



NANJING UNIVERSITY · SOFTWARE INSTITUTE  
南京大学 · 软件学院

# Routing and Routers

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# Routing and Routers

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- ☐ Router Basics
  - ☐ Router Startup procedure
  - ☐ Routing
  - ☐ Router configuration
-



# Router Basics

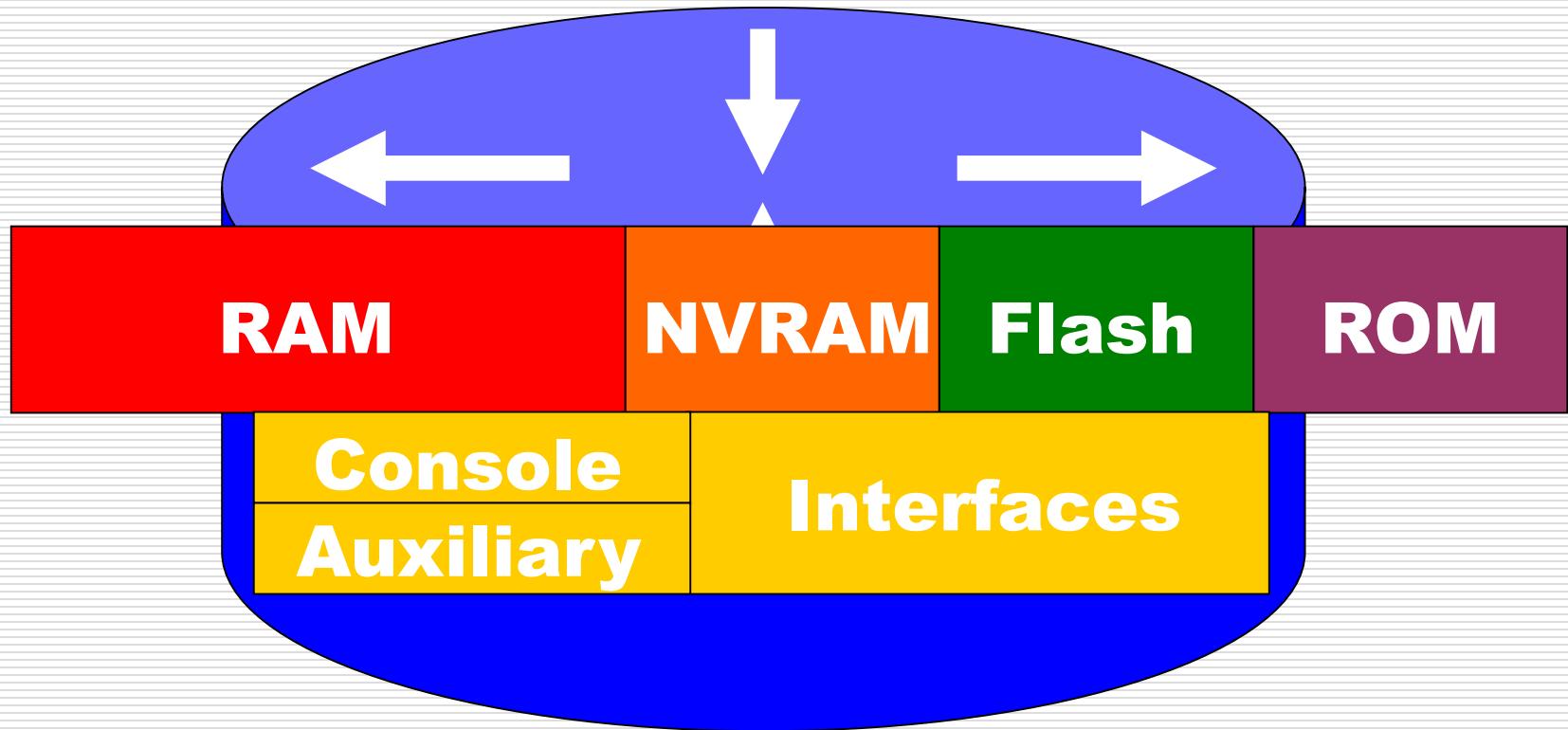
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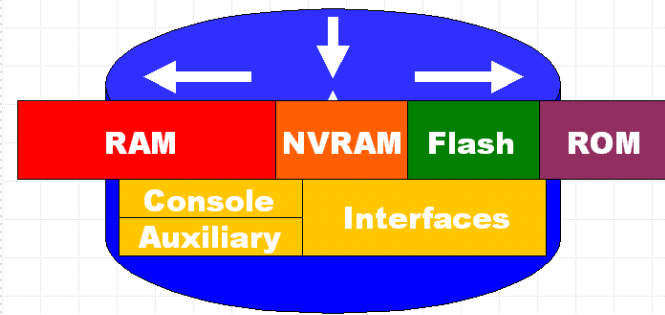




# Internal Components

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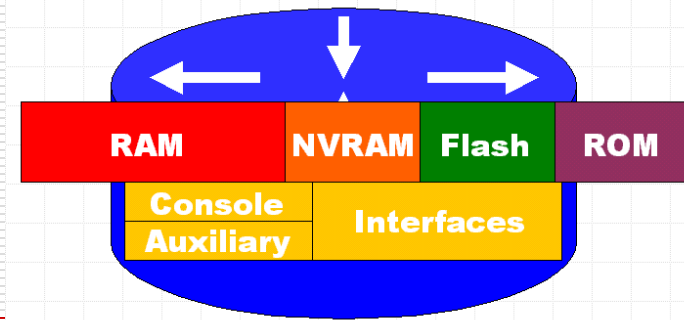




# RAM

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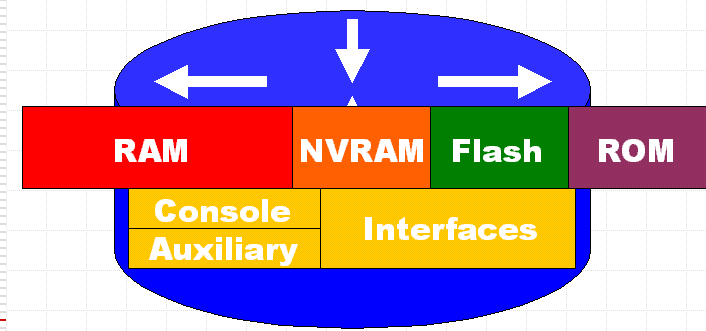
- ☐ Temporary storage for router configuration files
  - ☐ RAM content is lost on power down or restart
  - ☐ Stores...
    - Routing tables
    - ARP cache
    - Fast switching cache
    - Packet buffering
    - Packet hold queues
-



# NVRAM

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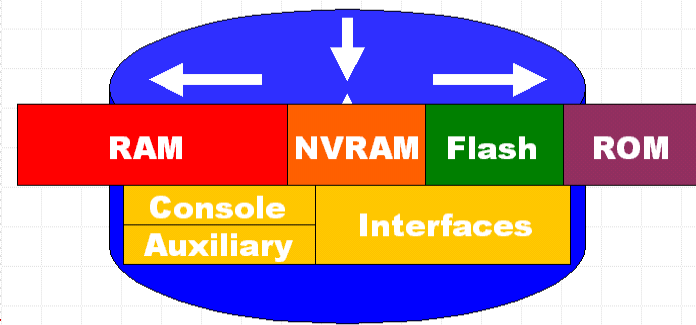
- ☐ Non-volatile RAM
  - ☐ Stores backup/startup configuration files
  - ☐ Content is not lost when router is powered down or restarted.
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# Flash

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- ☐ EEPROM (Electrically Erasable Programmable Read-Only Memory)
  - ☐ Holds the Cisco IOS (Internet Operating System)
  - ☐ Allows updating of software without replacing the Flash chip
  - ☐ Multiple versions of IOS can be stored
  - ☐ Retained on power down
-



# ROM

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- ❑ Contains POST (Power On Self Test)
  - ❑ A bootstrap program (loads the Cisco IOS)
  - ❑ And operating system software
    - Backup, trimmed down version of the IOS
    - Upgrades require installing new chip set
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# Interfaces

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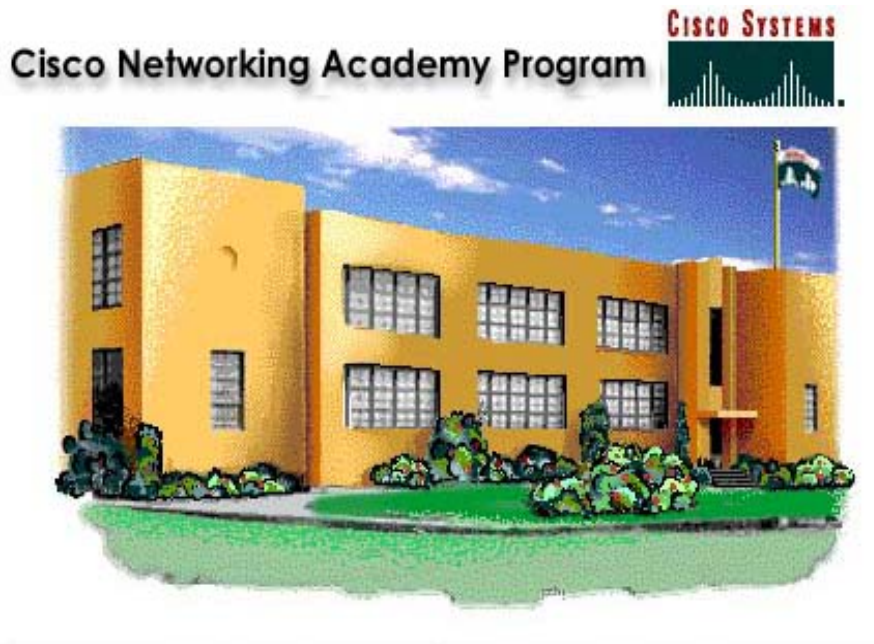
- ❑ Network connections through which packets enter and exit the router
- ❑ Attached to the motherboard or as separate modules.





# Router Startup Procedure

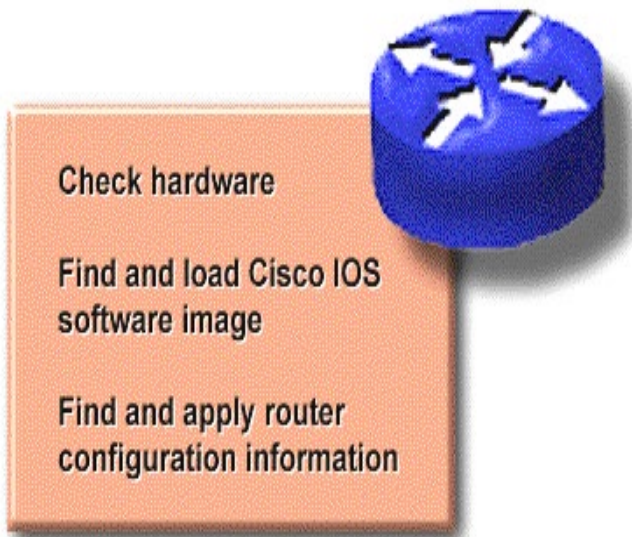
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# System Startup Procedure

## Overview of System Startup



1. Perform a power-up self test(POST): During this self test, the router executes diagnostics from ROM on all hardware modules.
2. Verify the basic operation of CPU, memory, and network interface ports.
3. Software initialization.



# Software Startup Procedure

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- Step 1 - The generic bootstrap loader, in ROM, executes on the CPU card.
  - Step 2 - The operating system (Cisco IOS) can be found in one of several places. The location is disclosed in the boot field of the configuration register.
  - Step 3 - The operating system image is loaded.
  - Step 4 - The configuration file saved in NVRAM is loaded into main memory and executed one line at a time.
  - Step 5 - If no valid configuration file in NVRAM, then executes a question-driven initial configuration routine referred to as the system configuration dialog, also called the setup mode.
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# Router Startup Procedure

路由器启动过程

ROM		Router#show version
Flash		Cisco Internetwork Operating System Software
TFTP S	IOS 版本 ←	IOS (tm) C2600 Software (C2600-I-M), Version 12.2(28), RELEASE SOFTWARE (fc5)
RO		Technical Support: <a href="http://www.cisco.com/techsupport">http://www.cisco.com/techsupport</a>
NVR		Copyright (c) 1986-2005 by cisco Systems, Inc.
TFTP S	Bootstrap 版本 ←	Compiled Wed 27-Apr-04 19:01 by miwang
Cons		Image text-base: 0x8000808C, data-base: 0x80A1FE0C
		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
	型号和 CPU ←	System image file is "flash:c2600-i-mx.122-28.bin"
	RAM 大小 ←	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.
	接口数量和类型 ←	2 FastEthernet/IEEE 802.3 interface(s)
		2 Low-speed serial(sync/async) network interface(s)
	NVRAM 大小 ←	32K bytes of non-volatile configuration memory.
	闪存大小 ←	16384K bytes of processor board System flash (Read/Write)
		Configuration register is 0x2102
		Router#

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# 基本的路由器配置

## 路由器基本配置命令语法

为路由器命名

```
Router(config)#hostname name
```

设置口令

```
Router(config)#enable secret password
```

```
Router(config)#line console 0
```

```
Router(config-line)#password password
```

```
Router(config-line)#login
```

```
Router(config)#line vty 0 4
```

```
Router(config-line)#password password
```

```
Router(config-line)#login
```

配置登录提示文字

```
Router(config)#banner motd # message #
```



# 执行基本的编址方案

## 路由器基本配置命令语法

配置接口

Router(config)#**interface** *type number*

Router(config-if)#**ip address** *address mask*

Router(config-if)#**description** *description*

Router(config-if)#**no shutdown**

保存路由器更改

Router#**copy running-config startup-config**

检查 **show** 命令的输出

Router#**show running-config**

Router#**show ip route**

Router#**show ip interface brief**

Router#**show interfaces**



# 检验基本的路由配置

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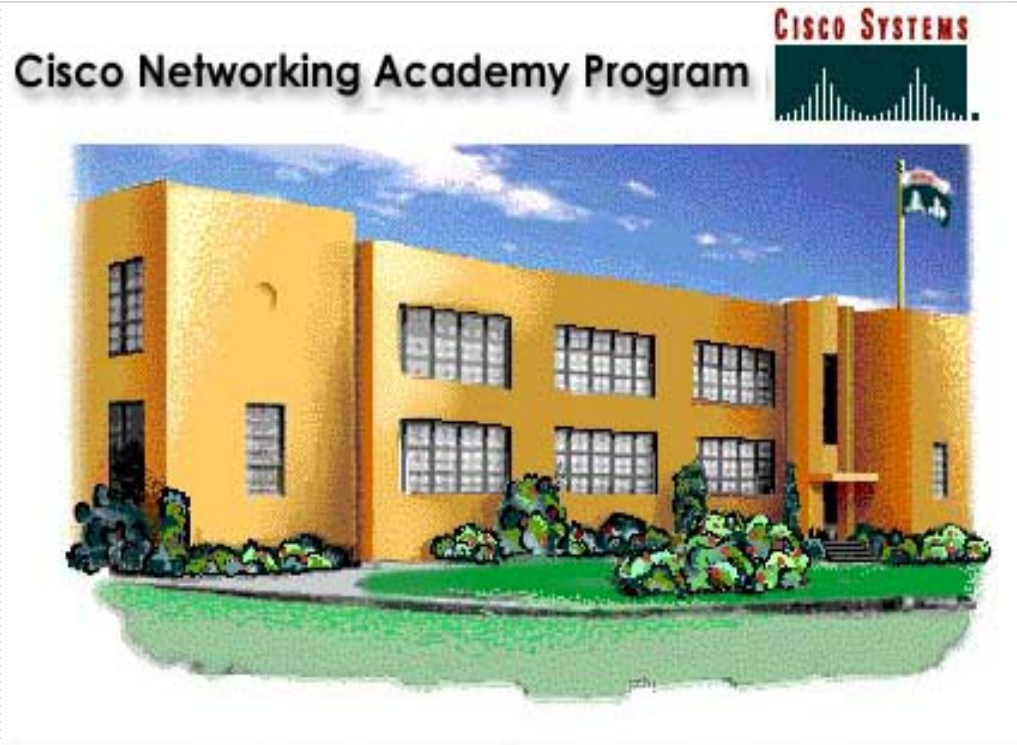
- -使用 *show running-config* 命令
  - -存储路由器基本配置 *copy running-config startup-config*
  - -其他检验路由器的命令：
    - *Show running-config* – 显示当前随机访问存储器中的配置
    - *Show startup-config* – 显示NVRAM中的配置文件
    - *Show IP route* – 现实路由表
    - *Show interfaces* – 显示所有接口的配置信息
    - *Show IP int brief* -显示接口的简要信息
-





# Routing

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# Routing Using Network Addressing

Destination Network	Direction and Router Port
1.0	1.1
2.0	2.1
3.0	3.1



- Network portion of address used to make path selections
- Node portion of address refers to router port to the path

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■ A router generally relays a packet from one data link to another, using two basic functions, a path determination function and a switching function.

■ The switching function allows a router to **accept a packet on one interface and forward it through a second interface.**

■ The path determination function enables the router to **select the most appropriate interface for forwarding a packet.**

■ The router uses the network portion of the address to make path selections to pass the packet to the next router

■ The node portion of the address is used by the the router directly connected to the destination network to deliver the packet to the correct host.



# Static and Dynamic Route

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## **Static Route**

Uses a protocol route that a network administrator enters into the router

## **Dynamic Route**

Uses a router that a network routing protocol adjusts automatically for topology or traffic changes



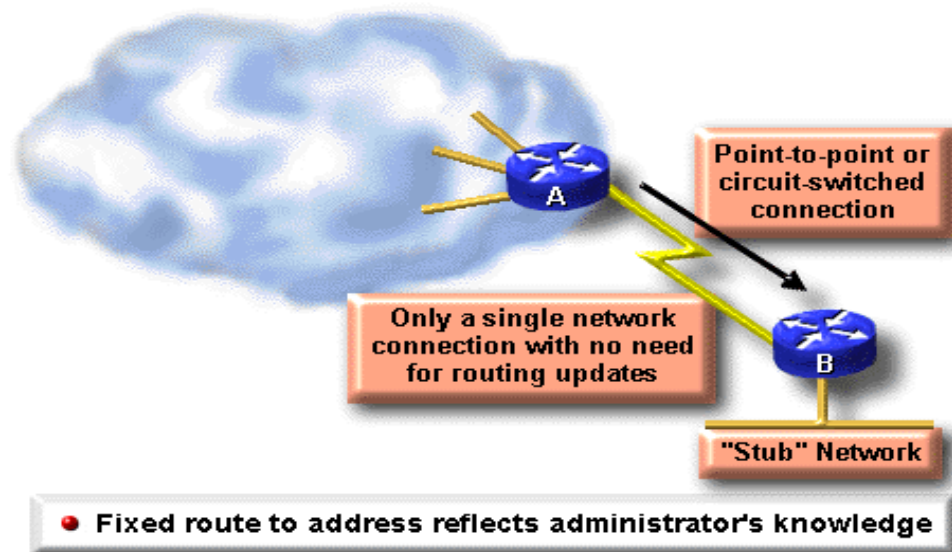
# Static and Dynamic Route

■ Whereas dynamic routing tends to reveal everything known about an internetwork, for security reasons, you may want to hide parts of an internetwork.

■ When a network is accessible by only one path, a static route to the network can be sufficient.

■ This type of partition is called a stub network.

## Static Routing Example





# Static Route Configuration

Router(config)#

```
ip route network [mask] {address | interface} [distance]
```

● Defines a path to an IP destination network or subnet

**A static route allows manual configuration of the routing table.**

ip route Command	Description
<b>network</b>	destination network or subnet
<b>mask</b>	subnet mask
<b>address</b>	IP address of the next-hop router
<b>interface</b>	the interface to use to get to the destination network
<b>distance</b>	administrative distance

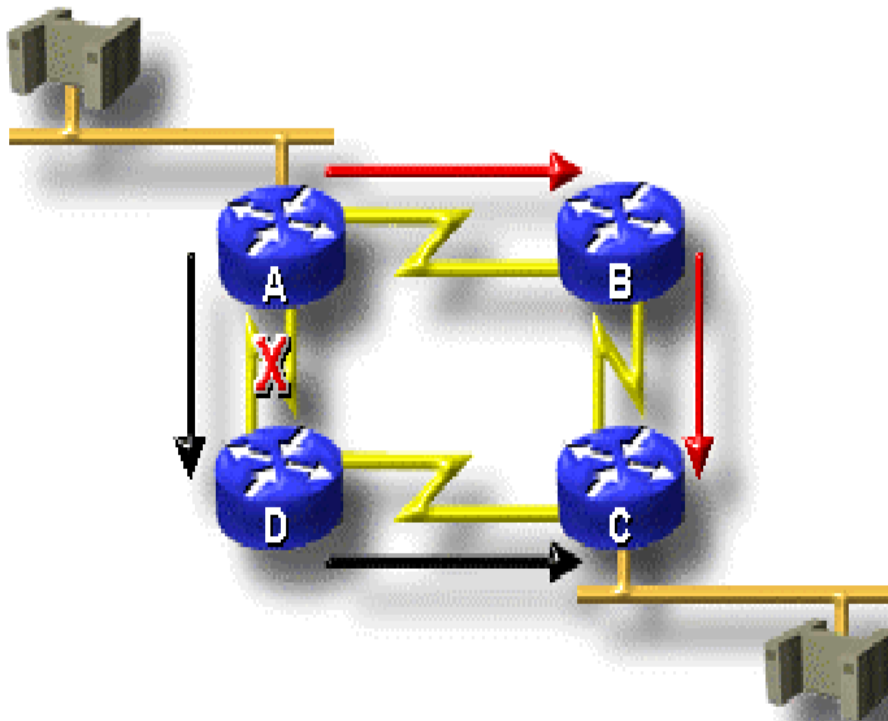
# Administrative Distance

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- ❑ The administrative distance is a rating of the trustworthiness of a routing information source, expressed as a numeric value from 0 to 255.
  - ❑ The higher the number, the lower the trustworthiness rating.
  - ❑ So the administrative distance of static routes is often low.(1 is the default)
-



# Dynamic Routing



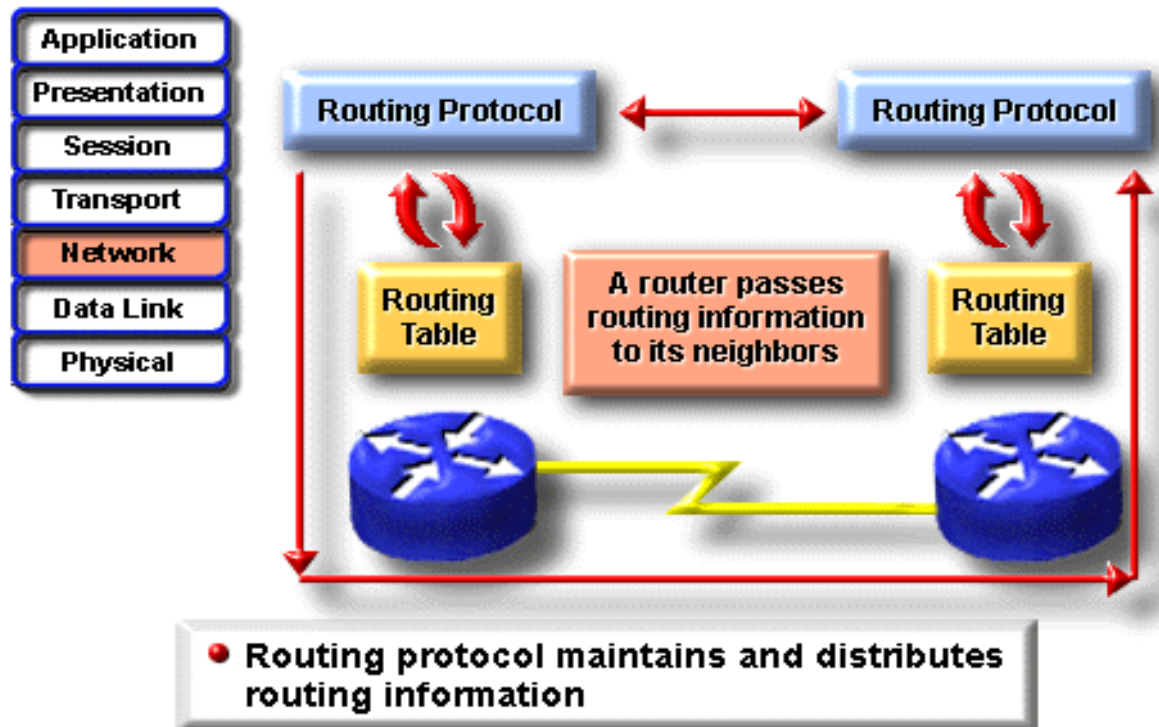
Dynamic routing protocols can also redirect traffic (or loadshare) between different paths in a network





# Dynamic routing

## Dynamic Routing Operations



■ Dynamic routing relies on a routing protocol to share knowledge among routers.

■ The dynamic routing depends on two basic router functions:

- maintenance of a routing table
- distribution of knowledge to other routers





# Time to Convergence

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**Convergence occurs when all routers use a consistent perspective of network topology**

**After a topology changes, routers must recompute routes, which distrupts routing**

**The process and time required for router reconvergence varies in routing protocols**

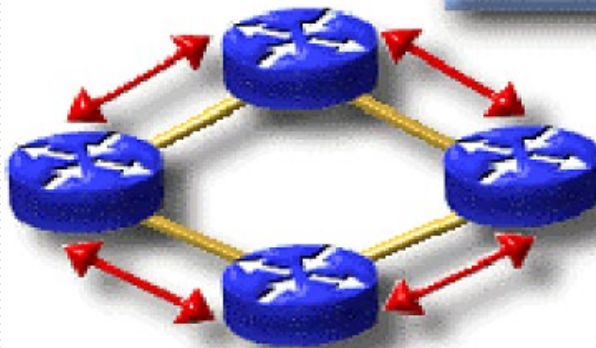
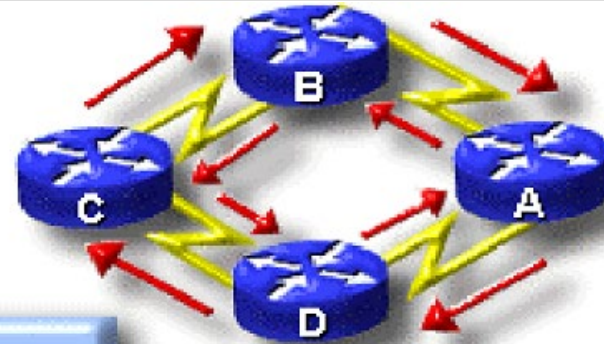


# Classification of Routing Protocols

**Distance Vector**

**Hybrid Routing**

**Link State**

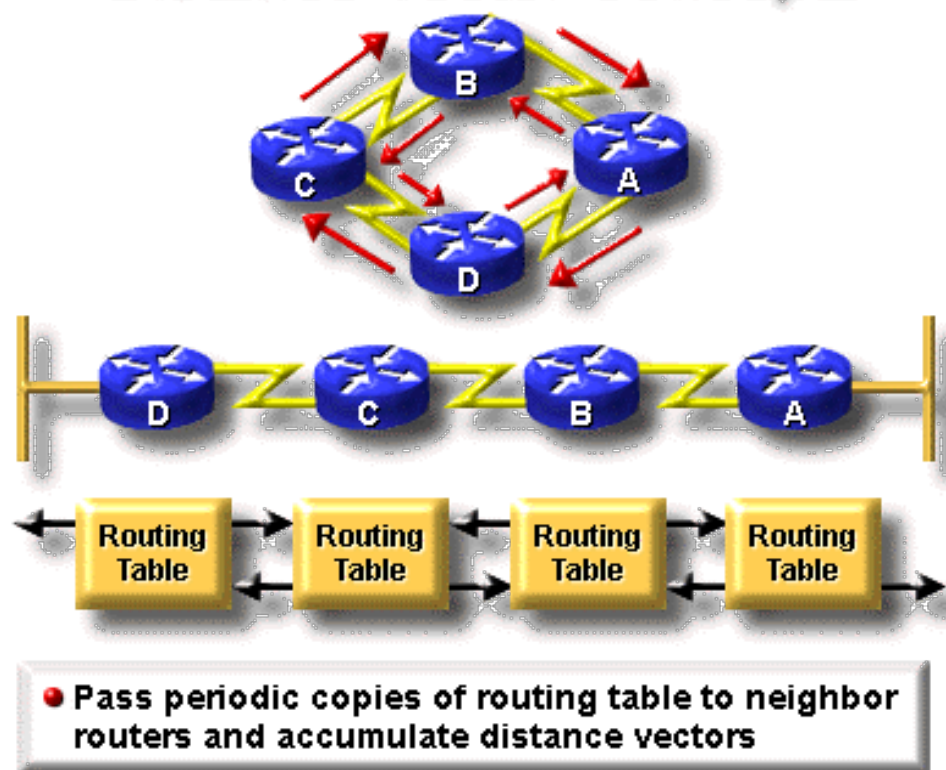




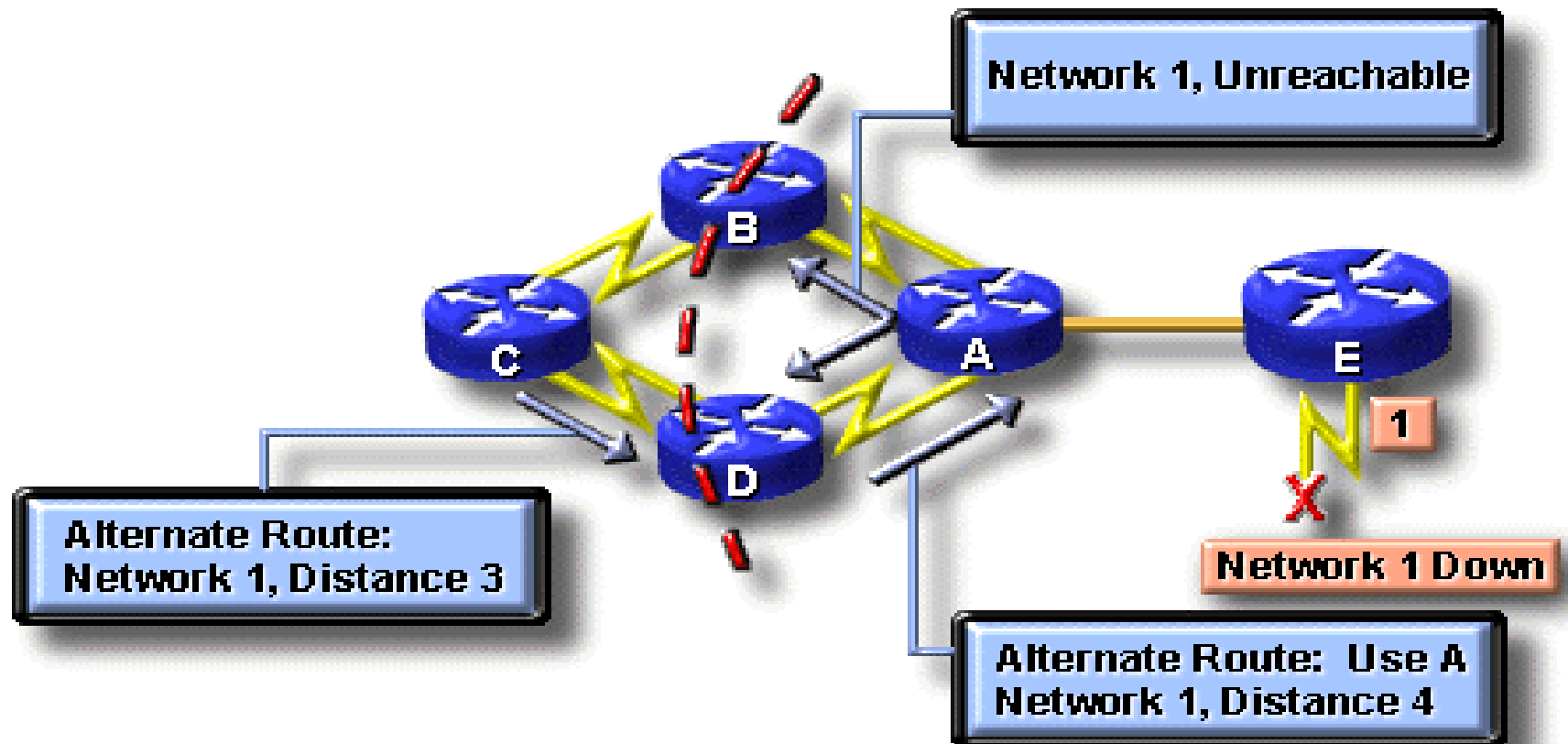
# Distance-Vector Protocol

- Distance-vector algorithms do not allow a router to know the exact topology of an internetwork
- Distance-vector-based routing algorithms (also known as *Bellman-Ford algorithms*) pass periodic copies of a routing table from router to router.

## Distance-Vector Concepts



# Problem: Routing Loops



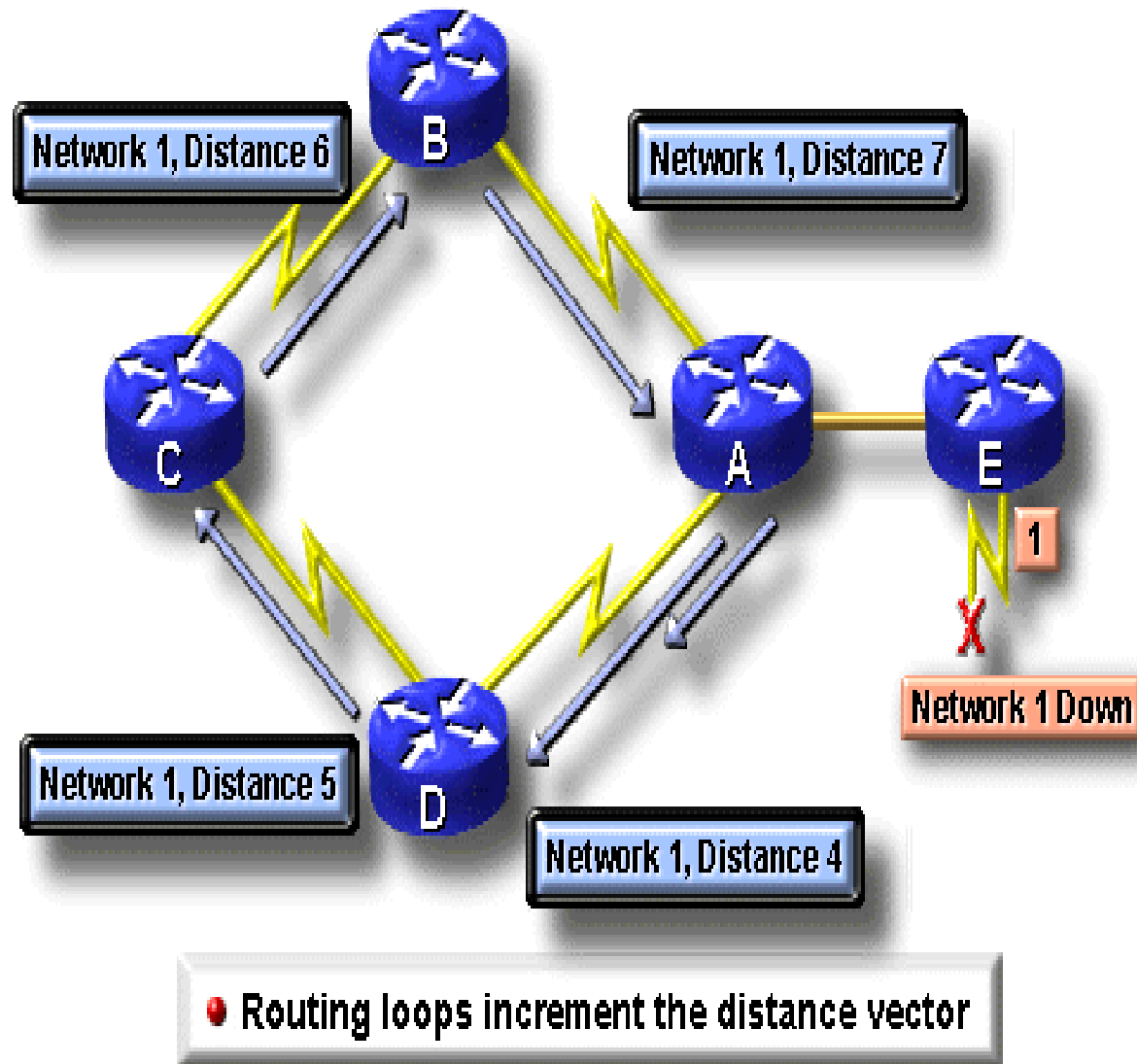
- Alternate routes, slow convergence, inconsistent routing

- The invalid updates of Network 1 will continue to loop until some other process stops the looping.

- This condition, called *count to infinity*, loops packets continuously around the network in spite of the fundamental fact that the destination network, Network 1, is down.

- While the routers are counting to infinity, the invalid information allows a routing loop to exist.

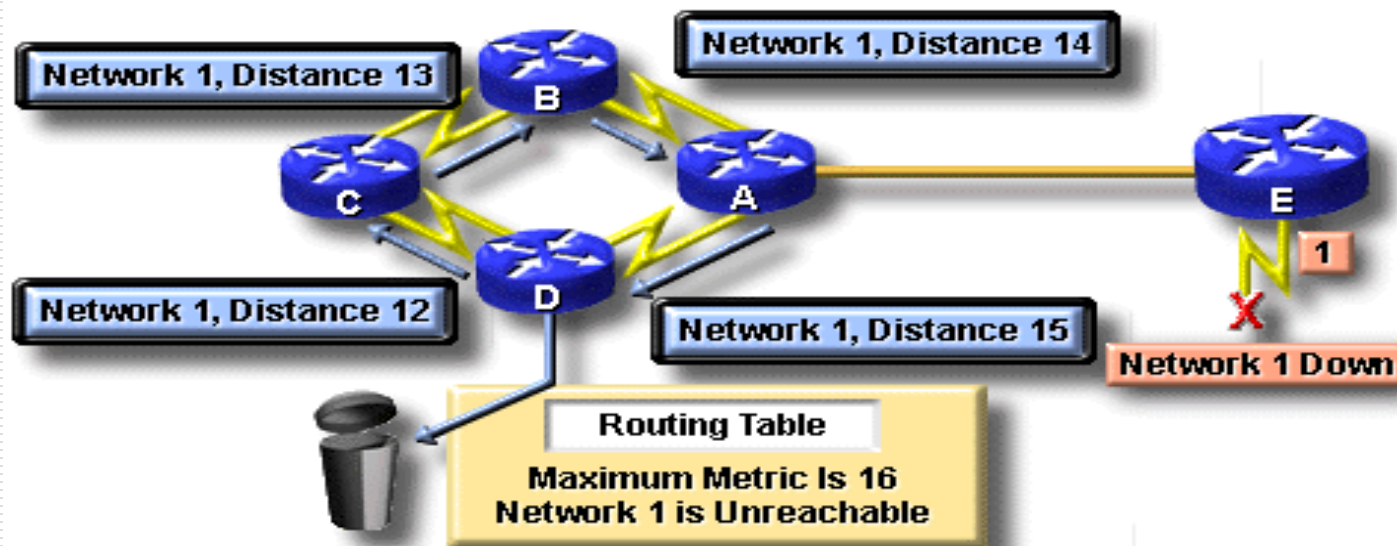
## Problem: Counting to Infinity





# Solution: Defining a Maximum

## Solution: Defining a Maximum



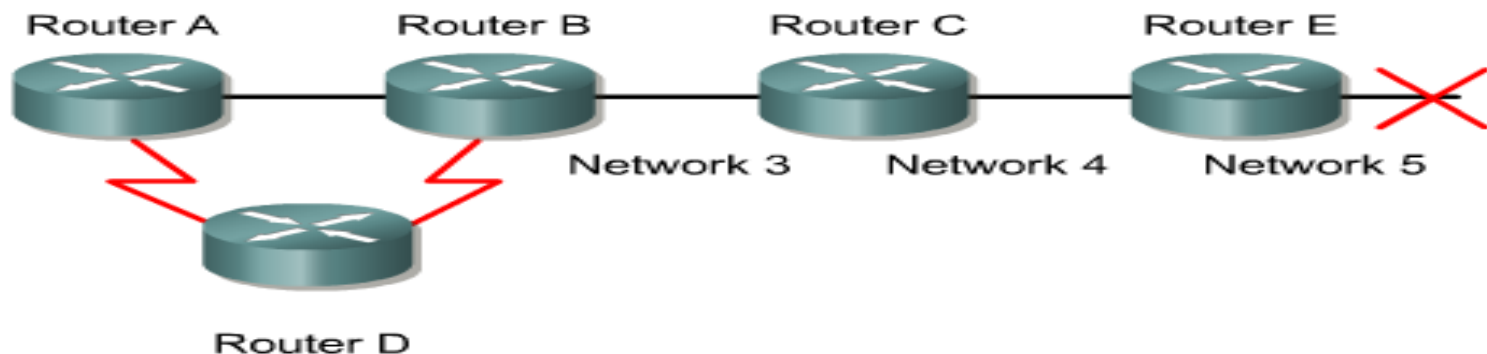
- Specify a maximum distance vector metric as infinity





# Solution: Route Poisoning

- When Network 5 goes down, Router E initiates route poisoning by making a table entry for Network 5 as 16, or unreachable.
- When Router C receives a route poisoning from Router E, it sends an update, called a poison reverse, back to Router E. This makes sure all routers on the segment have received the poisoned route information.



When Network 5 goes down, Router E initiates route poisoning by entering a table entry metric of 16 (unreachable).

	1980	1985	1990	1995	2000	2005	2010	2015	2020
Population	76.5	80.5	84.5	88.5	92.5	96.5	100.0	103.5	107.0
GDP per capita	1,000	1,200	1,400	1,600	1,800	2,000	2,200	2,400	2,600
Life expectancy at birth	65	68	71	74	77	80	83	86	89
Urban population (%)	35	40	45	50	55	60	65	70	75
Employment rate (%)	55	58	61	64	67	70	73	76	79
Unemployment rate (%)	15	12	10	8	7	6	5	4	3
Government expenditure as % of GDP	15	18	21	24	27	30	33	36	39
Private consumption as % of GDP	55	58	61	64	67	70	73	76	79
Investment as % of GDP	10	12	14	16	18	20	22	24	26
Exports as % of GDP	20	22	24	26	28	30	32	34	36
Imports as % of GDP	18	20	22	24	26	28	30	32	34
Current account balance as % of GDP	-2	-1	0	1	2	3	4	5	6
Foreign direct investment as % of GDP	5	6	7	8	9	10	11	12	13
Official development assistance as % of GDP	1	1	1	1	1	1	1	1	1
Research and development as % of GDP	2	2	2	2	2	2	2	2	2
Health expenditure as % of GDP	3	3	3	3	3	3	3	3	3
Educational expenditure as % of GDP	4	4	4	4	4	4	4	4	4
Environmental protection expenditure as % of GDP	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5
Energy consumption per capita	1,000	1,200	1,400	1,600	1,800	2,000	2,200	2,400	2,600
Fossil fuel consumption per capita	800	900	1,000	1,100	1,200	1,300	1,400	1,500	1,600
Renewable energy consumption per capita	200	300	400	500	600	700	800	900	1,000
Air pollution index	50	55	60	65	70	75	80	85	90
Water quality index	60	65	70	75	80	85	90	95	100
Forest cover (%)	30	32	34	36	38	40	42	44	46
Biodiversity index	50	52	54	56	58	60	62	64	66
Social inequality index	30	32	34	36	38	40	42	44	46
Gender inequality index	20	22	24	26	28	30	32	34	36
Human Development Index	0.50	0.55	0.60	0.65	0.70	0.75	0.80	0.85	0.90
Corruption perception index	30	32	34	36	38	40	42	44	46
Trust in government (%)	40	42	44	46	48	50	52	54	56
Civil liberties score	50	52	54	56	58	60	62	64	66
Press freedom index	60	62	64	66	68	70	72	74	76
Internet usage (%)	10	15	20	25	30	35	40	45	50
Mobility index	50	52	54	56	58	60	62	64	66
Quality of life index	60	62	64	66	68	70	72	74	76
Overall well-being index	70	72	74	76	78	80	82	84	86

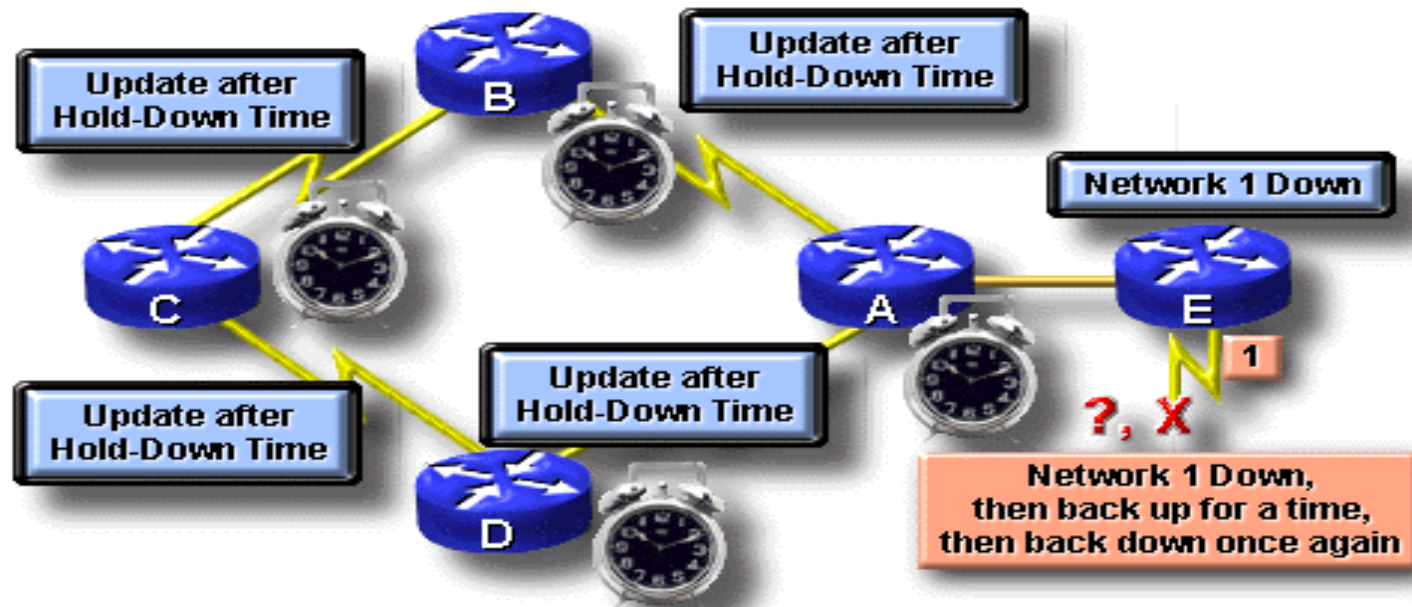






# Solution: Hold-Down Timers

## Solution: Hold-Down Timers



- Routers ignore network update information for some period

# Prevent Sending Route update

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- To prevent an interface from sending out any route update information, use the command:
    - Router(config-router)#Passive-interface f0/0
  - It is valid only when using distance-vector routing protocols, because link-state routing protocols do not get the topology information directly from the routing table of its neighbors
-

# Link-state Protocol

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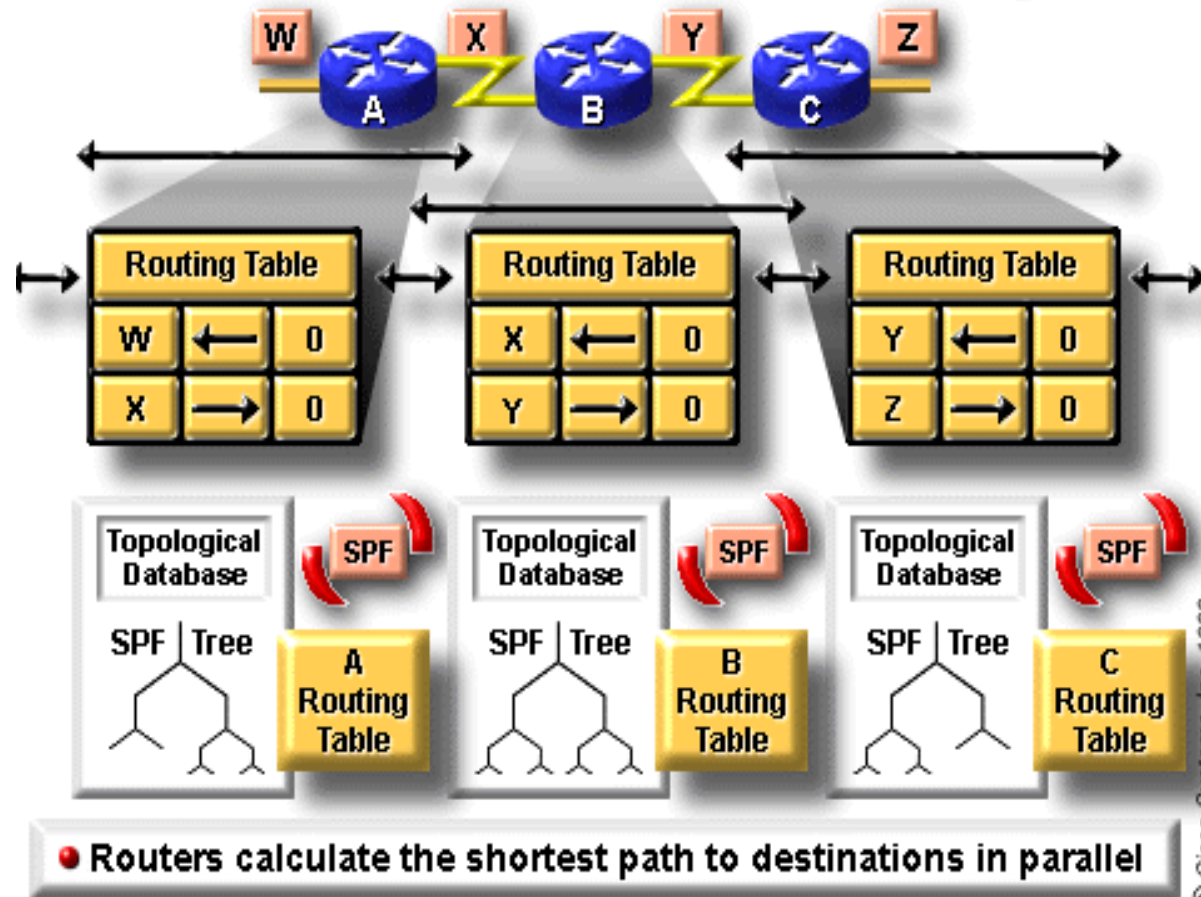
- Link-state based routing algorithms also known as SPF (shortest path first) algorithms, maintain a complex database of topology information.
  - Link-state routing uses:
    - link-state advertisements(LSAs)
    - a topological database
    - the SPF algorithm, and the resulting SPF tree
    - a routing table of paths and ports to each network
  - RFC 1583 contains a description of OSPF link-state concepts and operations.
-

1. Routers **exchange LSAs** with each other. Each router begins with directly connected networks

2. Each router in parallel with the others **constructs a topological database** consisting of all the LSAs from the internetwork.

3. **The SPF algorithm computes network reachability**. The router constructs this logical topology as a tree, with itself as root, consisting of all possible paths to each network in the link-state protocol internetwork. It then sorts these paths shortest path first (SPF).

## Link-State Network Discovery



4. **The router lists its best paths, and the ports to these destination networks, in the routing table.** It also maintains other databases of topology elements and status details.



# Link-state Concerns

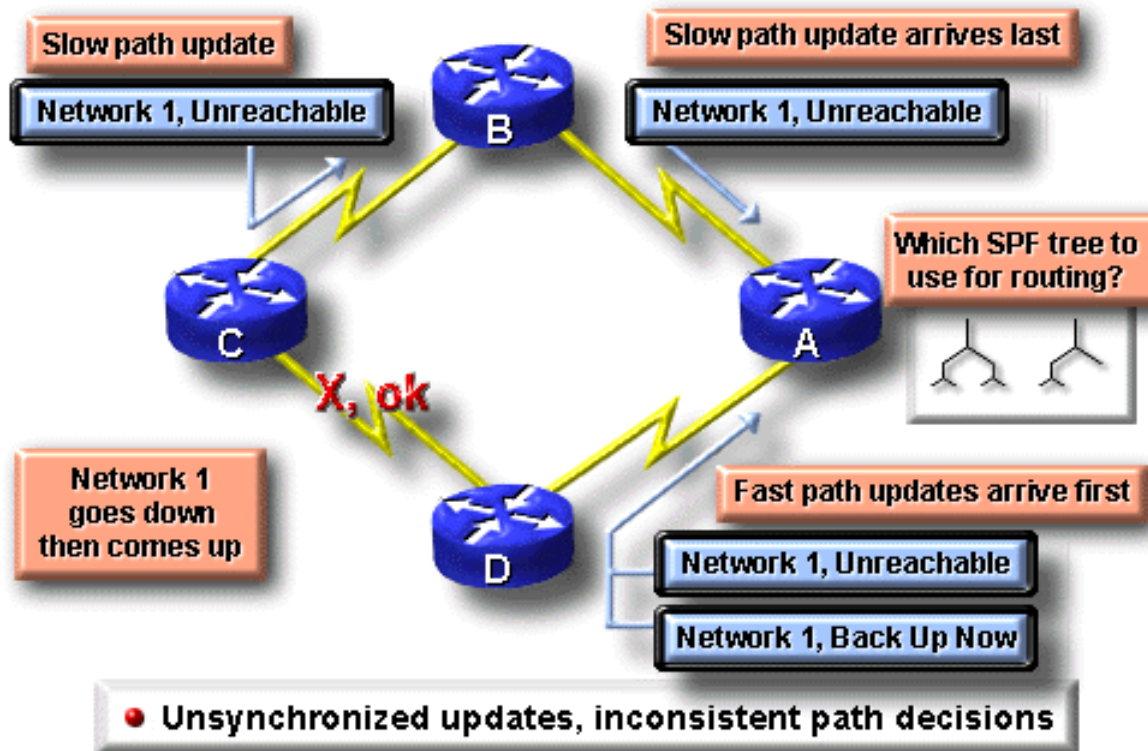
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- **There are two link-state concerns:**
    - **Processing and memory requirements**
      - Running link-state routing protocols in most situations requires that routers use more memory and perform more processing than distance-vector routing protocols.
    - **Bandwidth requirements**
      - During Initial link-state packet flooding, all routers using link-state routing protocols send LSA packets to all other routers. This action floods the internetwork as routers make their demand for bandwidth, and temporarily reduce the bandwidth available for routed traffic that carries user data.
-



# Problem: Link-state Updates

## Problem: Link-State Updates



- Link-state routing must make sure that all routers get all necessary LSA packets.
- Routers with different sets of LSAs calculate routes based on different topological data.

# Comparing: Link-state and Distance-Vector

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Distance-Vector	Link-State
<p>View network topology from neighbor's perspective</p> <p>Adds distance vectors from router to router</p> <p>Frequent, periodic updates: slow convergence</p> <p>Passes copies of routing tables to neighbor routers</p>	<p>Gets common view of entire network topology</p> <p>Calculates the shortest path to other routers</p> <p>Event-triggered updates: faster convergence</p> <p>Passes link-state routing updates to other routers</p>



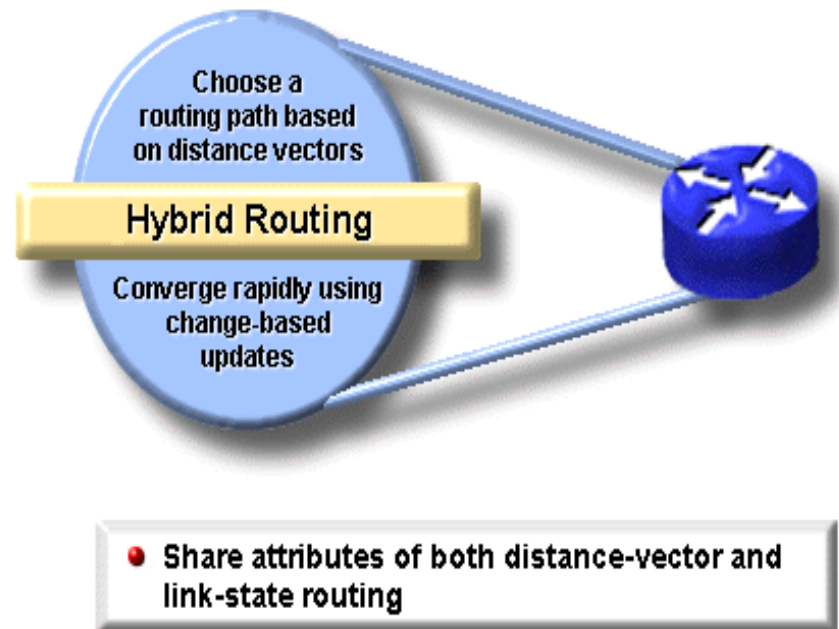


# Hybrid Protocols

## ■ Examples of hybrid protocols:

- OSI's *IS-IS* (*Intermediate System-to-Intermediate System*)
- Cisco's *EIGRP* (*Enhanced Interior Gateway Routing Protocol*).

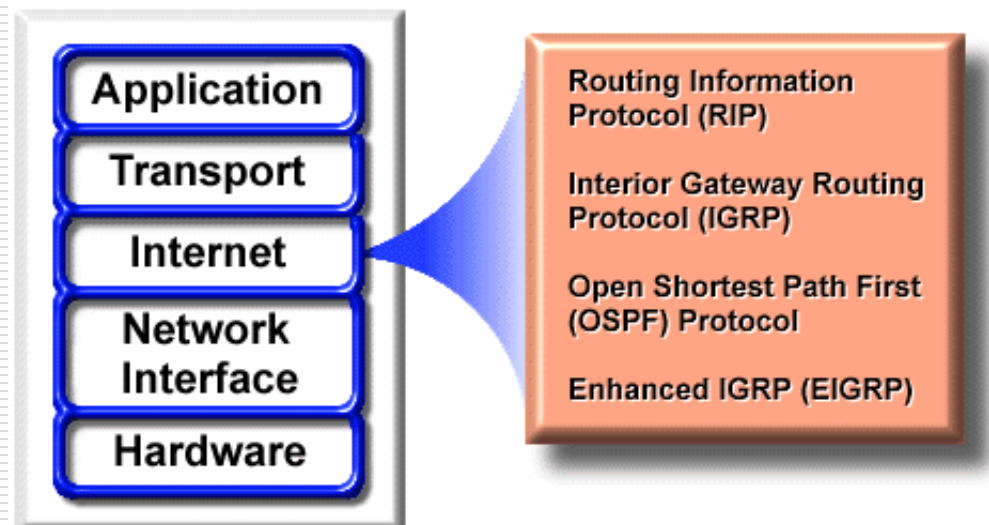
## Hybrid Routing







# Routing Protocols



- **Examples of IP routing protocols include:**
  - **RIP** - a distance-vector routing protocol
  - **IGRP** - Cisco's distance-vector routing protocol
  - **OSPF** - a link-state routing protocol
  - **EIGRP** - a balanced hybrid routing protocol



# Primary Goals of Routing Protocols

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- Optimal Route—pick the best route
  - Efficiency—minimal use of bandwidth and router processor resources
  - Rapid Convergence—the faster, the better. Some are quicker at converging than others.
  - Flexibility—can handle a wide variety of situations such as high usage and failed routes
-

# Dynamic Routing Configuration

Router(config)#

***router protocol [keyword]***

- Defines an IP routing protocol

Router(config-router)#

***network network-number***

- The network subcommand is a mandatory configuration command for each IP routing process

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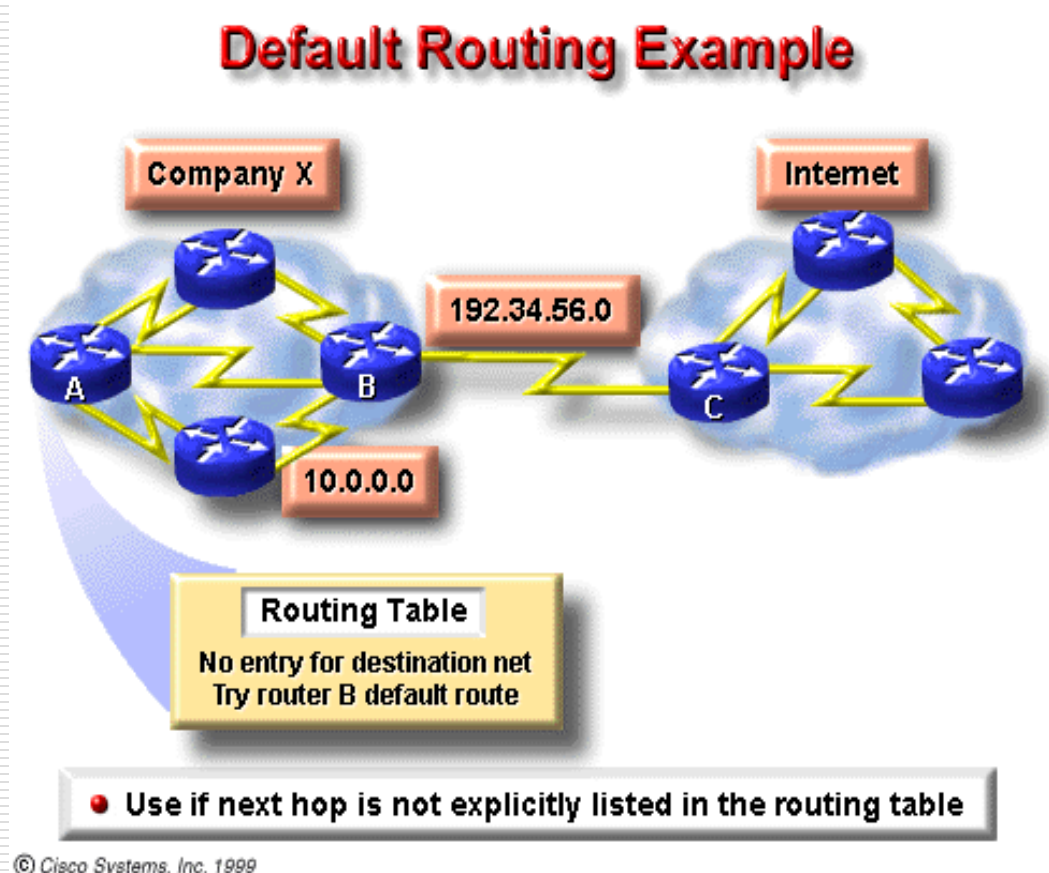
Router Commands	Description
<i>protocol</i>	either RIP, IGRP, OSPF, or Enhanced IGRP.
<i>options</i>	such as autonomous system, which is used with protocols that require it, such as IGRP

Network Command	Description
<b>network-number</b>	specifies a directly-connected network



# Define Default Route

- ❑ Default routes keep routing tables shorter.
- ❑ When an entry for a destination network does not exist in a routing table, the packet is sent to the default network.





# Define Default Route(I)

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- ❑ Define a default route using dynamic routing protocols
- ❑ Router(config)# ip default-network [network-number]

ip default network Command	Description
<i>network-number</i>	IP network number or subnet number defined as the default

---



# Define Default Route(II)

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- ❑ Define a default route as a static route:
  - ❑ Router(config)# ip route 0.0.0.0 0.0.0.0 [next-hop-ip-address| exit-interface]
  - ❑ After configure a default route, use show ip route will display: (172.16.1.2 is the default next-hop address)
    - ❑ Gateway of last resort is 172.16.1.2 to network 0.0.0.0
-

谢谢！