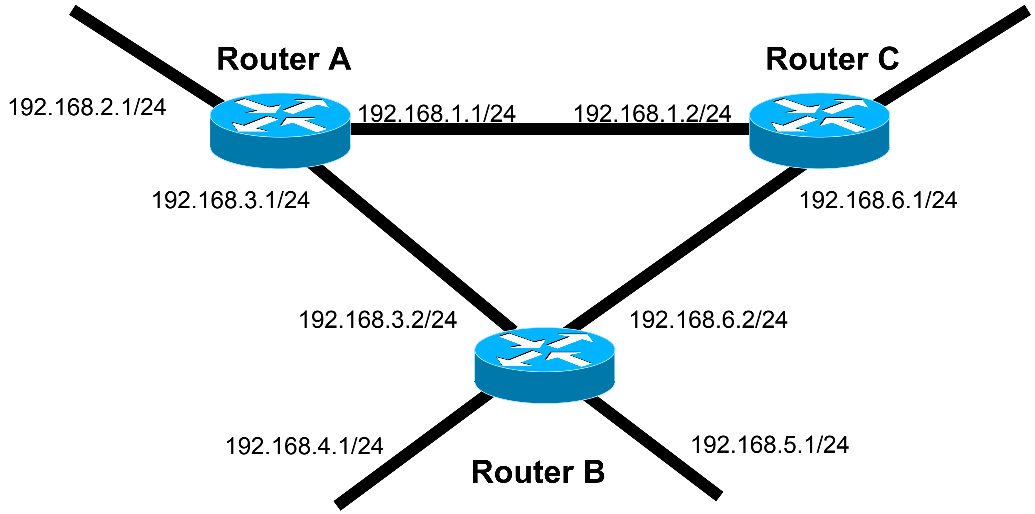
Routing Protocols Fundamental Concepts

This module will help you to learn basic information about routing protocols and issues

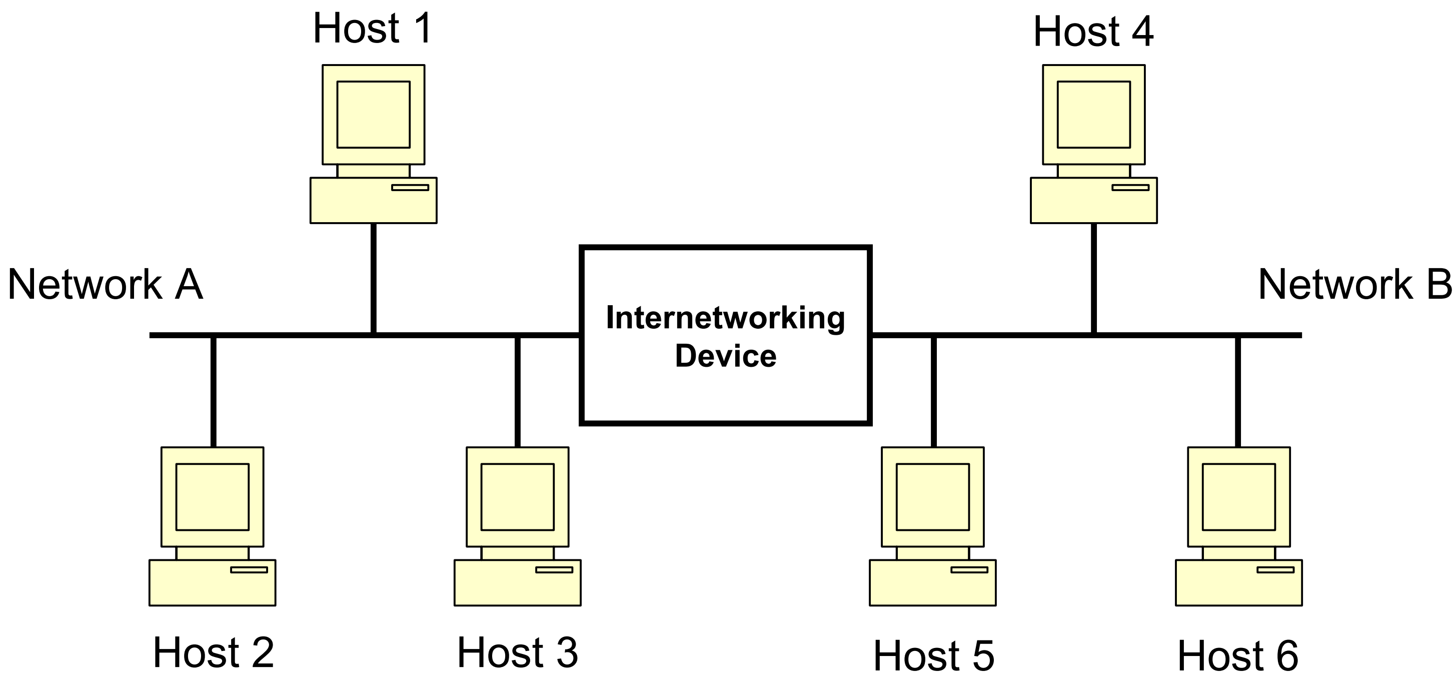


Agenda

- Important Pre-Routing Protocol Concepts
- Routing Protocols Classified
- Important Routing Concepts
- Distance Vector vs. Links State
- Advance Routing Concepts

What is Internetworking?

- internetwork – a collection of interconnected networks



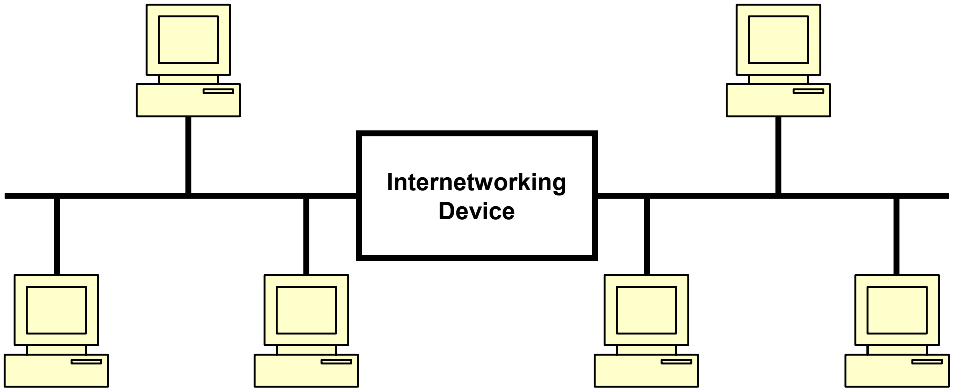
Important Elements of internet

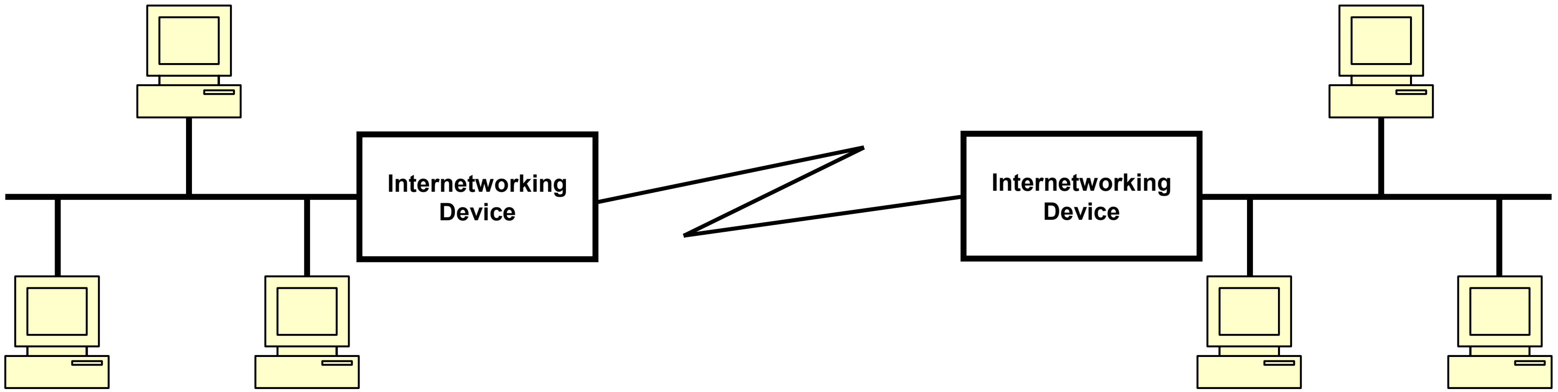
- **Hosts** – devices which attach to networks. Generally computers but may be embedded computers e.g. printers, printer servers, routers, etc.
- **Networks** – entities which provide communication capabilities to hosts
- **Internetworking Device** – a special entity allowing information to travel from one network to another
- **Networking Protocols** – rules of communication between hosts
- **Internetworking Protocols** – special protocols allowing internetworking capabilities

internet vs. Internet

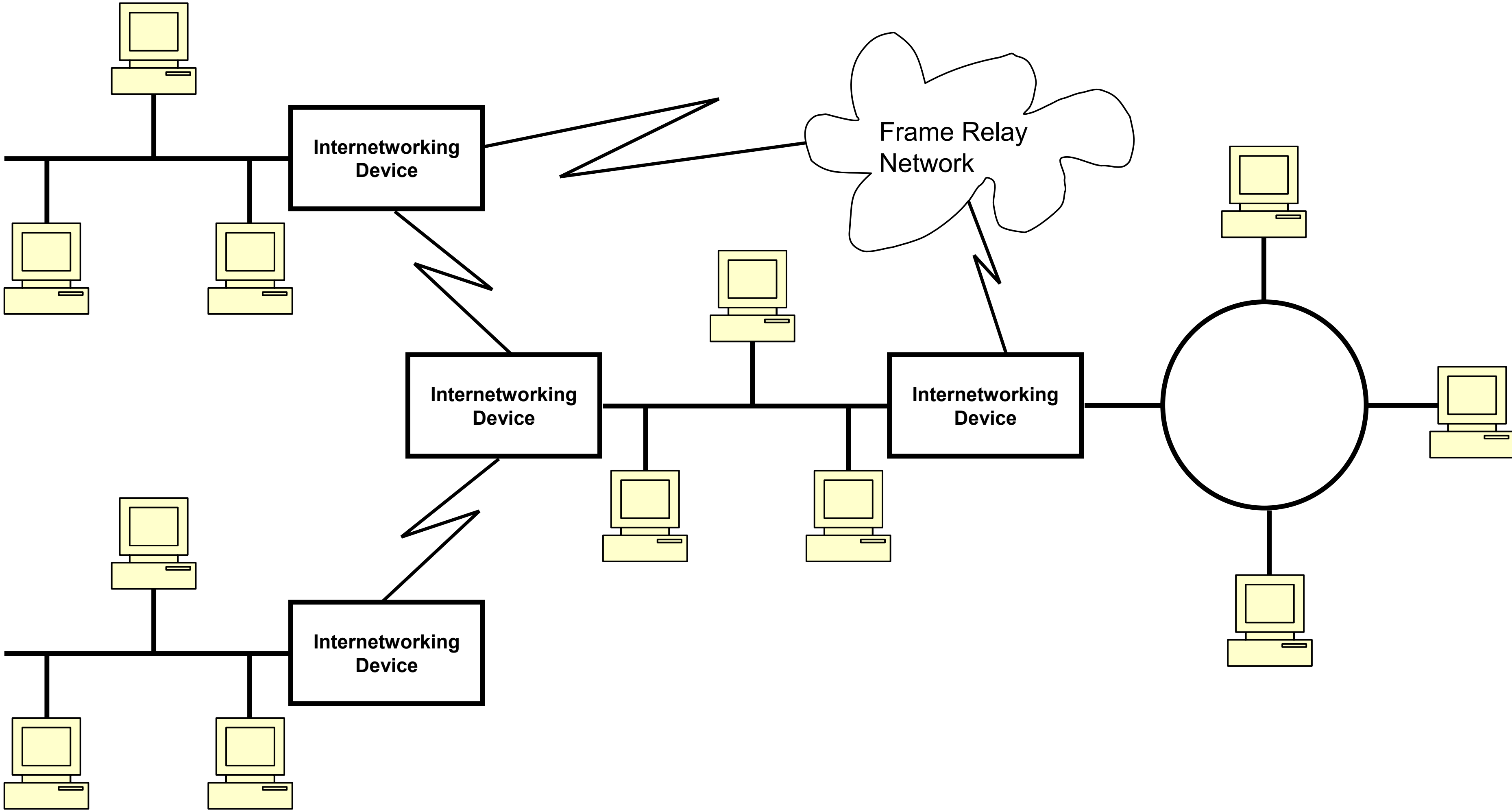
- internetwork – a collection of interconnected networks
- internetwork = internet (a short form)
- internetwork (common noun): any collection/connection of networks
- Internet (proper noun): a particular worldwide collection/connection of networks

Simple vs. Complex Internetwork





Simple vs. Complex Internetwork



Important Pre-Routing Protocol Concepts

- Routed Protocols and Routing Protocols
- MAC Addresses and IP Addresses
- Repeaters, Bridges and Routers
- Routing vs. Switching
- Routing Table
- How IP works on a host?
- Routing vs. Forwarding
- Static vs. Dynamic Routing

Routed Protocols and Routing Protocols

- Routed Protocol
  - Contains L3 Addresses
  - IP, IPX, Appletalk, DECnet, Vines, etc
- Routing Protocol
  - Assists Routed Protocols to do their Job
  - Populates Routing Table
  - Propagates Routing Information
  - RIP, OSPF, IGRP, EIGRP, BGP, IS-IS

MAC Addresses

- MAC addresses are layer 2 addresses
- Why we must have 2 layers and 2 addresses?
- MAC addresses also called:
  - Ethernet Addresses
  - Physical addresses
  - Token Ring addresses
  - FDDI Addresses
- Other examples of layer 2 addresses:
  - Frame Relay DLCI
  - X.25 LCN
  - ATM VPI/VCI
- Protocols which map layer 2 addresses to layer 3 addresses are called address resolution protocols – ARP, InverseARP

IP Addresses

- Layer 3 addresses
- Logical networks – independence from switching technologies and hardware
- 32 bits long (Version 4)
- Dotted decimal notation
- Structured (network.host)
- Classes (A, B, C, D, E)
- Private Addresses
- Subnetting and Subnet Mask (255.255.255.0 and /24)
- VLSM (All subnets are not of the same size)
- Supernetting (to combine Class C's into bigger networks)

Repeater, Bridge and Router

- **Repeater works on Layer 1**
  - Can perform medium conversion
  - Can extend LAN in terms of distance
- **Bridge works on Layer 2 (Bridge == Switch (nowadays))**
  - Can perform medium conversion
  - Can extend LAN in terms of distance and number of segments
  - Can increase LAN capacity by creating separate collision domains
  - Works on MAC addresses
  - Can eliminate loops using a Spanning Tree Protocol
- **Router works on Layer 3**
  - Can perform medium conversion
  - Can extend network in terms of distance and number of segments
  - Can increase network capacity by creating separate broadcast domains
  - Works on Layer 3 addresses
  - Can use better paths and eliminate loops using a routing protocol

Routing Table

- Also known as Route Table or Forwarding Database
- Each route entry contains at least two things
  - A destination address – this is the address of the network the router can reach
  - A pointer to the destination – this pointer will either indicate that the destination network is directly connected or it will indicate the address of another router on a directly connected network. That router, which will be one router hop closer to the destination is a *next hop router*

What does a Routing Table Look Like

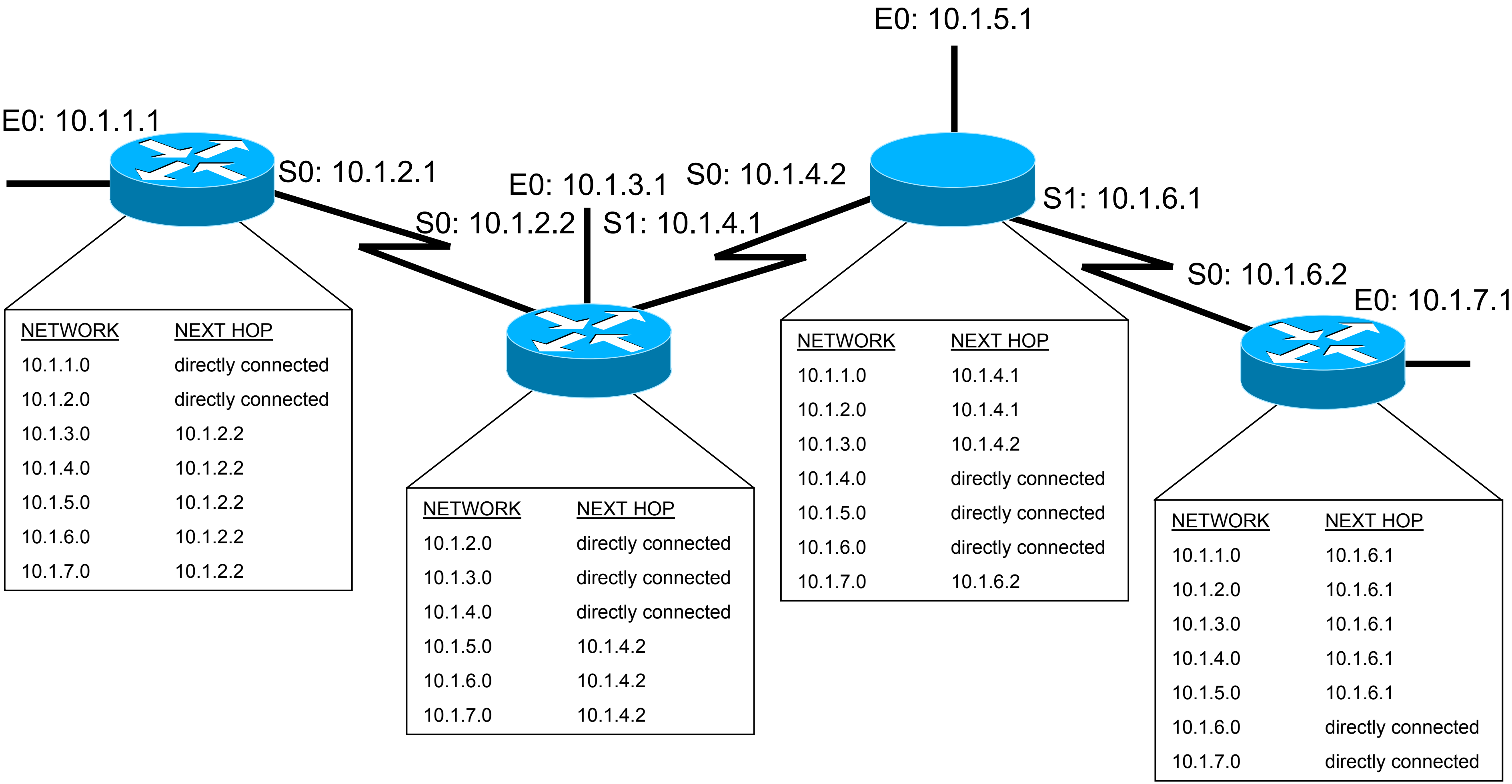
Command Prompt

```
(C) Copyright 1985-1999 Microsoft Corp.

C:\WINNT>route print
===========================================================================
Interface List
0x1 ........................... MS TCP Loopback interface
0x1000003 ...00 03 47 c2 f5 10 ...... Intel(R) PRO Adapter
0x2000004 ...00 53 45 00 00 00 ...... WAN (PPP/SLIP) Interface
===========================================================================
===========================================================================
Active Routes:
Network Destination        Netmask          Gateway       Interface  Metric
          0.0.0.0          0.0.0.0   202.163.118.48  202.163.118.48       1
        127.0.0.0        255.0.0.0        127.0.0.1       127.0.0.1       1
    202.163.97.20  255.255.255.255   202.163.118.48  202.163.118.48       1
   202.163.118.48  255.255.255.255        127.0.0.1       127.0.0.1       1
  202.163.118.255  255.255.255.255   202.163.118.48  202.163.118.48       1
        224.0.0.0        224.0.0.0   202.163.118.48  202.163.118.48       1
  255.255.255.255  255.255.255.255   202.163.118.48         1000003       1
Default Gateway:    202.163.118.48
===========================================================================
Persistent Routes:
  None

C:\WINNT>
```

Route Table Example



NETWORK	NEXT HOP
10.1.1.0	directly connected
10.1.2.0	directly connected
10.1.3.0	10.1.2.2
10.1.4.0	10.1.2.2
10.1.5.0	10.1.2.2
10.1.6.0	10.1.2.2
10.1.7.0	10.1.2.2

NETWORK	NEXT HOP
10.1.2.0	directly connected
10.1.3.0	directly connected
10.1.4.0	directly connected
10.1.5.0	10.1.4.2
10.1.6.0	10.1.4.2
10.1.7.0	10.1.4.2

NETWORK	NEXT HOP
10.1.1.0	10.1.4.1
10.1.2.0	10.1.4.1
10.1.3.0	10.1.4.2
10.1.4.0	directly connected
10.1.5.0	directly connected
10.1.6.0	directly connected
10.1.7.0	10.1.6.2

NETWORK	NEXT HOP
10.1.1.0	10.1.6.1
10.1.2.0	10.1.6.1
10.1.3.0	10.1.6.1
10.1.4.0	10.1.6.1
10.1.5.0	10.1.6.1
10.1.6.0	directly connected
10.1.7.0	directly connected

Basic Routing Table Commands

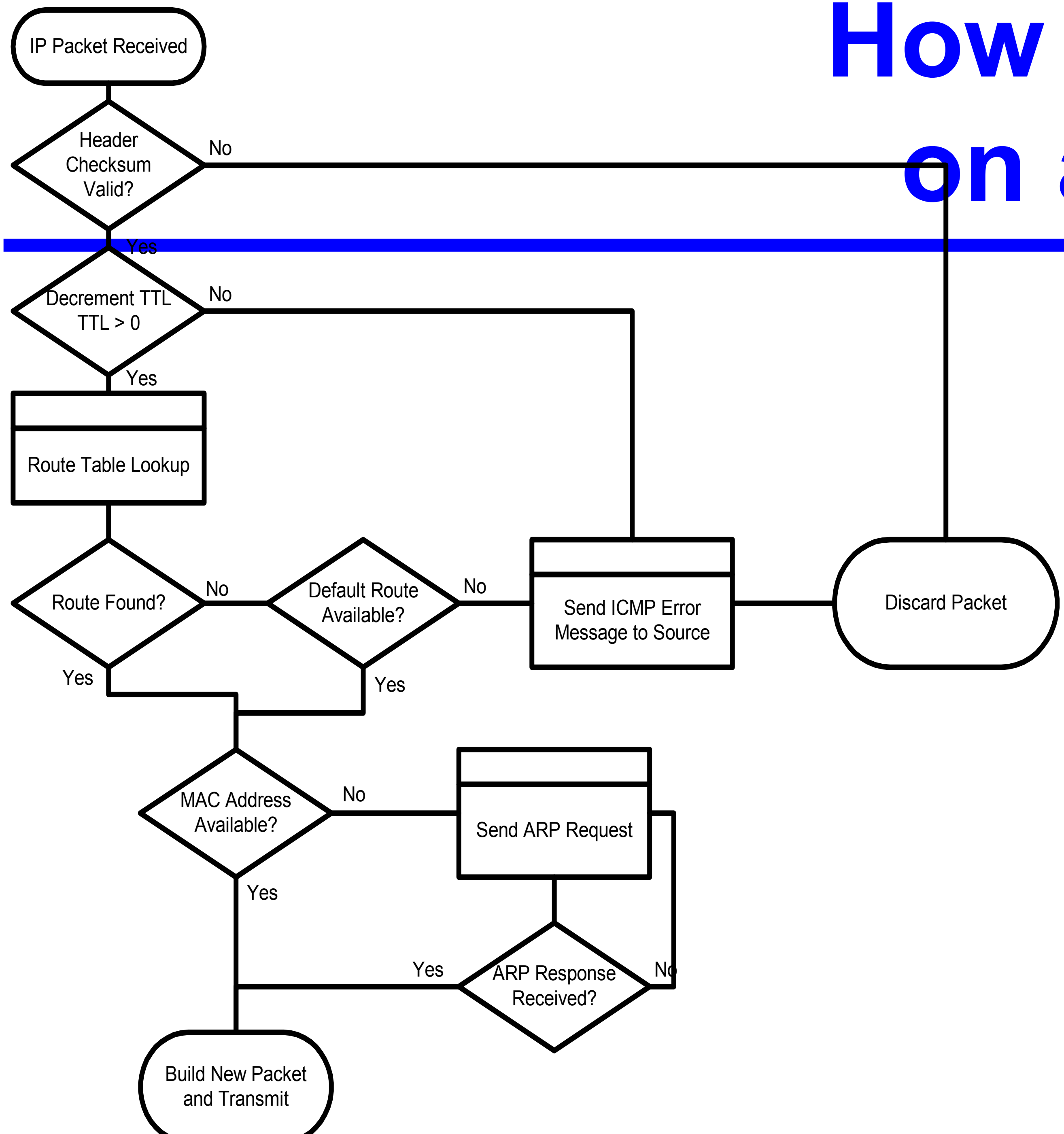
- Linux
  - `route`
- Windows NT/2000/XP
  - `route print`

Routing vs. Switching

- How does routing differ from switching?
  - Switch works on MAC address
  - MAC address is not a true address so you cannot truly route based on MAC addresses
  - Switch is simple ⇒ hardware implementation possible ⇒ switches are fast and economical
  - All ports on a switch must be of the same MAC type
- Which is better?
- Why have both?
- The golden rule of network design:

"Switch where you can, route where you must"

How IP works on a host?



Routing vs. Forwarding

- **Routing** – the process with which the routing table gets updated. May use dynamic routing protocols, static routing, etc. Associates each network entry in the routing table with an outgoing link
- **Forwarding** – the actual act of using the information in the routing table to forward an incoming IP datagram to an outgoing link
- Recent trend in internetworking – let us decouple routing from forwarding
- Why decouple routing from forwarding?
  - High Speed Links demand fastest possible forwarding rates
  - Routing information changes slowly over time

Static vs. Dynamic Routing

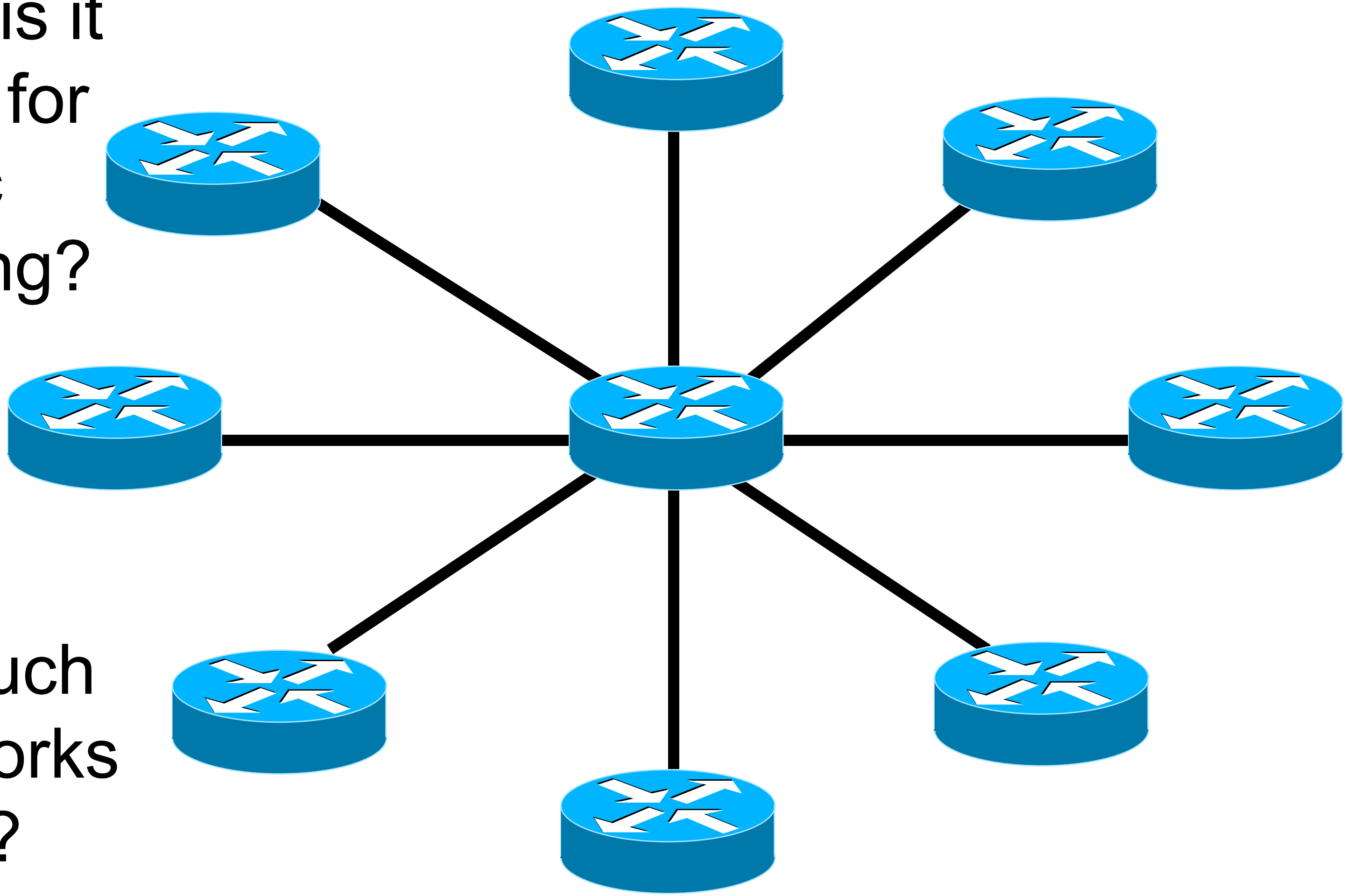
- **Static Routing** – route(s) configured manually, i.e. entered into and removed from, the routing table by a human being or a script
- **Dynamic Routing** – route(s) entered into and removed from the routing table automatically through the activity of a distributed application known as a Routing Protocol e.g. RIP, IGRP, OSPF, BGP
- Do we need static routing? When is static routing better than dynamic routing?
- Which dynamic Routing Protocol should we run?

Static Routing Features

- Performed by humans so much more and precise control
- May be better if the network topology will not change
- Requires reconfiguration if topology of the network changes
- May be required in case of routing protocols which do not support discontiguous subnets
- May work well in small internetworks with few or no alternative routes
- The hub and spoke internetwork is ideal for static routing

The hub and spoke internetwork is ideal for static routing

Why is it ideal for static routing?

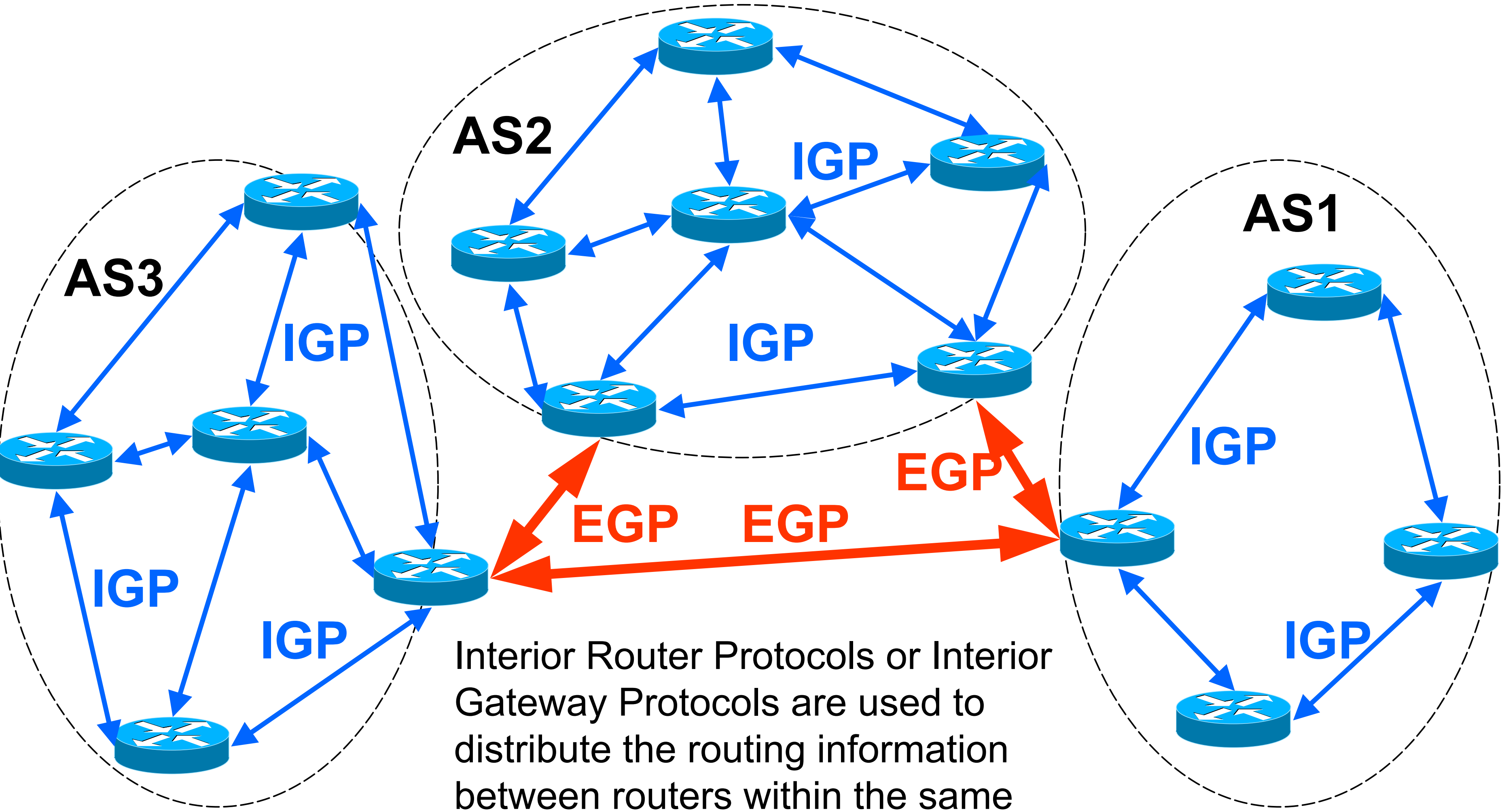


Do such networks exist?

Routing Protocols Classified

- Based on extent of routing information flow
  - Interior Gateway Protocols (IGP)
  - Exterior Gateway Protocols (EGP)
- Based on type of information used for determining routing table
  - Distance Vector Routing Protocols
  - Link State Routing Protocols
- Based on ability to use VLSM and Supernetting
  - Classful Routing Protocols
  - Classless Routing Protocols

IGP vs. EGP

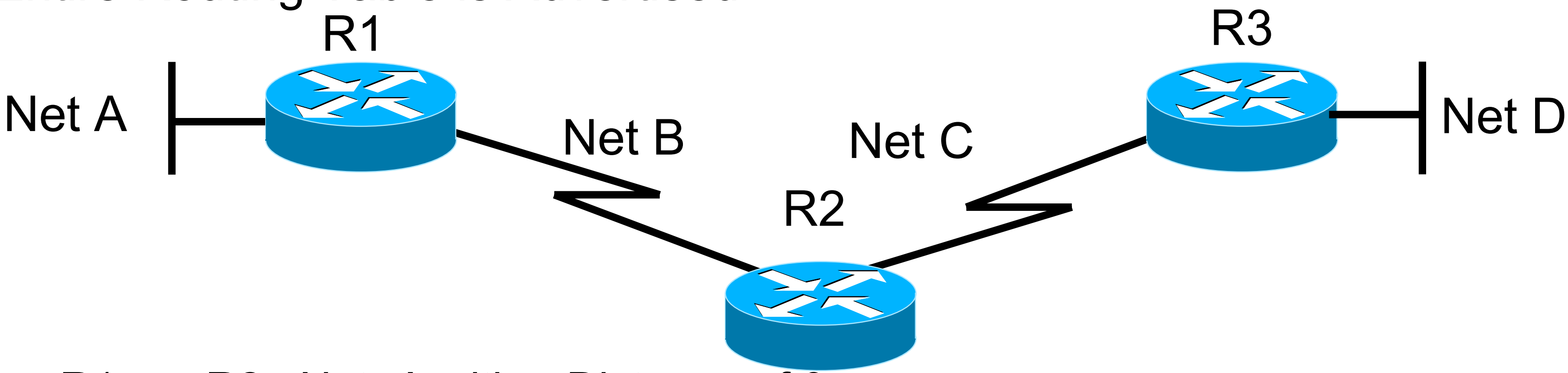


Interior Router Protocols or Interior Gateway Protocols are used to distribute the routing information between routers within the same Autonomous System

Distance-Vector

Distance Vector protocols **advertise the network and their distance** to their network.

Entire Routing Table is Advertised.



R1 = > R2: Net -A with a Distance of 0

R2's Table: Net-A distance of 1
Net-B distance of 0
Net-C distance of 0

R2 = > R3: Net-A with a distance of 1
Net-B distance of 0

R3's Table: Net-A distance of 2, Net-B distance of 1, …...

Each router collects the updates and builds a routing table

Common Characteristics of Distance Vector Routing Protocols

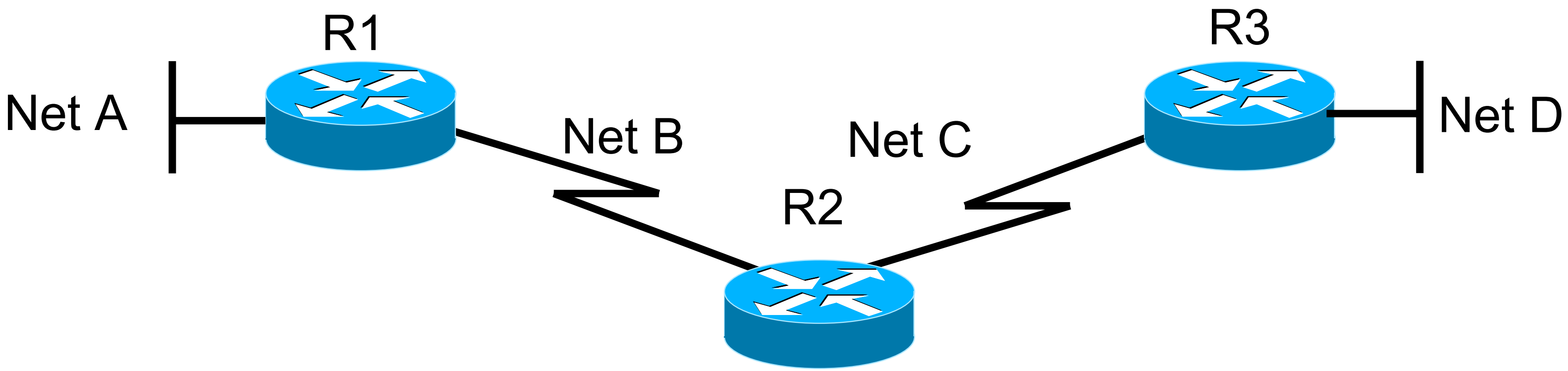
- **Periodic Updates** – period ranges from 10 to 90 seconds (30 seconds for RIP)
- **Neighbors** – routers sharing the same datalink
- **Broadcast updates** – for example to the broadcast IP address 255.255.255.255
- **Full Routing Table Updates** – there are some exceptions

Distance Vector Routing Protocols

- RIP for IP
- XNS RIP
- Novell IPX RIP
- IGRP (Cisco Proprietary)
- DEC DNA Phase IV
- AppleTalk Routing Table Maintenance Protocol (RTMP)

Link State

Link State protocols <u>flood the state of their links</u> **(cost & condition) to their neighbors.**



R1=>R2: Here is the state of my Links (Link state packet (LSP) update**)**

R2=>R3: Here is the state of my links, an here is the state of R1 Links

R3 has a complete picture (LSD) of the State of the Links of the entire Routers in its area. Same goes for R1, & R2.

The Link state database (LSD) **in all the Routers are the same.**

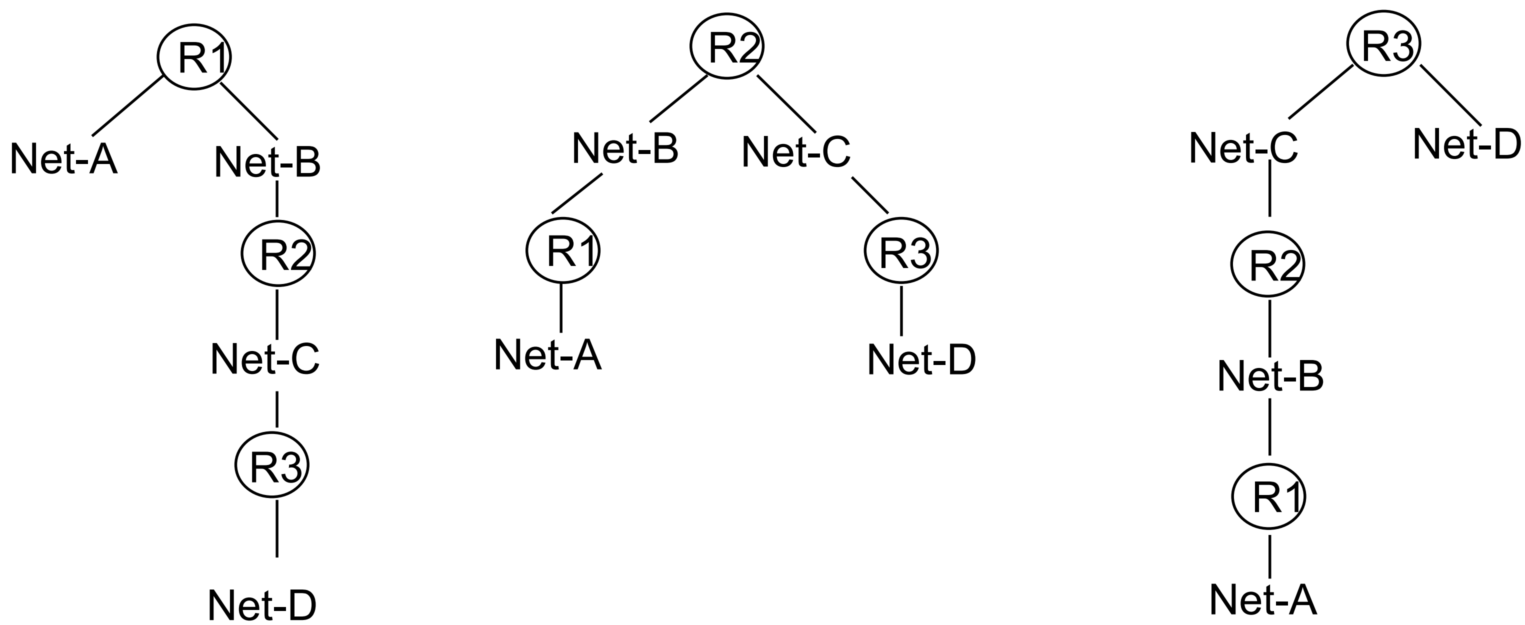
Synchronization ensures same Database

From the Synchronized Link State Database (LSD) of the Entire Area, Each Router builds a unique Shortest Path (SPF) Tree

Link State Algorithm

Synchronized LSD of all the Routers

- SPF Tree for Each Router



From these SPF Tree, each Router then computes their different Routing Tables.

Common Characteristics of Link State Routing Protocols

- **Neighbor Discovery** and formation of Adjacency
- **Link State Flooding** – after the formation of adjacencies
- **Link State Database** – the topological database that stores the LSA’s as series of records
- **SPF Algorithm** – also known as Dijkstra’s Algorithm – used to develop routes from the LSD
- **Areas** – a subset of routers that makeup the internetwork. Routers within an area share an identical Link State Database

Link State Routing Protocols

- Internet's OSPF
- Novell's NLSP
- ISO's IS-IS
- ATM's PNNI

Which is better Distance Vector or Link State

- Distance Vector
  - Routing by Rumor
  - Road Sign Analogy
  - Susceptible to routing loops
  - Long Reconvergence time
  - Simple
  - Consume less resources on the routers
  - Chatty
- Link State
  - Road Map Analogy
  - Scalable
  - Converge fast
  - Consume more resources on the router
  - Quiet
  - New technology

Classful vs Classless Routing Protocols

- **Classful** - Classful protocols do NOT include any subnet mask information in their advertisements.
  - All networks are summarized on major net boundaries
  - All members of local network are assumed to have the same mask as “my” interface (No VLSM)
  - Assume to know all subnets that exist for major networks that I am connected to.
- **Classless**
  - Subnet mask information included in updates
  - Supports Supernets

Routing Protocols Classified

	Distance Vector	Link State
Classfull	RIP, IGRP	
Classless	RIPv2, EIGRP	OSPF, IS-IS, NLSP

Important Routing Concepts

- Route Summarization
- Default Routing
- Alternate Routing
- Administrative Distance
- Routing Loops
- Autonomous System
- Metrics
- Convergence

Route Summarization

- What is route summarization?
  - 10.1.1.0/24 and 10.1.2.0/24 can be written as 10.1.0.0/23
- How does route summarization help?
  - Decreases the size of the routing table
  - Faster lookup and forwarding made possible

Default Routing

- What is a default route?
- Route to 0.0.0.0
- Also known as Gateway of last resort
- For hosts generally this is the best option
- Routers should also have it
- Not a must to have a default route

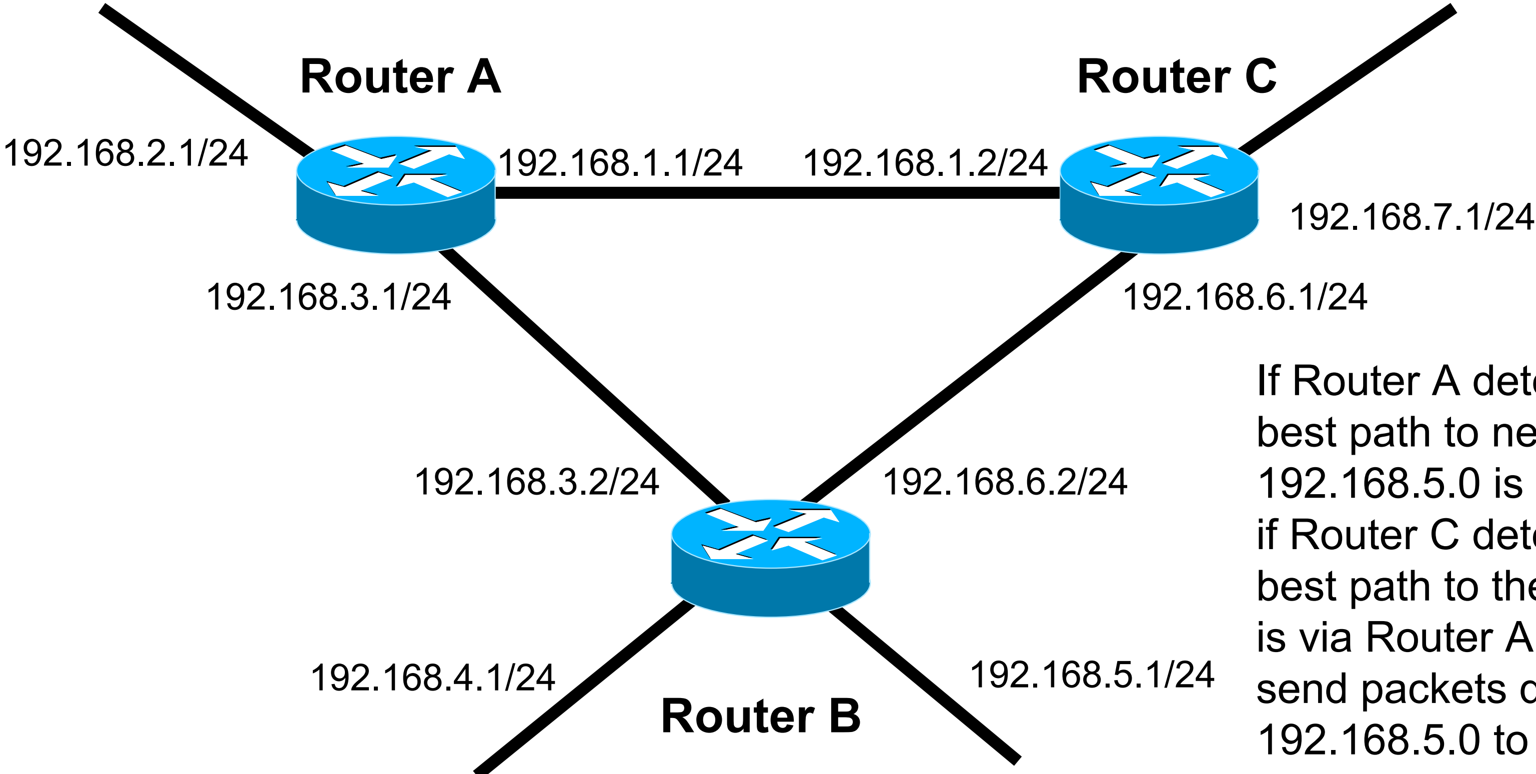
Alternate Routing

- Multiple routes to the same destination
- All routing protocols support equal cost load balancing
- IGRP/EIGRP also supports unequal cost load balancing

Administrative Distance

- A measure of preference for a source of routing information
- Some typical administrative distances
  - Directly connected - 0
  - Static – 1 (next hop router), - 0 (exit interface)
  - RIP (V1 and V2) – 120
  - OSPF – 110
  - IGRP – 100
  - BGP – ?

Routing Loops



If Router A determines that the best path to network 192.168.5.0 is via Router C and if Router C determines that the best path to the same network is via Router A, Router A will send packets destined for 192.168.5.0 to C, C will send them back to A, A will again send them to C, and so on. This continuous circling of traffic between two or more destinations is referred to as a routing loop.

Autonomous System

- **Old Definition**
  - A group of routers under a common administrative domain running a common routing protocol
- **New Definition**
  - An internetwork under a common administration
- Benefits of Autonomous Systems
  - Control over the flow of routing information

Metrics

- A metric is a variable assigned to routes as a means of ranking them from the best to the worst or from the most preferred to the least preferred
- Different routing protocols use different, and sometimes multiple metrics
- Factors affecting metric
  - Hop Count
  - Bandwidth
  - Load
  - Delay
  - Reliability
  - Cost

More About Metrics

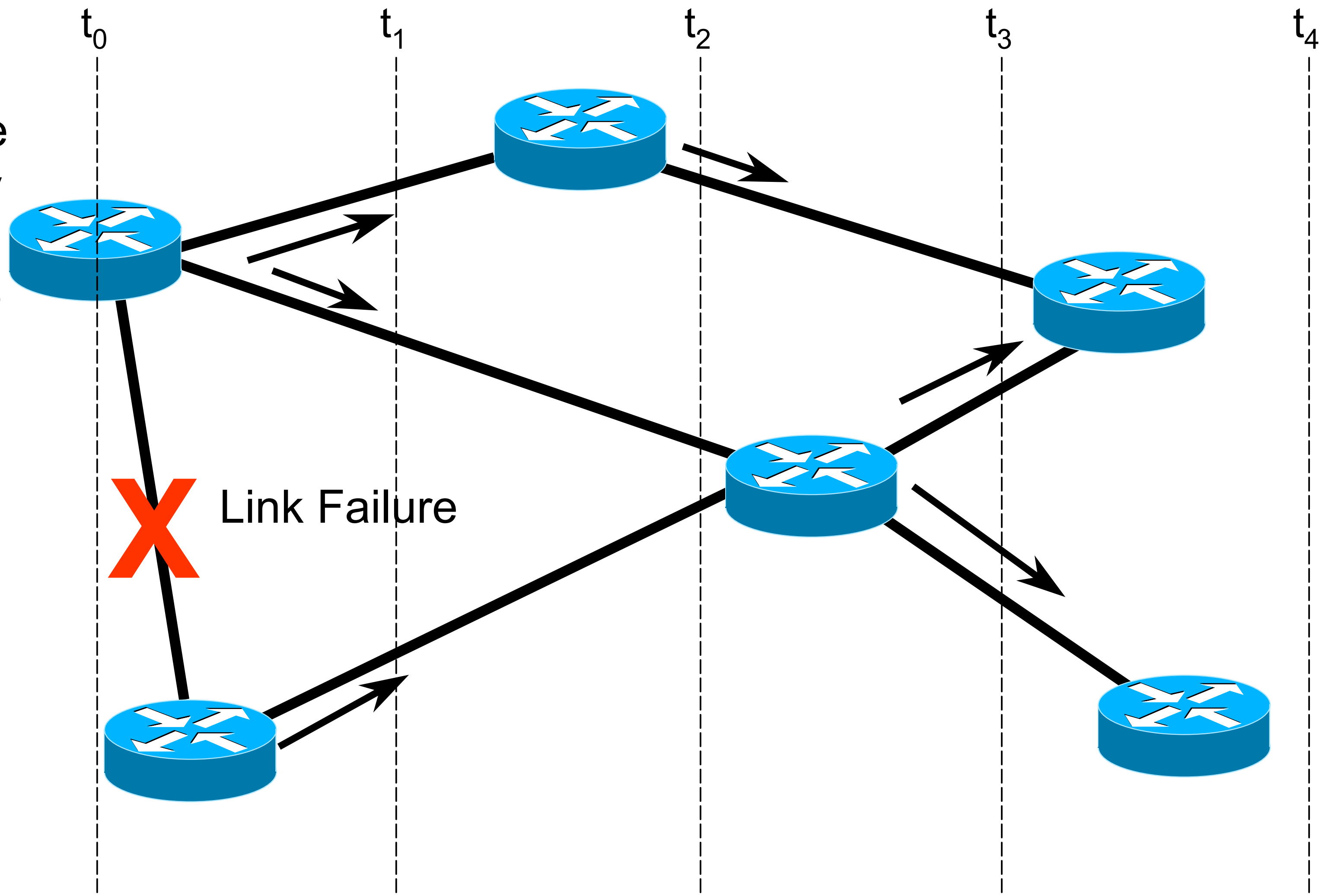
- Simple Metric – uses just one factor, e.g. hop-count
- Composite Metric – uses multiple factors
- References used for Metrics
  - Reference Bandwidth
  - Hop Count Limit

Convergence

- The reachability information in the routing tables of all the routers in the internetwork must be consistent
- The process of bringing all the routing tables to a state of consistency is called *convergence*
- The time it takes to share information across an internetwork and for all routers to calculate the best paths is *convergence time*

Reconvergence takes time

Reconvergence after a topology change takes time. While the internetwork is in an unconverged state, routers are susceptible to bad routing information.



Convergence Steps

- Convergence involves four primary activities (in distance vector routing protocols):
- **Update** – send out or receive new information periodically
- **Invalid** – if an update for a route is not heard within this time then mark the route as unreachable, usually this is equal to six time the update period
- **Holddown** – an update with a hop count higher than the metric recorded in routing table will cause the route to go into holddown for three update periods
- **Flush** – after 60 seconds of the expiration of the invalid timer flush the route entry from the routing table