Chapter 3
Internetworking

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Agenda

Chapter 3. Internetworking

3.1 Switching and Bridging
VCI, bridge (STP)

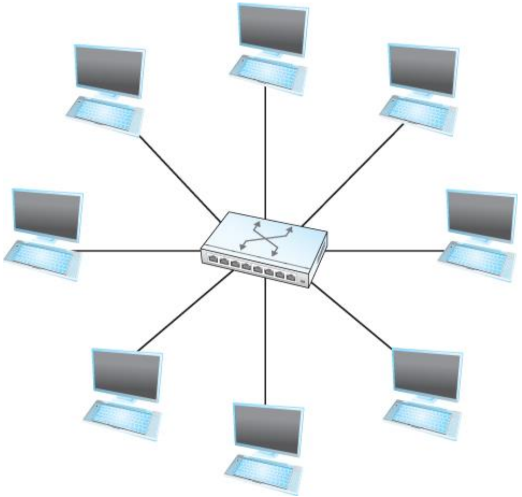
3.2 Basic Internetworking
Class IP, Subneting, ARP, DHCP, ICMP

3.3 Routing
Routing, Distance Vector, Link State

Switching and Forwarding

SWITCH

- A mechanism that allows us to interconnect links to form a large network.
- A multi-input, multi-output device which transfers packets from an input to one or more outputs.
- Every host on a switched network has its own link to the switch.
- A switch's primary job is to receive incoming packets on one of its links and to transmit them on some other link



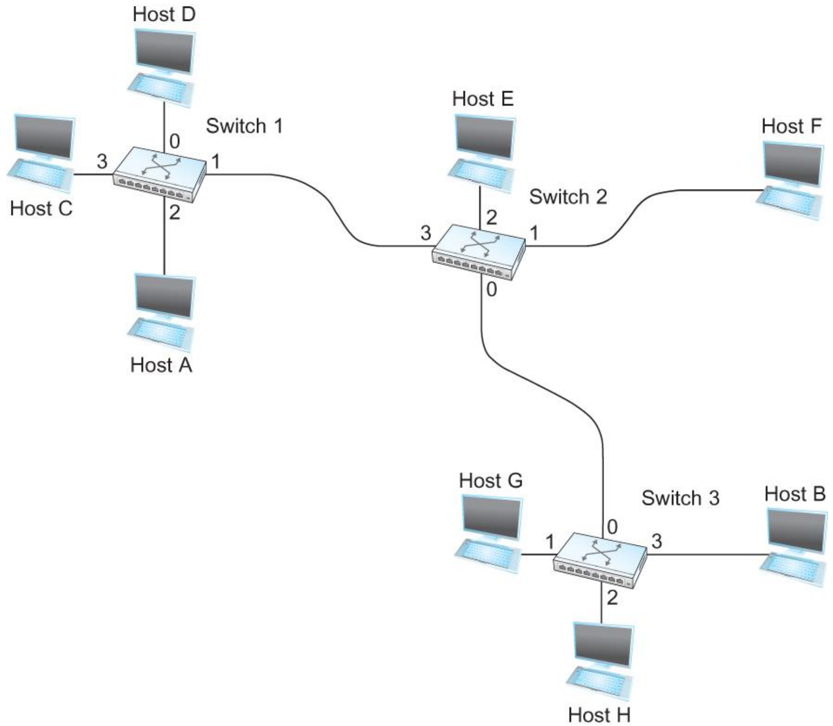
Switching and Forwarding

- How does the switch decide which output port to place each packet on?

- It looks at the header of the packet for an identifier that it uses to make the decision
- Two common approaches
  a) **Datagram** or Connectionless Approach.
  b) **Virtual circuit** or Connection-oriented Approach.
- A third approach **source routing** is less common.

a. Datagram Approach

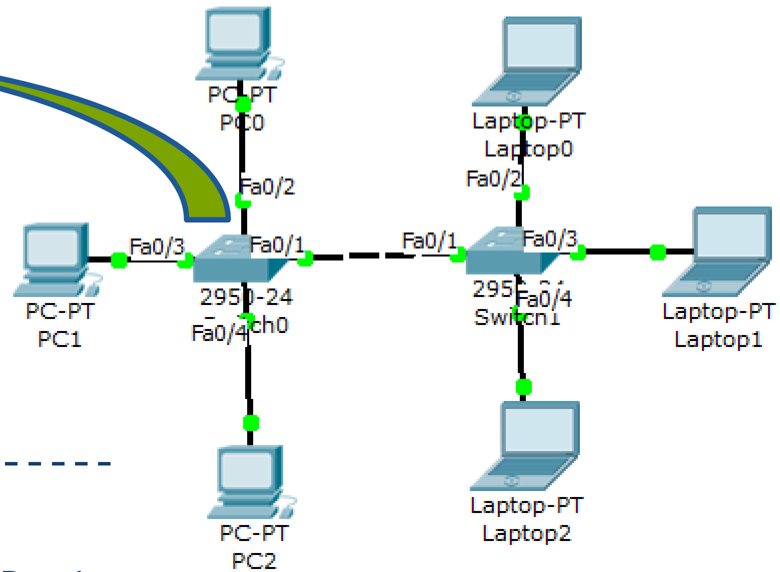
- Every packet contains enough information to enable any switch to decide how to get it to destination
- To decide how to forward a packet, a switch consults a *forwarding table* (sometimes called a *routing table*)



Destination	Port
A	3
B	0
C	3
D	3
E	2
F	1
G	0
H	0

Forwarding Table for Switch 2

MAC Add Table in CISCO



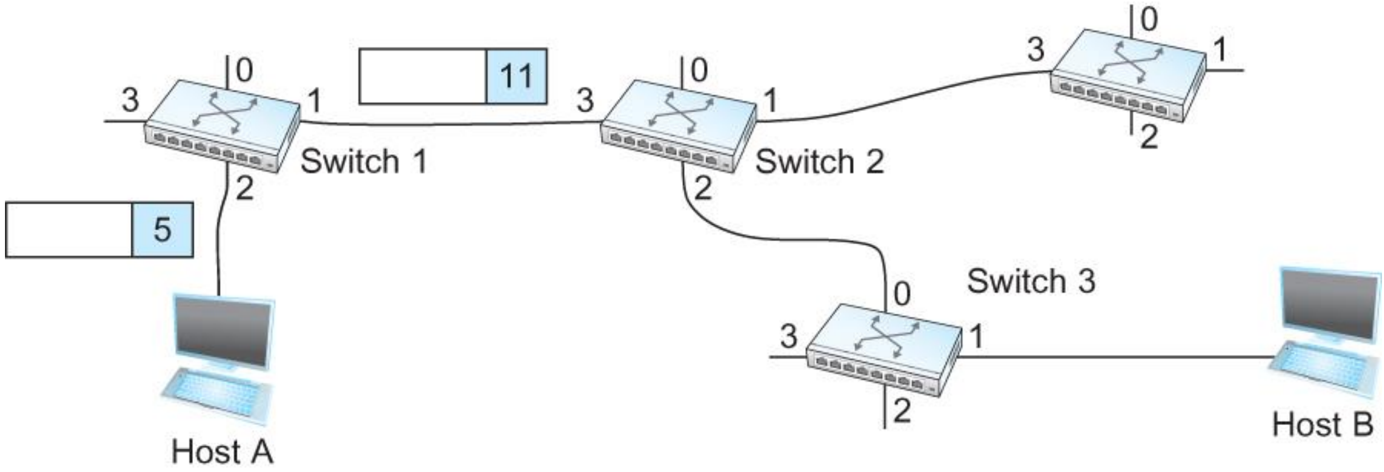

```
GBS_SW#sh mac-address-table

          Mac Address Table
-------------------------------------------

Vlan    Mac Address       Type        Ports
----    -----------       --------    -----

   1    0009.7cba.c915    DYNAMIC     Fa0/1
   1    000b.be7a.69bc    DYNAMIC     Fa0/3
   1    0030.a368.e65a    DYNAMIC     Fa0/1
   1    0060.2f58.3453    DYNAMIC     Fa0/4
   1    0060.5c94.ee01    DYNAMIC     Fa0/1
   1    0060.7083.2b34    DYNAMIC     Fa0/1
   1    00e0.a3bc.03a8    DYNAMIC     Fa0/2
GBS_SW#
```

Which CLIENT...?

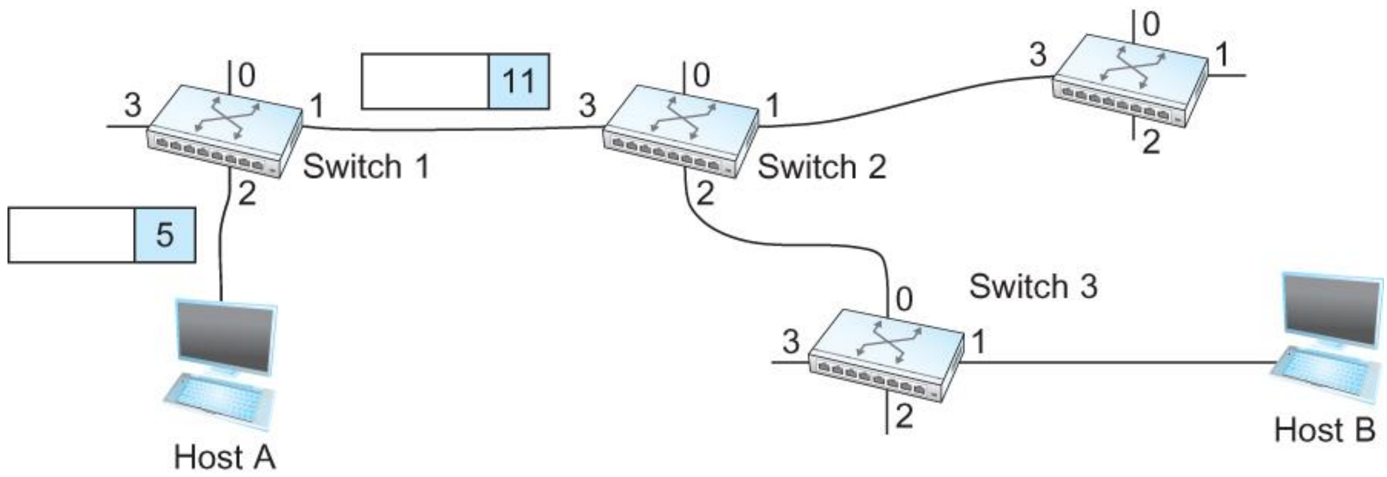
b. Virtual-Circuit Approach

Virtual Circuit Switching

- Widely used technique for Packet Switching
- Uses the concept of *Virtual Circuit* (VC)
- Also called *a connection-oriented model*
- First set up a virtual connection from the source host to the destination host and then send the data



VCI



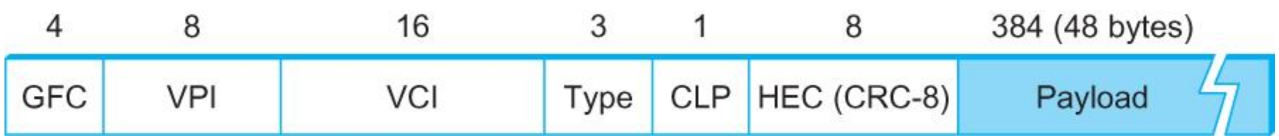
	In Int	In VCI	Out Int	Out VCI
SW-1	2	5	1	11
SW-2	3	11	2	7
SW-3	0	7	1	4

Switching and Forwarding

- Comparison with the **Datagram Model**
  - Datagram network has no connection establishment phase and each switch processes each packet independently
  - Each arriving packet competes with all other packets for buffer space
  - If there are no buffers, the incoming packet must be dropped
- In **VC**, we could imagine providing each circuit with a different quality of service (QoS)
  - The network gives the user some kind of performance related guarantee
- Most popular examples of VC technologies are Frame Relay and ATM
  - One of the applications of Frame Relay is *the construction of VPN*

Switching and Forwarding

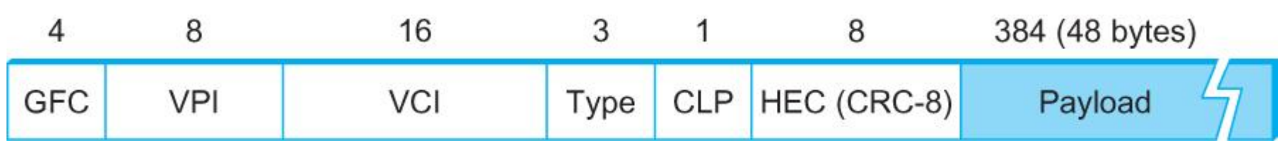
- *ATM (Asynchronous Transfer Mode)*



- Connection-oriented packet-switched network
- Packets are called cells
  - 5 byte header + 48 byte payload
- Fixed length packets are easier to switch in hardware
  - Simpler to design
  - Enables parallelism

Switching and Forwarding

- ATM
  - User-Network Interface (UNI)
    - Host-to-switch format
    - GFC: Generic Flow Control
    - VCI: Virtual Circuit Identifier
    - Type: management, congestion control
    - CLP: Cell Loss Priority
    - HEC: Header Error Check (CRC-8)

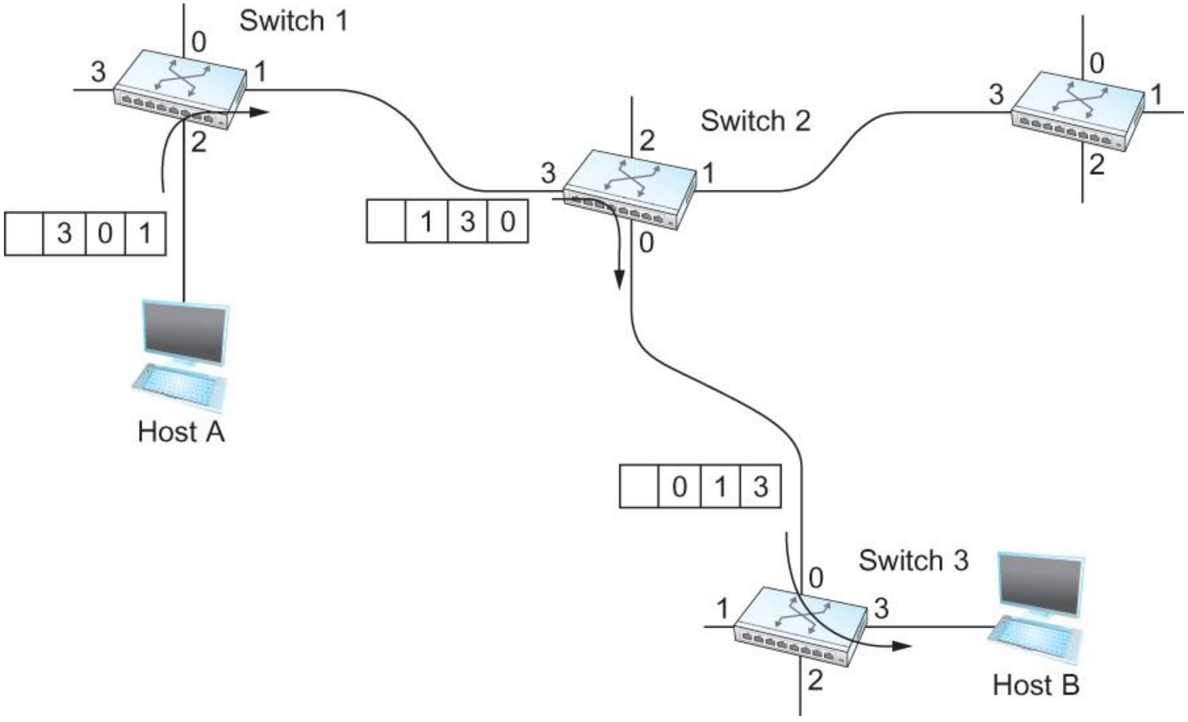


  - Network-Network Interface (NNI)
    - Switch-to-switch format
    - GFC becomes part of VPI field

c. Source Routing

Source Routing

- All the information about network topology that is required to switch a packet across the network is provided by the source host



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Bridges and LAN Switches

- Class of switches that is used to forward packets between shared-media LANs such as Ethernets
  - ✓ Known as **LAN switches**
  - ✓ Referred to as **Bridges**

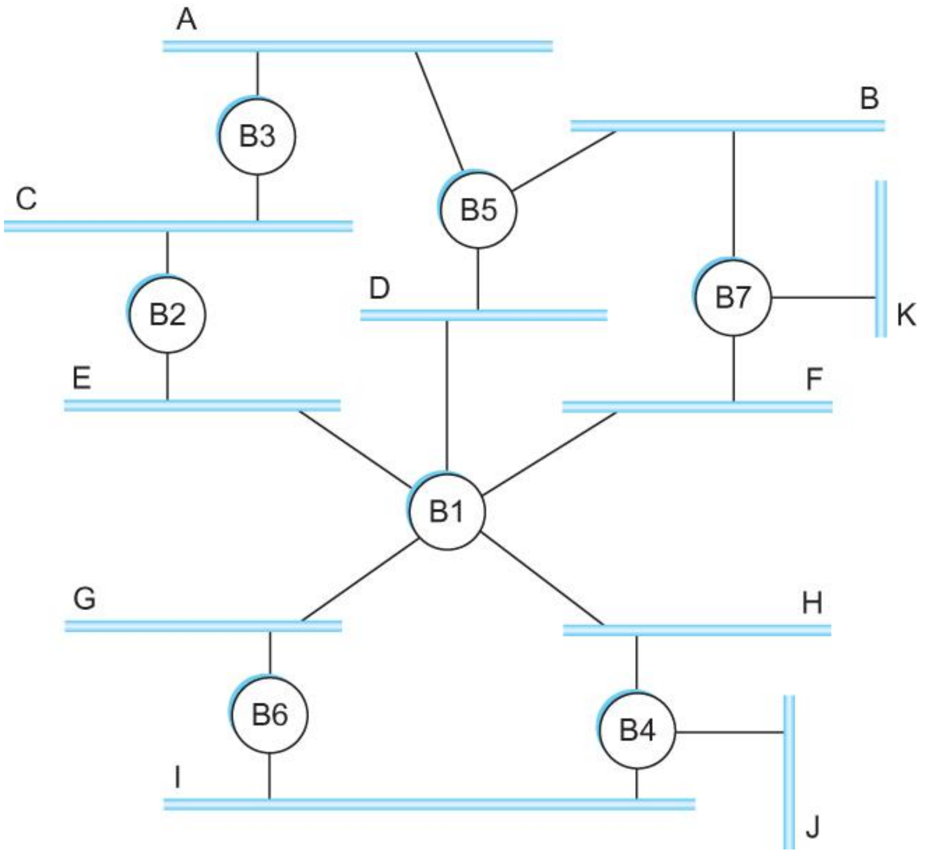
- Suppose you have a pair of Ethernets that you want to interconnect
  - One approach is put a **repeater** in between them
  - An alternative would be to put a node between the two Ethernets and have the node forward frames from one Ethernet to the other
    - This node is called a **Bridge**
    - A collection of LANs connected by one or more bridges is usually said *to form an Extended LAN*

Bridges and LAN Switches

- Strategy works fine **if** the extended LAN does **not have a loop** in it

- Why?
  - Frames potentially loop through the extended LAN forever

✓ B1, B4, and B6
✓ B1, B2, B3, and B5
✓ B1, B5, and B7



Bridges and LAN Switches

- How does an extended LAN come to have a loop in it?

  1) Network is managed by more than one administrator
     - For example, it spans multiple departments in an organization
  2) Loops are built into the network to provide redundancy in case of failures

- Solution :

  Spanning Tree Algorithm

  Switch with ***Spanning Tree Protocol (STP)***

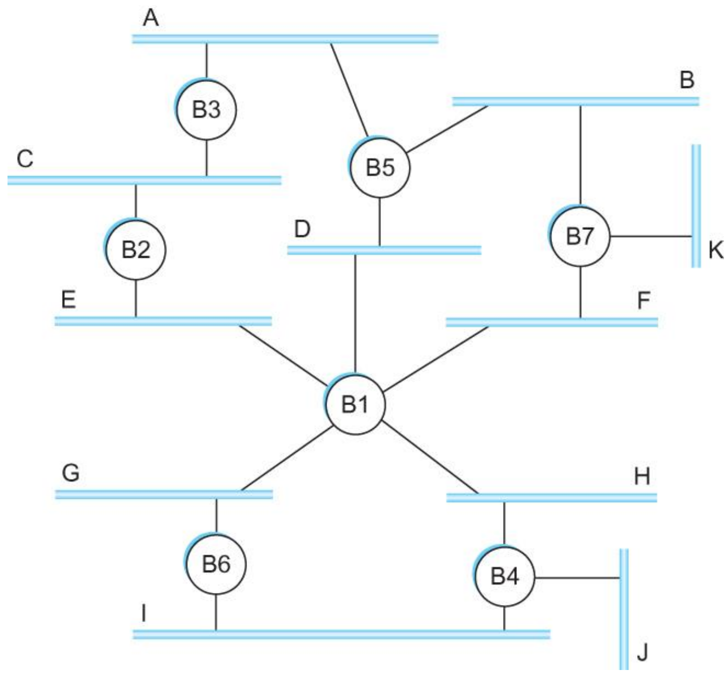
Spanning Tree Algorithm

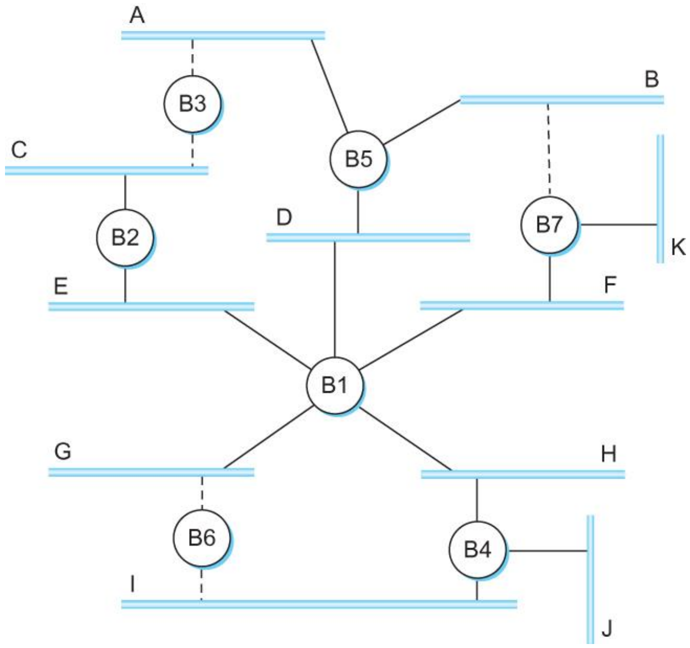
Algorithm selects ports as follows:

1) Each bridge has a unique identifier
2) Elect the bridge with the smallest id as **The Root** of the spanning tree
3) The root bridge always forwards frames out over all of its ports
4) Each bridge computes the *shortest path* to the root and notes which of its ports is on this path
5) Finally, all the bridges connected to a given LAN elect a single *designated bridge* that will be responsible for forwarding
6) Each LAN's designated bridge is the one that is *closest* to the root
7) If two or more bridges are equally close to the root, *smallest id*
8) Each bridge is connected to more than one LAN

Spanning Tree Algorithm

- B1 is the root bridge
- B3 and B5 are connected to LAN A, but B5 is the designated bridge
- B5 and B7 are connected to LAN B, but B5 is the designated bridge





Spanning Tree Algorithm

- Even after the system has stabilized, the root bridge continues to send configuration messages periodically
  - Other bridges continue to forward these messages

- When a bridge fails, the downstream bridges will not receive the configuration messages

- After waiting a specified period of time, they will once again claim to be the root and the algorithm starts again

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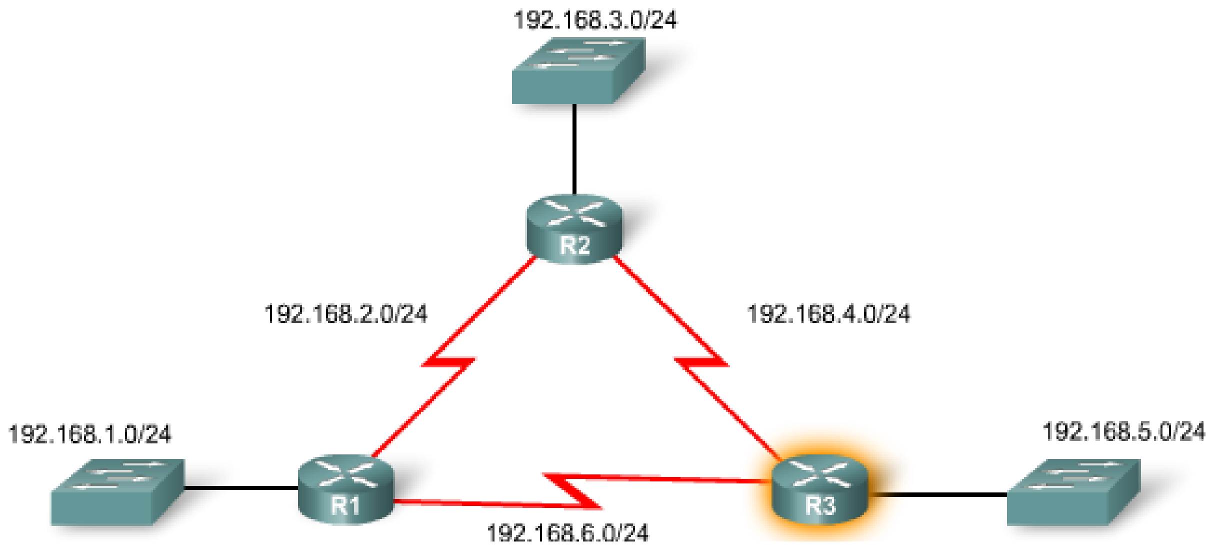
Internetworking



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Internetworking...

is An arbitrary collection of networks interconnected (IP) to provide some sort of host-host to packet delivery service.

Assigning Addresses

Describe the process for requesting IP public addresses, the role ISPs play in the process, and the role of the regional agencies that manage IP address registries

Global	**IANA**				
Regional Internet Registries	**AfriNIC** Africa Region	**APNIC** Asia/ Pacific Region	**LACNIC** Latin America And Caribbean Region	**ARIN** North America Region	**RIPE NCC** Europe, Middle East, Central Asia Region

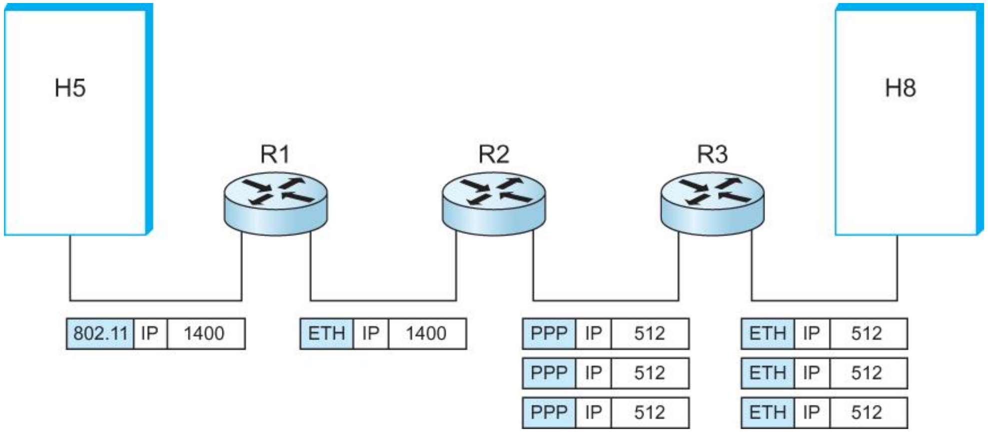
Internet Protocols

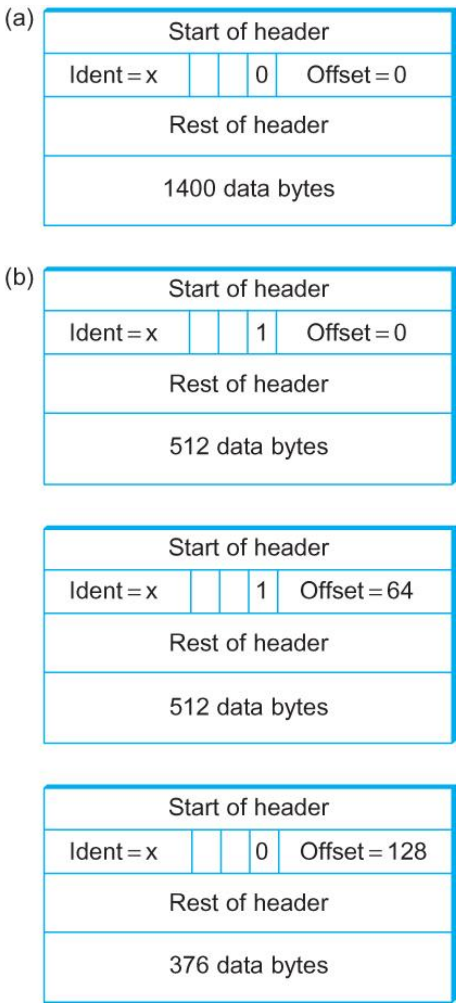
- What is IP
  - IP stands for Internet Protocol
  - Key tool used today to build scalable, heterogeneous internetworks
  - It runs on all the nodes in a collection of networks and defines the infrastructure that allows these nodes and networks to function as a single logical internetwork
- Internet Protocols
  - IPv4
  - IPv6 (*wait... chapter 4*)

IP Fragmentation & Reassembly

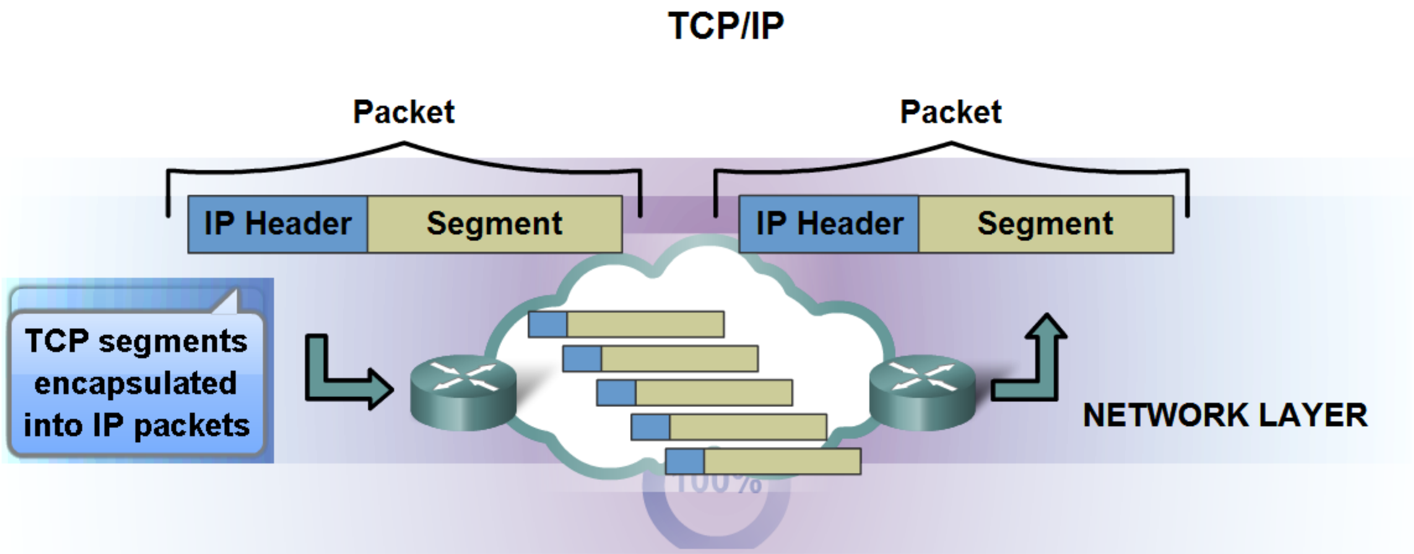
- Each network has some MTU (Maximum Transmission Unit)
  - Ethernet (1500 bytes), FDDI (4500 bytes)
- Strategy
  - Fragmentation occurs in a router when it receives a datagram that it wants to forward over a network which has (MTU < datagram)
  - Reassembly is done at the receiving host
  - All the fragments carry the same identifier in the *Ident* field
  - Fragments are self-contained datagrams
  - IP does not recover from missing fragments

IP Fragmentation & Reassembly





Role of IPv4 Protocols



IP Packets flow through the internetwork.

- Connectionless - No connection is established before sending data packets.
- Best Effort (unreliable) - No overhead is used to guarantee packet delivery.
- Media Independent - Operates independently of the medium carrying the data.

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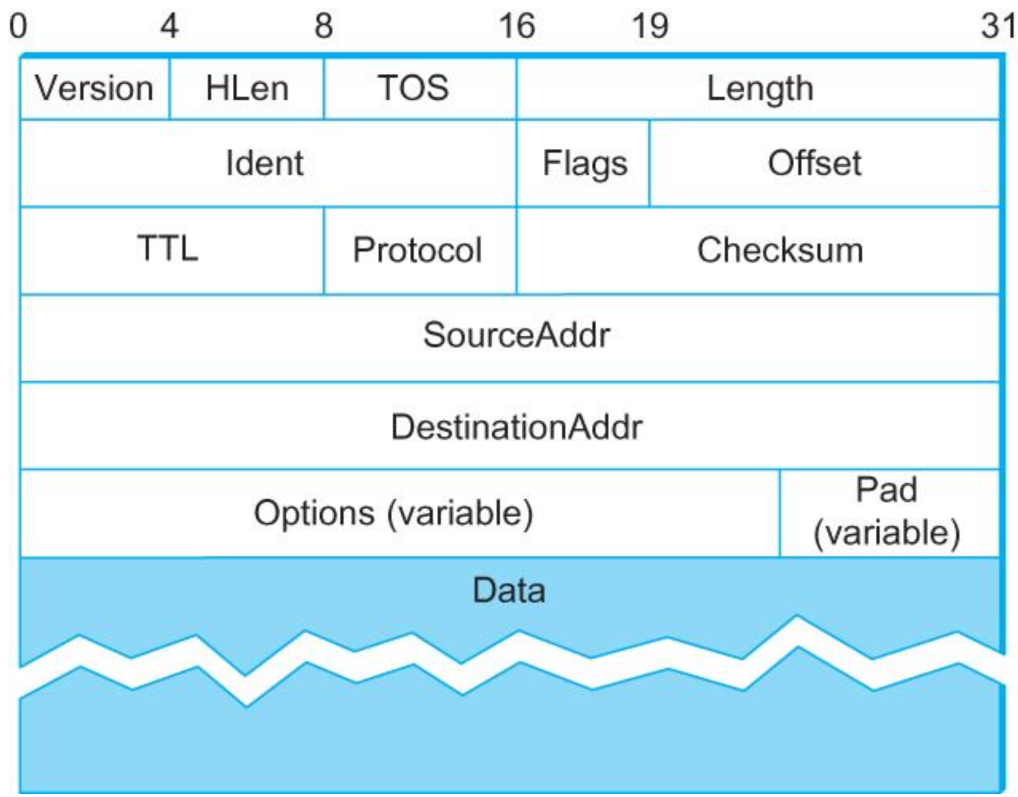
IPv4 Format


0
4
8
16
19
31
Version
HLen
TOS
Length
Ident
Flags
Offset
TTL
Protocol
Checksum
SourceAddr
DestinationAddr
Options (variable)
Pad (variable)
Data

IPv4 Class

IP Address Classes

Address Class	1st octet range (decimal)	1st octet bits (green bits do not change)	Network(N) and Host(H) parts of address	Default subnet mask (decimal and binary)	Number of possible networks and hosts per network
A	1-127**	00000000-01111111	N.H.H.H	255.0.0.0	128 nets (2^7) 16,777,214 hosts per net (2^24-2)
B	128-191	10000000-10111111	N.N.H.H	255.255.0.0	16,384 nets (2^14) 65,534 hosts per net (2^16-2)
C	192-223	11000000-11011111	N.N.N.H	255.255.255.0	2,097,150 nets (2^21) 254 hosts per net (2^8-2)
D	224-239	11100000-11101111	NA (multicast)		
E	240-255	11110000-11111111	NA (experimental)		

** All zeros (0) and all ones (1) are invalid hosts addresses.

IPv4

Define public address and private address

The private address blocks are:

10.0.0.0 to 10.255.255.255	**(10.0.0.0 /8)**
172.16.0.0 to 172.31.255.255	**(172.16.0.0 /12)**
192.168.0.0 to 192.168.255.255	**(192.168.0.0 /16)**

IPv4 Convert

Exponent	2^7	2^6	2^5	2^4	2^3	2^2	2^1	2^0
Position	128	64	32	16	8	4	2	1
Bits	1	1	1	1	0	1	0	1
	1 BYTE / 1 Octet							
Add these numbers together	128 +	64 +	32 +	16 +	0 +	4 +	0 +	1
Decimal	245							

A 1 in this position means 64 is added to the total.

A 0 in any position means that 0 is added to the total.

Subnetting

- Subnetting provides a first step to reducing total number of network numbers that are assigned.
  - Easy for Managed and Decrease of Using IP.
- Add another level to address/routing hierarchy: subnet

What is…

1) Network/Subnet : ID parent
2) Host/client/node : Childs
3) Gateway (GW) : IP add on Router (1st allocation IP)
4) Broadcast (BC) : IP add on Switch (Last allocation IP)
5) Prefix/ "/" : how many bit are Used (#of bit 1)
6) Subnet Mask (SM) : Binary of Prefix

Subnetting

How many Subnet and Hosts?

Number of subnets available=

$2^{\text{number-of-bits-1}}-2$

*(***subnet zero and subnet extended***)*

Number of hosts per subnet available=

$2^{\text{number-of-bits-0}}-2$

*(***gateway and broadcast***)*

Subnetting (Ex.1)

CCNA International Exam, 2012

Given the address 192.168.20.19/28, which of the following are valid host addresses on this subnet?

A. 192.168.20.29

B. 192.168.20.16

C. 192.168.20.17

D. 192.168.20.31

E. 192.168.20.0

11111111. 11111111. 11111111.11110000

^

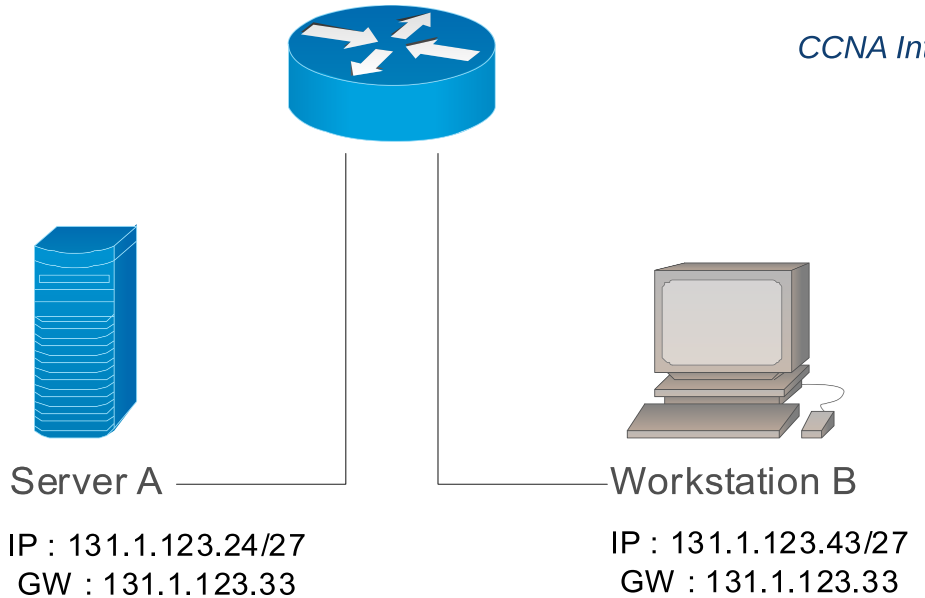
$2^4=16$

192.168.20.16 ………………………………………… 192.168.20.31

.17 .30

Subnetting (Ex.2)

CCNA International Exam, 2012

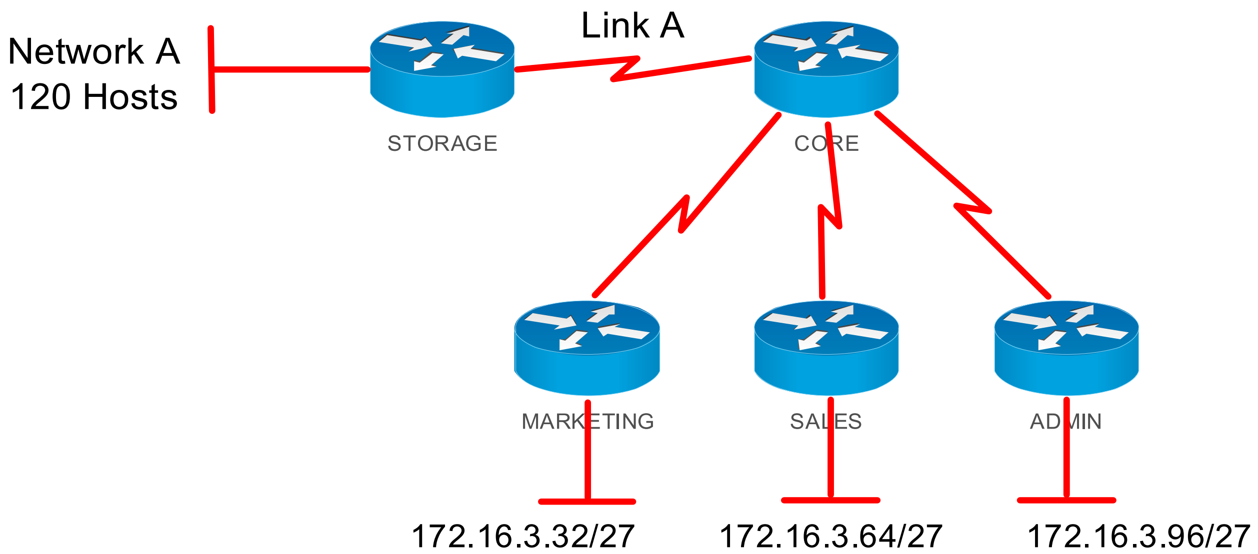


Refer to the exhibit. The user at Workstation B reports that Server A cannot be reached. What is preventing Workstation B from reaching Server A?

A. The IP address for Server A is a broadcast address.
B. The IP address for Workstation B is a subnet address.
C. The gateway for Workstation B is not on the same subnet.
D. The gateway for Server A is not on the same subnet.

Subnetting (Ex.3)

CCNA International Exam, 2012



Refer to the exhibit. All of the routers in the network are configured with the IP Subnet-Zero command. Which network addresses should be used for Link A and Network A? (Choose two.)

A. Network A - 172.16.3.48/26

B. Network A - 172.16.3.128/25

C. Network A - 172.16.3.192/26

D. Link A - 172.16.3.0/30

E. Link A - 172.16.3.40/30

F. Link A - 172.16.3.112/30

Supernetting

Supernetting/CIDR/VLSM

- Classless Inter-Domain Routing
- Variable Length Subnet Mask
- Prefix Aggregation a.k.a. Route Summarization

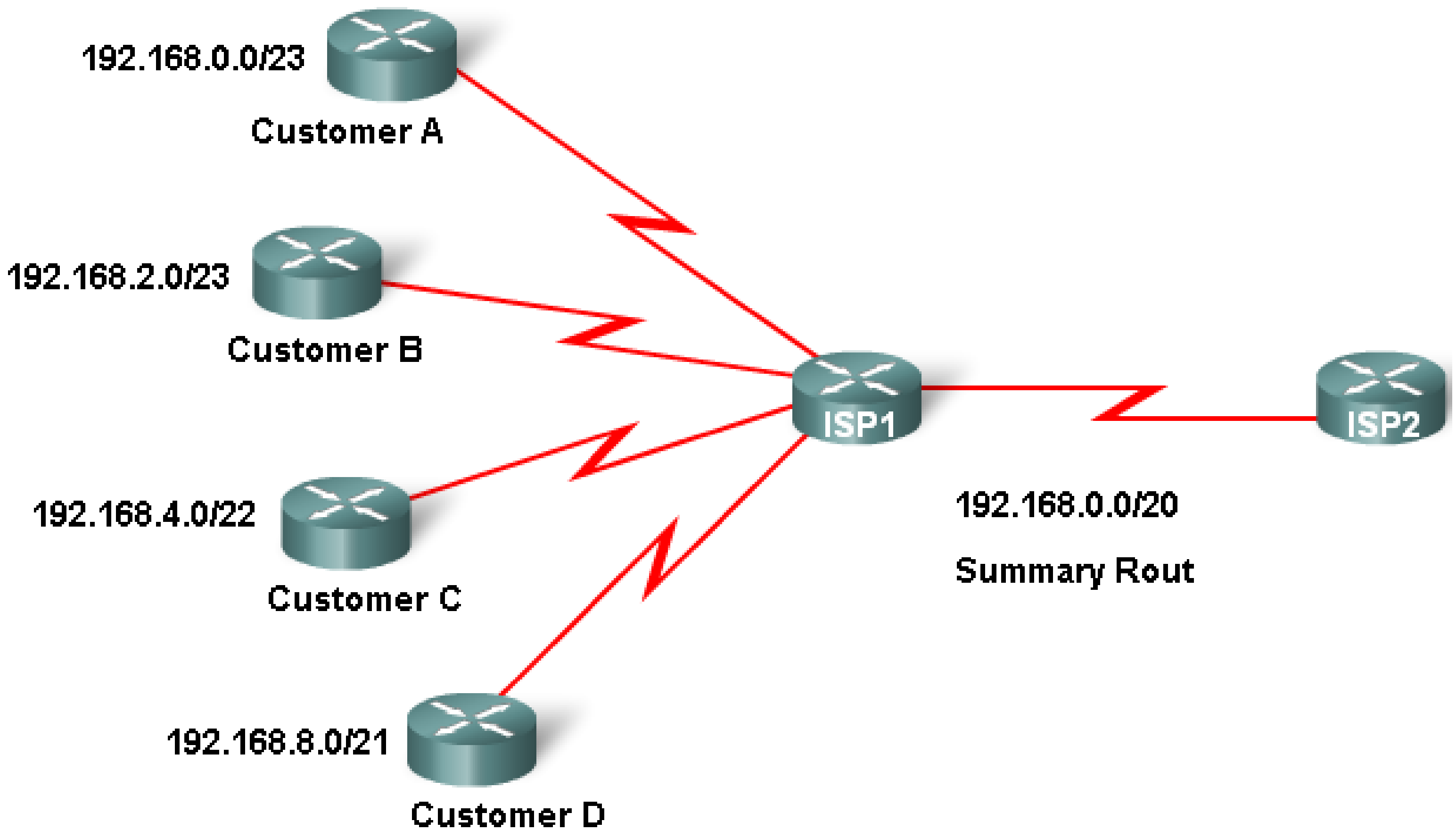
✓ A technique that addresses two scaling concerns in the Internet

- The growth of backbone routing table as more and more network numbers need to be stored in them
- Potential exhaustion of the 32-bit address space

✓ Address assignment efficiency

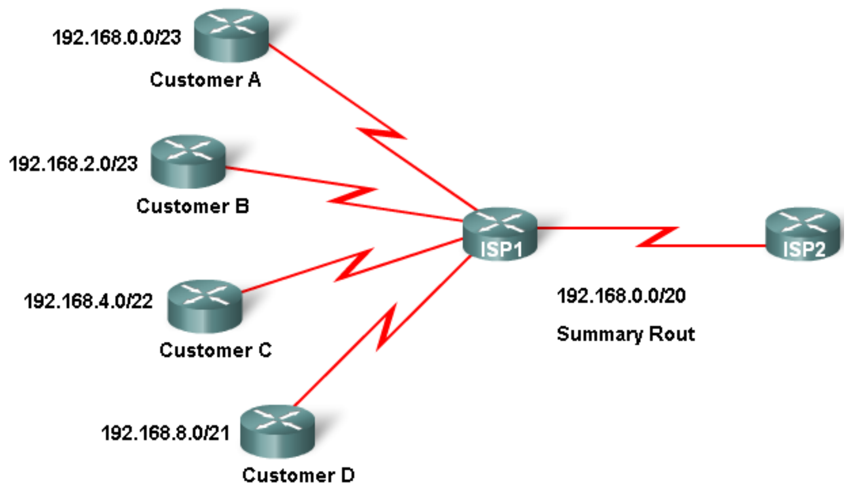
- Arises because of the IP address structure with class A, B, and C addresses

Supernetting [Ex.1]



CISCO, 2008

Supernetting

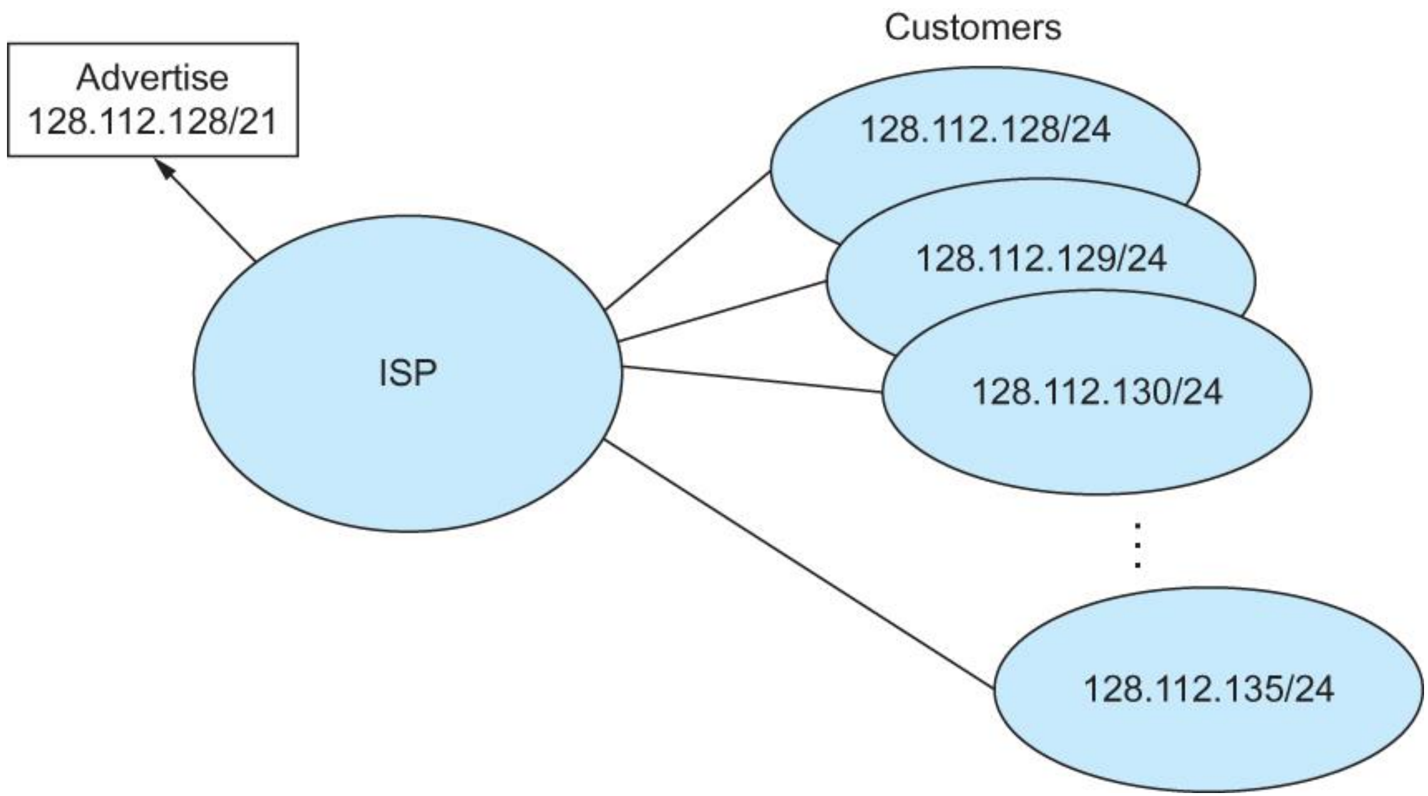


192.168.0.0/23 00000000
192.168.2.0/23 00000010
192.168.4.0/22 00000100
192.168.8.0/21 00001000

00000000

192.168.0.0/20 ← Route Summarization

Supernetting [Ex.2]



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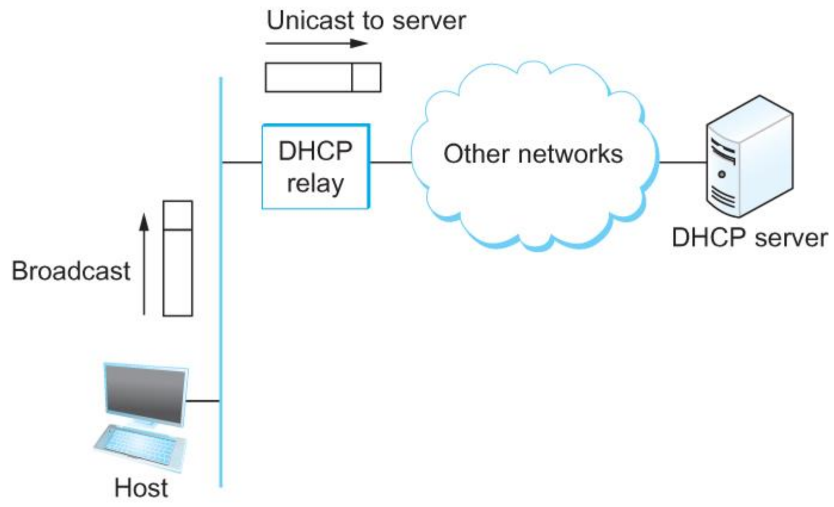
ARP

- Map IP addresses into physical addresses
  - destination host
  - next hop router
- Techniques
  - encode physical address in host part of IP address
  - table-based
- *ARP (Address Resolution Protocol)*
  - table of IP to physical address bindings
  - broadcast request if IP address not in table
  - target machine responds with its physical address
  - table entries are discarded if not refreshed (*ARP cache*)

DHCP

- Drawbacks of manual configuration
  - A lot of work to configure all the hosts in a large network
  - Configuration process is error-prune
- Automated Configuration Process is required



- DHCP server is responsible for providing configuration information to hosts
- There is at least one DHCP server for an administrative domain
- DHCP server maintains a pool of available addresses

ICMP

- *Internet Control Message Protocol (ICMP)*
- Defines a collection of error messages that are sent back to the source host whenever a router or host is unable to process an IP datagram successfully
  - Destination host unreachable due to link /node failure
  - Reassembly process failed
  - TTL had reached 0 (so datagrams don't cycle forever)
  - IP header checksum failed
- ICMP-Redirect
  - From router to a source host
  - With a better route information

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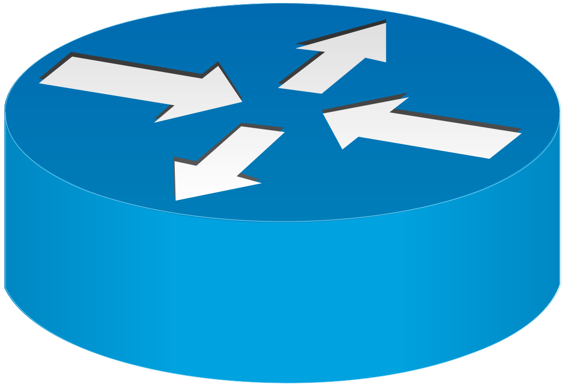
Routing



Forwarding versus Routing

- **Forwarding**:
  - to select an output port based on destination address and routing table
- **Routing**:
  - process by which routing table is built

Routing Table

- Forwarding table VS Routing table
  - Forwarding table
    - Used when a packet is being forwarded and so must contain enough information to accomplish the forwarding function
    - A row in the forwarding table contains the mapping from a network number to an outgoing interface and some MAC information, such as Ethernet Address of the next hop
  - Routing table
    - Built by the routing algorithm as a precursor to build the forwarding table
    - Generally contains mapping from network numbers to next hops

Example

(a)

Prefix/Length	Next Hop
18/8	171.69.245.10

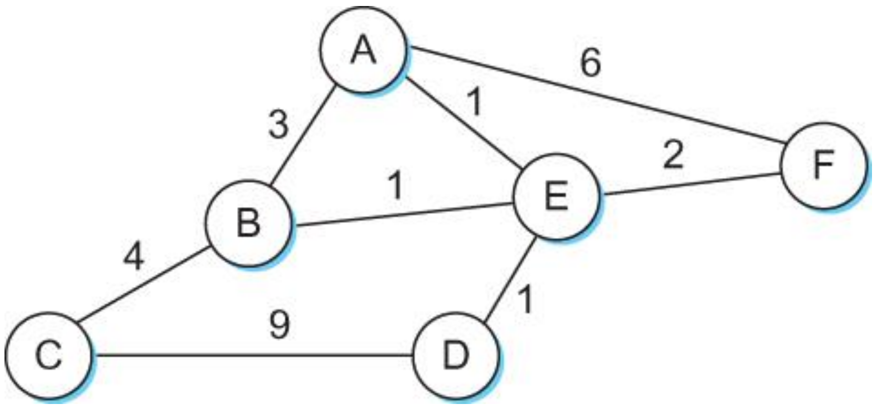
(b)

Prefix/Length	Interface	MAC Address
18/8	if0	8:0:2b:e4:b:1:2

Example rows from (a) routing and (b) forwarding tables

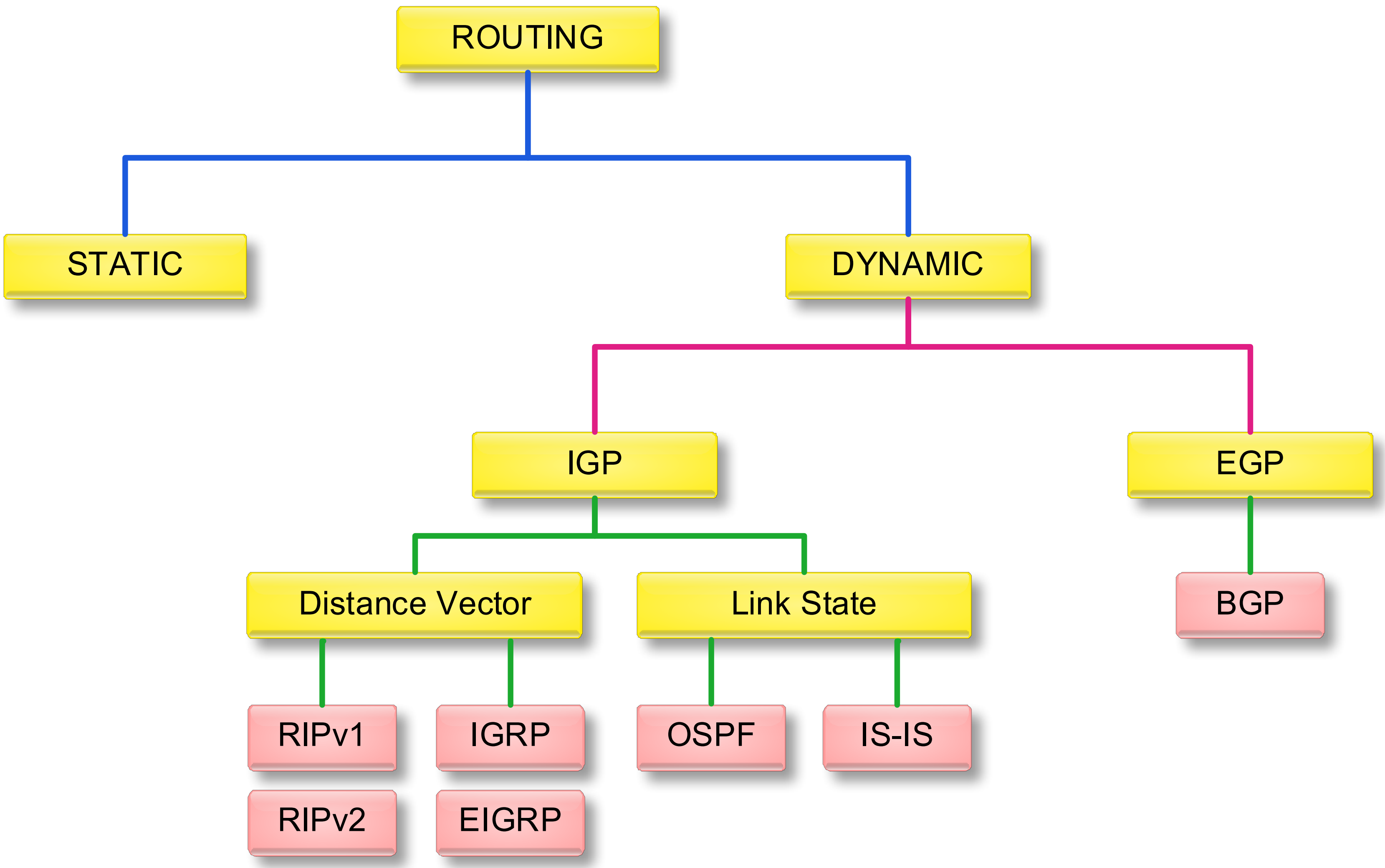
Routing Example

- Network as a Graph

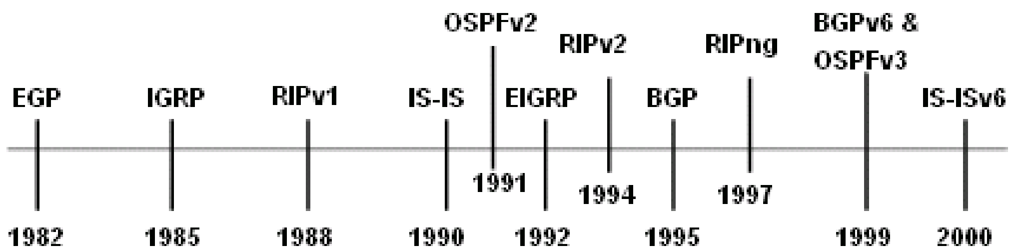


- The basic problem of routing is to find the lowest-cost path between any two nodes
  - Where the cost of a path equals the sum of the costs of all the edges that make up the path.

Routing Protocol



Routing Protocol Evolution



	Interior Gateway Protocols				Exterior Gateway Protocols
	Distance Vector Routing Protocols		Link State Routing Protocols		Path Vector
Classful	RIP	IGRP			EGP
Classless	RIPv2	EIGRP	OSPFv2	IS-IS	BGPv4
IPv6	RIPng	EIGRP for IPv6	OSPFv3	IS-IS for IPv6	BGPv4 for IPv6

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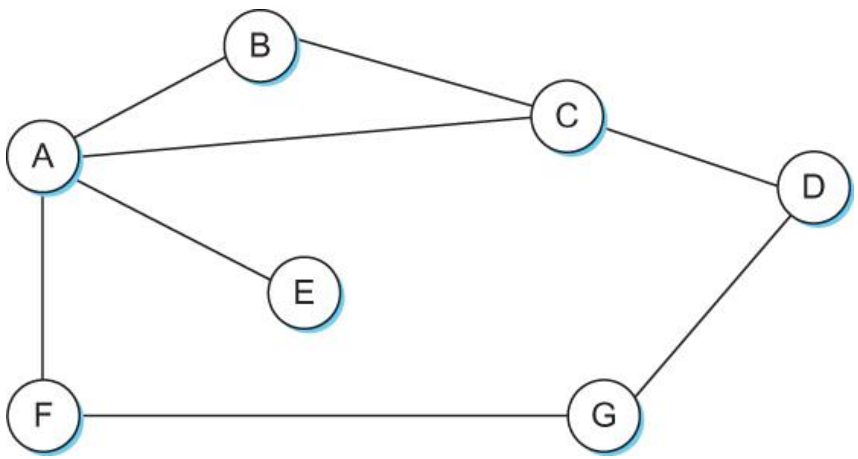
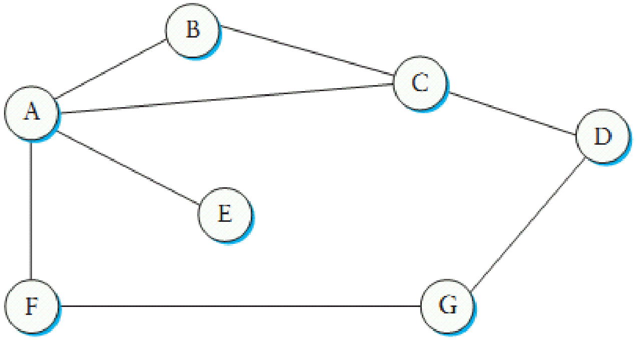
Distance Vector

- Each node constructs a one dimensional array (a vector) containing the "**distances**" (costs) to all other nodes and distributes that vector to its immediate neighbors.
- Starting assumption is that each node knows the cost of the link to each of its directly connected neighbors.



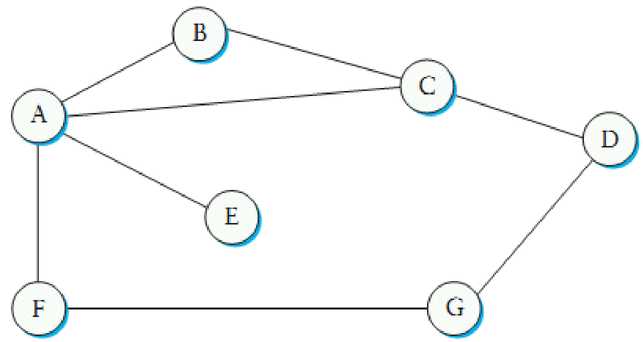
- Each router maintains a table of [**Destination, Cost, NextHop**] tuples, and exchanges a list of (Destination, Cost) pairs with its directly connected **neighbors**.

Distance Vector



Information Stored at Node	Distance to Reach Node						
	A	B	C	D	E	F	G
A	0	1	1	∞	1	1	∞
B	1	0	1	∞	∞	∞	∞
C	1	1	0	1	∞	∞	∞
D	∞	∞	1	0	∞	∞	1
E	1	∞	∞	∞	0	∞	∞
F	1	∞	∞	∞	∞	0	1
G	∞	∞	∞	1	∞	1	0

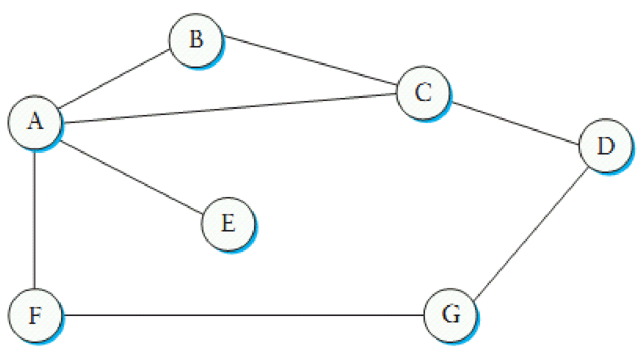
Distance Vector



Destination	Cost	NextHop
B	1	B
C	1	C
D	∞	—
E	1	E
F	1	F
G	∞	—

Destination	Cost	NextHop
B	1	B
C	1	C
D	2	C
E	1	E
F	1	F
G	2	F

Distance Vector

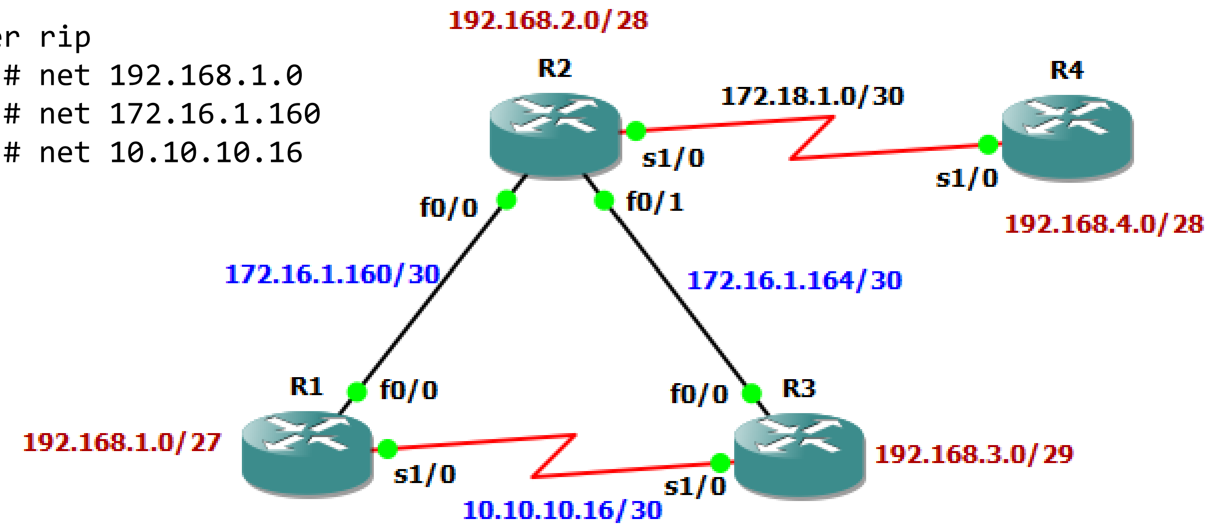


COMPLETE

Information Stored at Node	Distance to Reach Node						
	A	B	C	D	E	F	G
A	0	1	1	2	1	1	2
B	1	0	1	2	2	2	3
C	1	1	0	1	2	2	2
D	2	2	1	0	3	2	1
E	1	2	2	3	0	2	3
F	1	2	2	2	2	0	1
G	2	3	2	1	3	1	0

DV Example : RIP

```
R1(config)# router rip
R1(config-router)# net 192.168.1.0
R1(config-router)# net 172.16.1.160
R1(config-router)# net 10.10.10.16
```




```
R1# show ip route

 172.16.0.0/30 is subnetted, 2 subnets
R       172.16.1.164 [120/1] via 172.16.1.162, 00:00:09, FastEthernet0/0
C       172.16.1.160 is directly connected, FastEthernet0/0
R    172.18.0.0/16 [120/1] via 172.16.1.162, 00:00:09, FastEthernet0/0
R    192.168.4.0/24 [120/2] via 172.16.1.162, 00:00:09, FastEthernet0/0
     10.0.0.0/30 is subnetted, 1 subnets
C       10.10.10.16 is directly connected, Serial1/0
     192.168.1.0/27 is subnetted, 1 subnets
C       192.168.1.0 is directly connected, Loopback1
R    192.168.2.0/24 [120/1] via 172.16.1.162, 00:00:11, FastEthernet0/0
R    192.168.3.0/24 [120/1] via 10.10.10.18, 00:00:03, Serial1/0
```

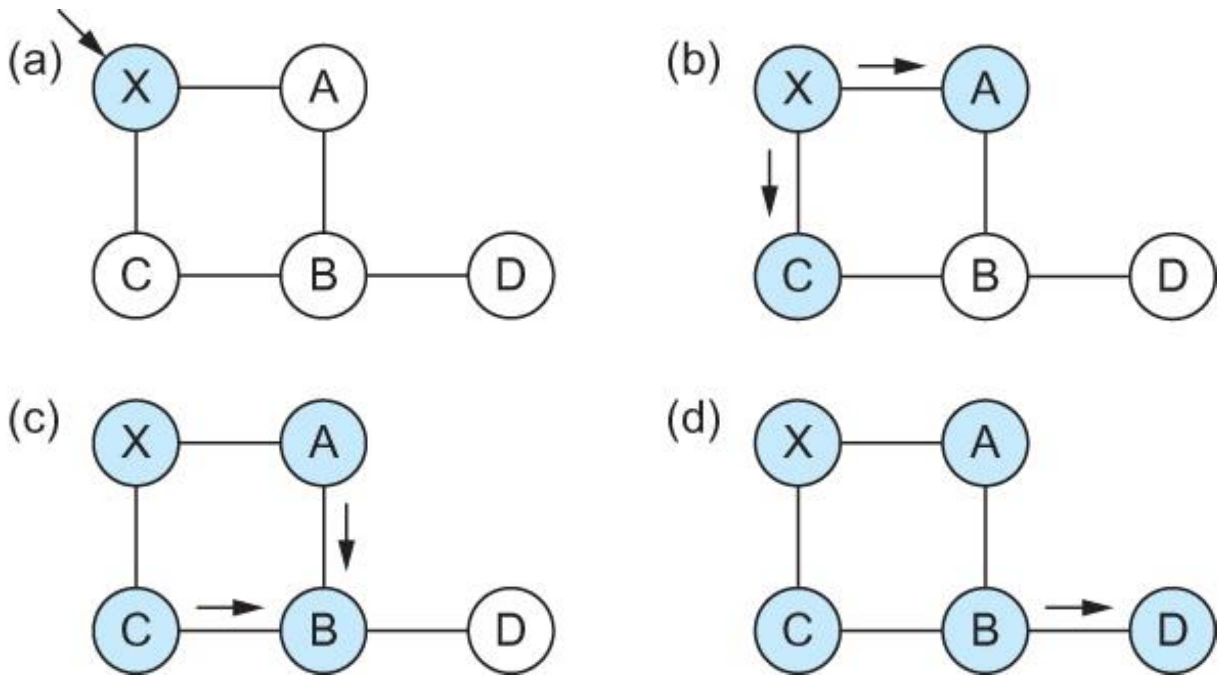
Link State Routing

- Each node is assumed to be capable of finding out the state of the link to its neighbors (up or down) and the cost of each link.

- Every node knows how to reach its directly connected neighbors, and if we make sure that the totality of this knowledge is disseminated to every node, then every node will have enough knowledge of the network to build a complete map of the network.

Link State Routing

Reliable Flooding



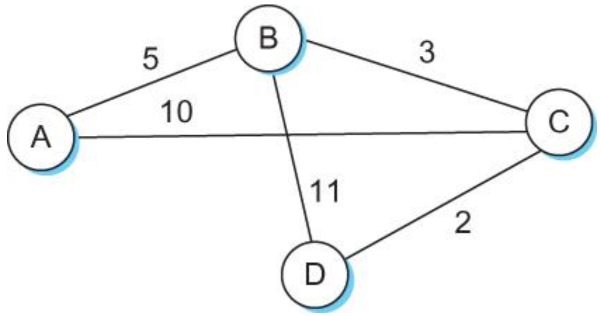
Flooding of link-state packets. (a) LSP arrives at node X; (b) X floods LSP to A and C; (c) A and C flood LSP to B (but not X); (d) flooding is complete

Shortest Path Routing

The algorithm works as follows:

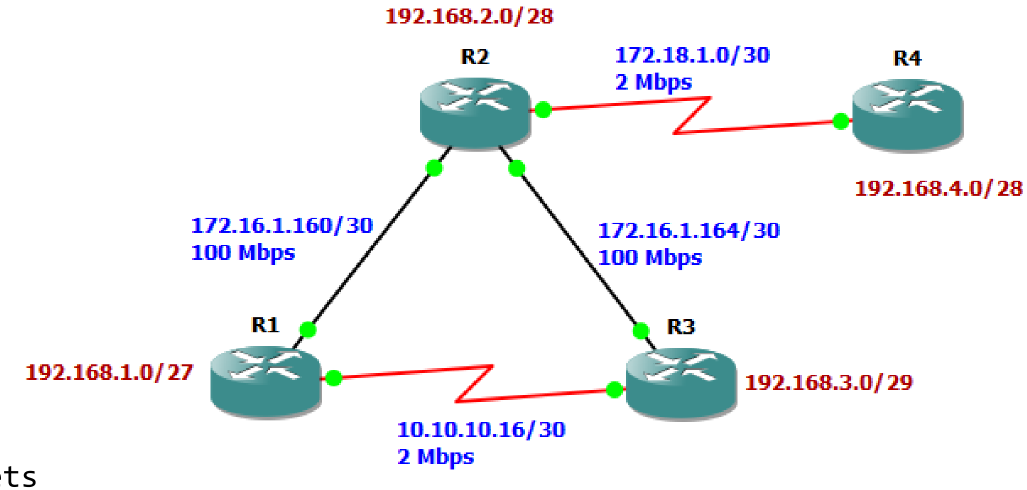
1) Initialize the Confirmed list with an entry for myself; this entry has a cost of 0.
2) For the node just added to the Confirmed list in the previous step, call it node Next and select its LSP.
3) For each neighbor (Neighbor) of Next, calculate the cost (Cost) to reach this Neighbor as the sum of the cost from myself to Next and from Next to Neighbor.
4) If the Tentative list is empty, stop. Otherwise, pick the entry from the Tentative list with the lowest cost, move it to the Confirmed list, and return to step 2.

Shortest Path Routing



Step	Confirmed	Tentative	Comments
1	(D,0,–)		Since D is the only new member of the confirmed list, look at its LSP.
2	(D,0,–)	(B,11,B) (C,2,C)	D's LSP says we can reach B through B at cost 11, which is better than anything else on either list, so put it on Tentative list; same for C.
3	(D,0,–) (C,2,C)	(B,11,B)	Put lowest-cost member of Tentative (C) onto Confirmed list. Next, examine LSP of newly confirmed member (C).
4	(D,0,–) (C,2,C)	(B,5,C) (A,12,C)	Cost to reach B through C is 5, so replace (B,11,B). C's LSP tells us that we can reach A at cost 12.
5	(D,0,–) (C,2,C) (B,5,C)	(A,12,C)	Move lowest-cost member of Tentative (B) to Confirmed, then look at its LSP.
6	(D,0,–) (C,2,C) (B,5,C)	(A,10,C)	Since we can reach A at cost 5 through B, replace the Tentative entry.
7	(D,0,–) (C,2,C) (B,5,C) (A,10,C)		Move lowest-cost member of Tentative (A) to Confirmed, and we are all done.

LS Example : OSPF




```
R1# sh ip route

 172.16.0.0/30 is subnetted, 2 subnets
O       172.16.1.164 [110/2] via 172.16.1.162, 00:00:02, FastEthernet0/0
C       172.16.1.160 is directly connected, FastEthernet0/0
     172.18.0.0/30 is subnetted, 1 subnets
O IA    172.18.1.0 [110/65] via 172.16.1.162, 00:00:02, FastEthernet0/0
     192.168.4.0/32 is subnetted, 1 subnets
O IA    192.168.4.1 [110/66] via 172.16.1.162, 00:00:02, FastEthernet0/0
     10.0.0.0/30 is subnetted, 1 subnets
C       10.10.10.16 is directly connected, Serial1/0
     192.168.1.0/27 is subnetted, 1 subnets
C       192.168.1.0 is directly connected, Loopback1
     192.168.2.0/32 is subnetted, 1 subnets
O       192.168.2.1 [110/2] via 172.16.1.162, 00:00:04, FastEthernet0/0
     192.168.3.0/32 is subnetted, 1 subnets
O       192.168.3.1 [110/3] via 172.16.1.162, 00:00:06, FastEthernet0/0
```

Task Chapter 3

[Bahasa/handwriting]
[Deadline-03/10/13]
[12.01pm]

No. 1 : Exercise Chapter 3, Peterson 5th Ed. Page 294, no. 46!

No. 2 : Exercise Chapter 3, Peterson 5th Ed. Page 295, no. 48!

Bibliography

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THANK YOU

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