S - Static, I - IGRP, R - RIP,

<output omitted>

Gateway of last resort is not set

     172.16.0.0/24 is subnetted, 3 subnets
S       172.16.1.0 [1/0] via 172.16.2.2
C       172.16.2.0 is directly connected, Serial0/0/0
C       172.16.3.0 is directly connected, FastEthernet0/0
```

Type of route:
S - Static

Destination Network

Administrative Distance

Cost of Path

Next Hop IP
Or, Exit Interface
Or, Fully Specified

Static Routing table record if it was configured with Exit Interface

```
S     192.168.1.0/24 is directly connected, Serial0/0/0
S     192.168.2.0/24 is directly connected, Serial0/0/0
```

NOTE : AD of Static Routes is 1 and AD of Directly Connected Routes is 0

Types of Static Routes

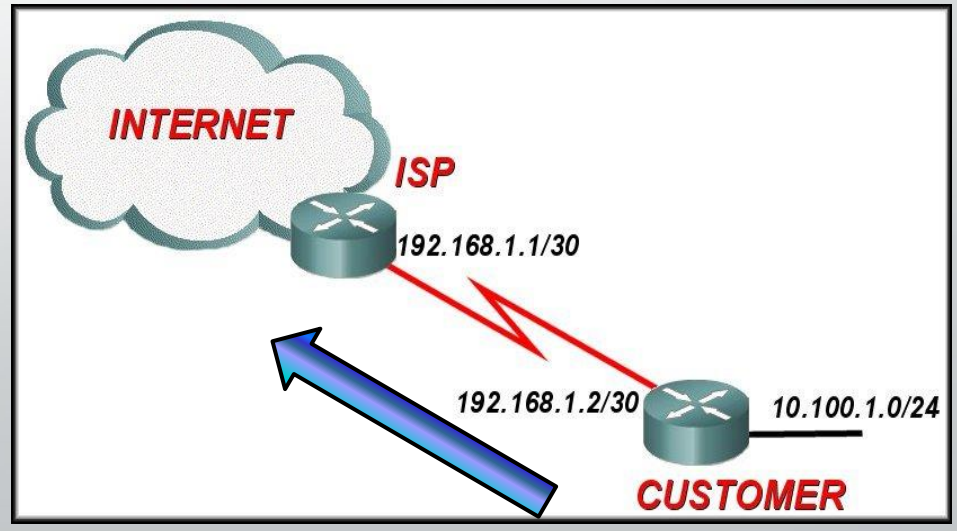
Static Route Applications

Static Routes are often used to:

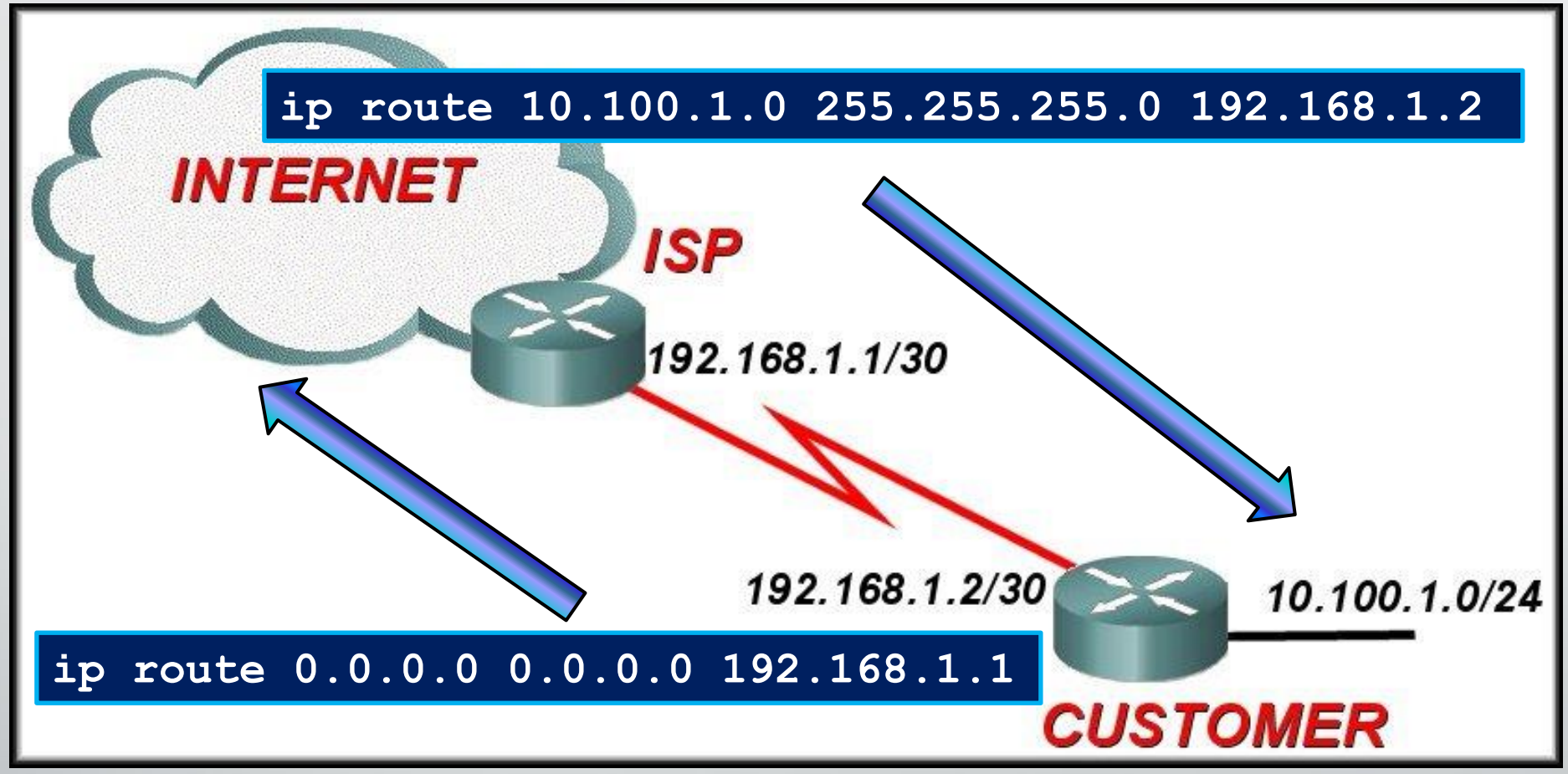
1. Connect to a specific network
2. Provide a Gateway of Last Resort for a stub network
3. Summarize routing table entries
4. Create a backup route in case a primary route link fails

Default Static Routing

- A **default path** to send all IP packets
  - when no other routes in the routing table match the packet destination IP address.
  - when a router has only one other router to which it is connected. This condition is known as a stub router.
- Uses a special network address as destination: **0.0.0.0/0**
  - Has a subnet mask of 0. Meaning, it will check zero bits and hence it will match all IPs!
- Conventionally, always points towards the border/ISP Router.
- Configuring a default static route creates a Gateway of Last Resort.



Configuring Default Static Route



- **Note: A static route usually always points towards the specific network, while default static route points towards outside the network where a border router is connected to the internet

Verifying Default Static Route

```
CUSTOMER#show ip route
Codes: C - connected, S - static, I - IGRP, R - RIP, M - mobile, B - BGP
<output omitted>
       * - candidate default, U - per-user static route, o - ODR
       P - periodic downloaded static route

Gateway of last resort is 192.168.1.1 to network 0.0.0.0

   10.0.0.0/8 is subnetted, 1 subnets
C     10.100.1.0/24 is directly connected, FastEthernet0/0
C     192.168.1.0/24 is directly connected, Serial0/0/1
S*    0.0.0.0/0 [1/0] via 192.168.1.1
```

Commands to Verify Static Routes

- Along with **ping** and **traceroute**, useful commands to verify static routes include:
  - **`show ip route`**
  - **`show ip route static`**
  - **`show ip route network`**

Objectives

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Dynamic Routing

- Routing Algorithms
  - Global - Link State
  - Decentralized - Distance Vector

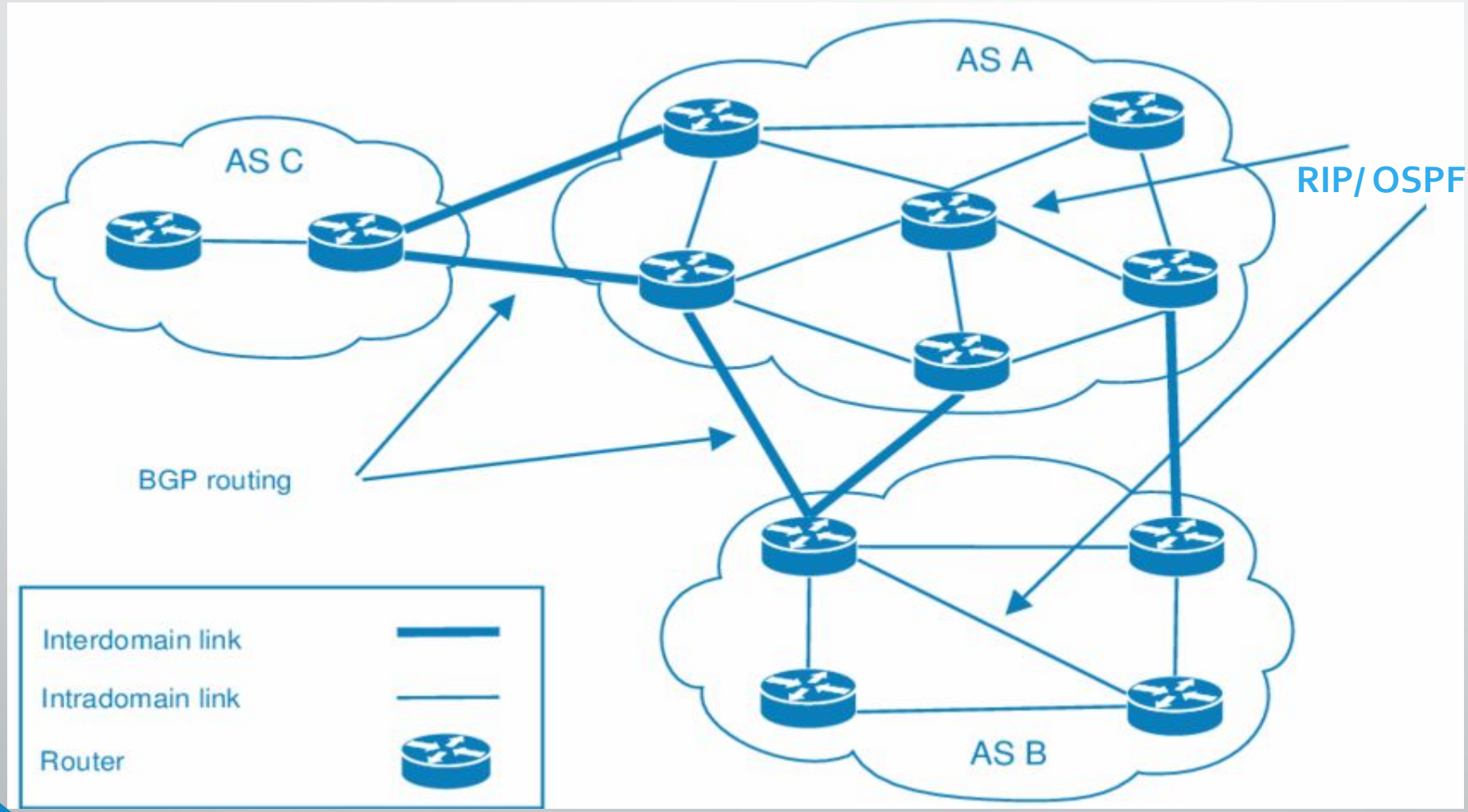
Routing Algorithms

- Given a set of routers and links connecting the routers.
- Routing algorithm finds a "good" path from the source to destination router.
- Good path = Least cost path

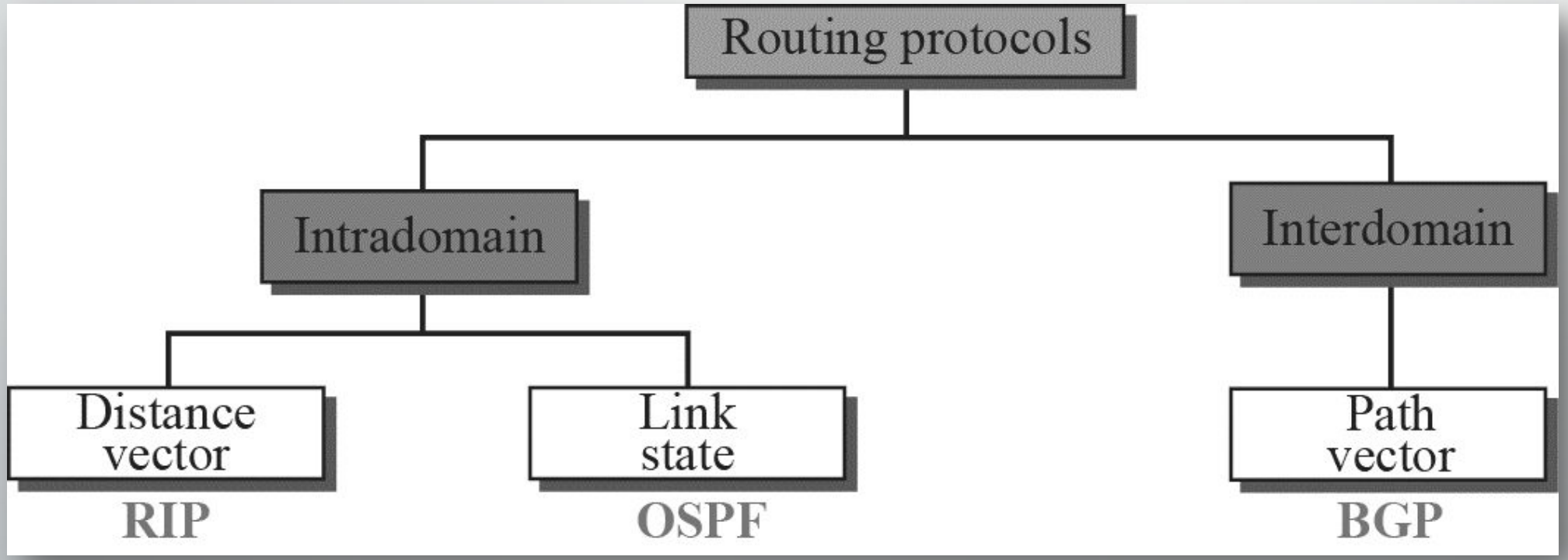
Autonomous Systems

- Internet is divided into autonomous systems.
- An autonomous system (AS) is a group of networks and routers under the authority of a single administration.
- Routing ***inside*** an autonomous system is called **intra-domain routing**. Routing ***between*** autonomous systems is called **inter-domain routing.**

Autonomous Systems



Popular Routing Protocols



Routing Algorithm classification

Global or Decentralized

Global:

- all routers have complete topology and link cost info
- "link state" algorithms

Decentralized:

- router knows physically-connected neighbors, link costs to neighbors
- iterative process of computation, exchange of info with neighbors
- "distance vector" algorithms

- Distance Vector routing protocols are like road signs.
  - Routers must make preferred path decisions based on a distance or metric to a network.
- Link-State routing protocols are more like a road map.
  - They create a topological map of the network and each router uses this map to determine the shortest path to each network.

Distance vector algorithm

Basic idea:

- Each node periodically sends its own distance vector estimate to neighbors
- When a node x receives new DV estimate from neighbor;
- It updates its own DV using B-F equation

Operation of Distance Vector

- Periodic Updates:
  - Periodically broadcast the entire routing table to each of its neighbors (RIP – every 30 seconds).
    - Inefficient
  - Router is only aware of the:
    - Network addresses of its own interfaces.
    - Network addresses the neighbors running the same routing protocol.

Link-State Routing Protocols

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- Centralized Routing Algorithm
  - computes the least-cost path using complete, global knowledge about the network.
- Link-state routing protocols are also known as shortest path first protocols
  - The Link state routing protocol uses Dijkstra's algorithm which is used to find the shortest path from one node to every other node in the network.
- While they have the reputation of being much more complex than distance vector, the basic functionality and configuration of link state routing protocols are not complex.

Link-State Routing Process
5 Step Process

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1. Each router learns about its own directly connected networks.
2. Each router is responsible for contacting its neighbors (exchange Hello packet) on directly connected networks.
3. Each router builds a link-state packet (LSP) containing the state of each directly connected link.
4. Each router floods the LSP to all routers, who then store all LSPs received in a database.
5. Each router uses the LSPs to construct a database that is a complete map of the topology and computes the best path to each destination network.

Comparison

	Distance Vector	Link State
Network view	Topology knowledge from the neighbor point of view	Common and complete knowledge of the network topology
Best Path Calculation	Based on fewest number of hops	Based on the link cost
Updates	Full routing table	Link State Updates
Algorithm	Bellman-Ford	Dijsktra
CPU and Memory	Low utilization	Intensive
hierarchical Structure	No	Yes
Convergence time	Moderate	Fast

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The End