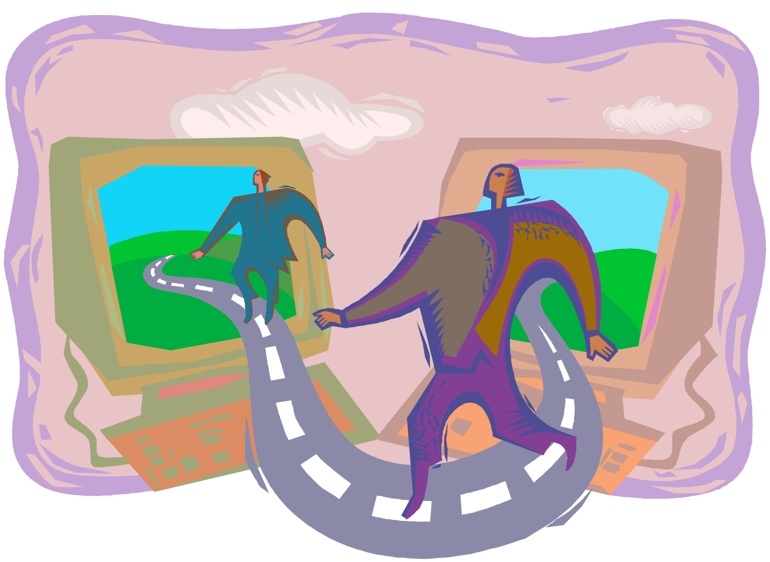
Discussion #9
EE450



-IP Fragmentation

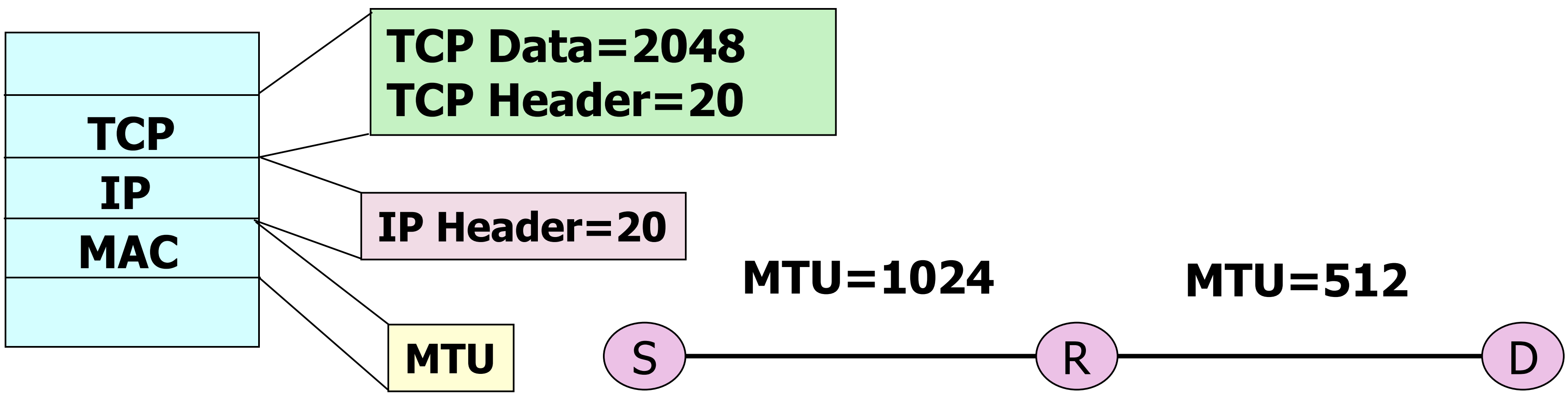
- Addressing and Subnetting

Problem#1: Description

- Suppose that a TCP message that contains 2048 bytes of data and 20 bytes of TCP header is passed to IP for delivery across two networks of the Internet (i.e. from the source host to a router to the destination host).
- The first network has an MTU of 1024 bytes and the second network has an MTU of 512 bytes.
- Each network's MTU gives the total packet size that may be sent including the network header.

Problem#1: Question

- Give the sizes of the fragments delivered to the network layer at the destination host, assuming all IP headers are 20 bytes.



Problem#1: Solution

Across the first network:

- Packets have room for 1024-20=1004 bytes of IP-level data.
- Since 1004 is not multiple of 8, each fragment can contain at most $8 \times \lfloor 1004/8 \rfloor = 1000$ bytes.
- We need to transfer 2048 +20 bytes of such data.
- This would be fragmented into fragments of size 1000,1000 and 68 bytes.
- **For Packet sizes across the first network , add 20 bytes to each fragment.**

Problem#1: Solution

Unfragmented and fragmented datagrams

The M bit and the offset field in the header are used for IP fragmentation as illustrated.

Start of Header				
Ident=x			0	Offset=0
Rest of Header				
2068 data bytes				

Start of Header				
Ident=x			**1**	***Offset=0***
Rest of Header				
1000 data bytes				

Start of Header				
Ident=x			**1**	***Offset=125***
Rest of Header				
1000 data bytes				

Start of Header				
Ident=x			**0**	***Offset=250***
Rest of Header				
68 data bytes				

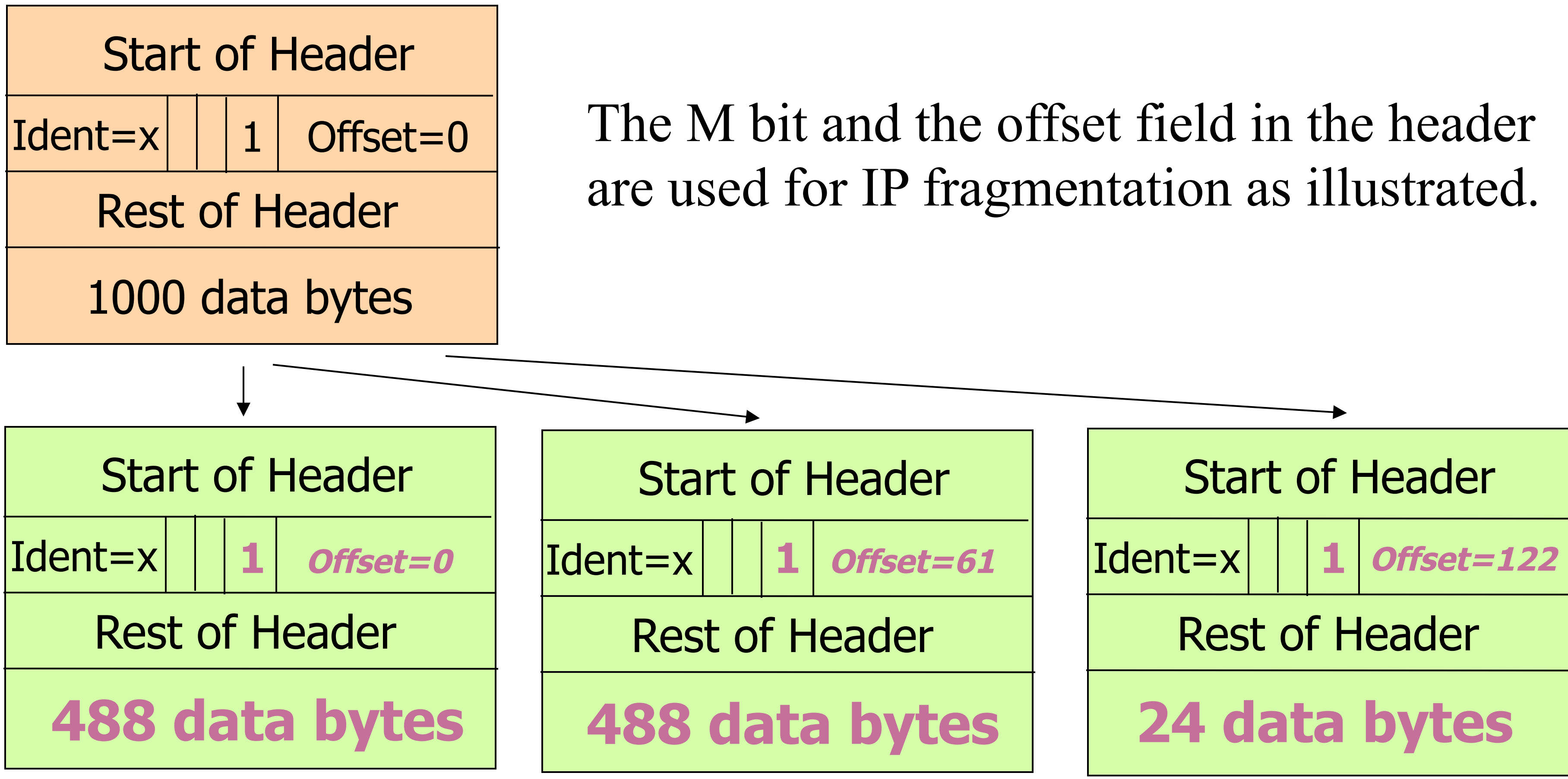
Problem#1: Solution

Across the second network:

- Packets have room for 512-20=492 bytes of IP-level data.
- So the 68-byte packet will not be fragmented but the other two 1000-byte packets will be fragmented.
- Since 492 is not multiple of 8, each fragment can contain at most $8 \times \lfloor 492/8 \rfloor = 488$ bytes.
- Each 1000-byte fragment would be fragmented into fragments of size 488,488 and 24 bytes.
- **For Packet sizes across the second network, add 20 bytes to each fragment.**

Problem#1: Solution

Unfragmented and fragmented datagrams



The M bit and the offset field in the header are used for IP fragmentation as illustrated.

Problem#1: Solution

Unfragmented and fragmented datagrams

Start of Header				
Ident=x			1	Offset=125
Rest of Header				
1000 data bytes				

The M bit and the offset field in the header are used for IP fragmentation as illustrated.

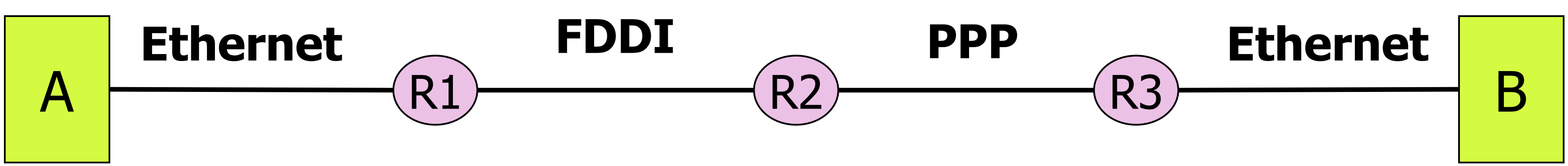
Start of Header				
Ident=x			**1**	***Offset=125***
Rest of Header				
488 data bytes				

Start of Header				
Ident=x			**1**	***Offset=186***
Rest of Header				
488 data bytes				

Start of Header				
Ident=x			**1**	***Offset=247***
Rest of Header				
24 data bytes				

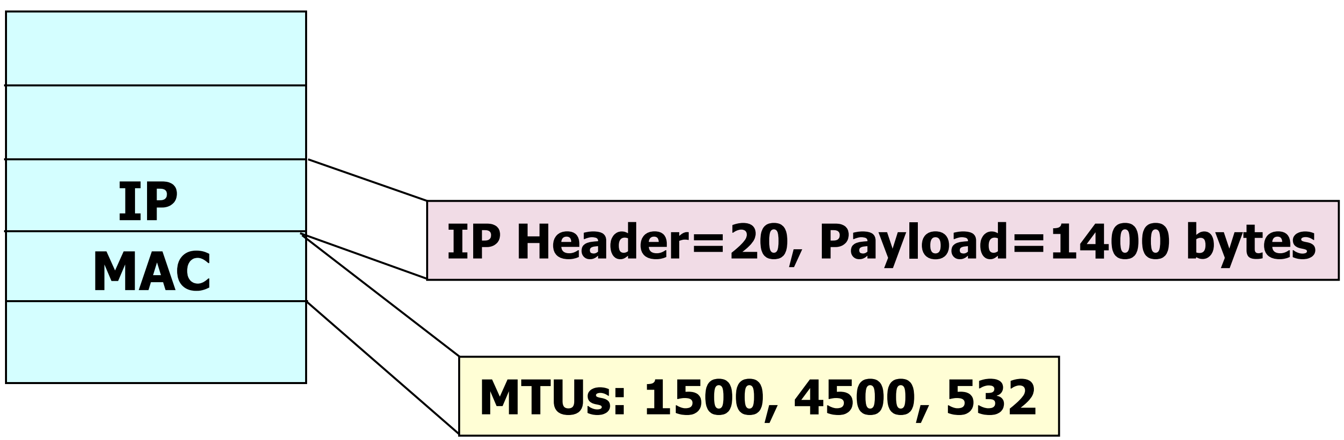
Problem#2: Description

- We have an IP datagram of size 1420 bytes (including the IP header) traversing the sequence of physical networks with different MTUs as follow:
  - Ethernet : MTU = 1500 bytes
  - FDDI : MTU = 4500 bytes
  - PPP : MTU = 532 bytes



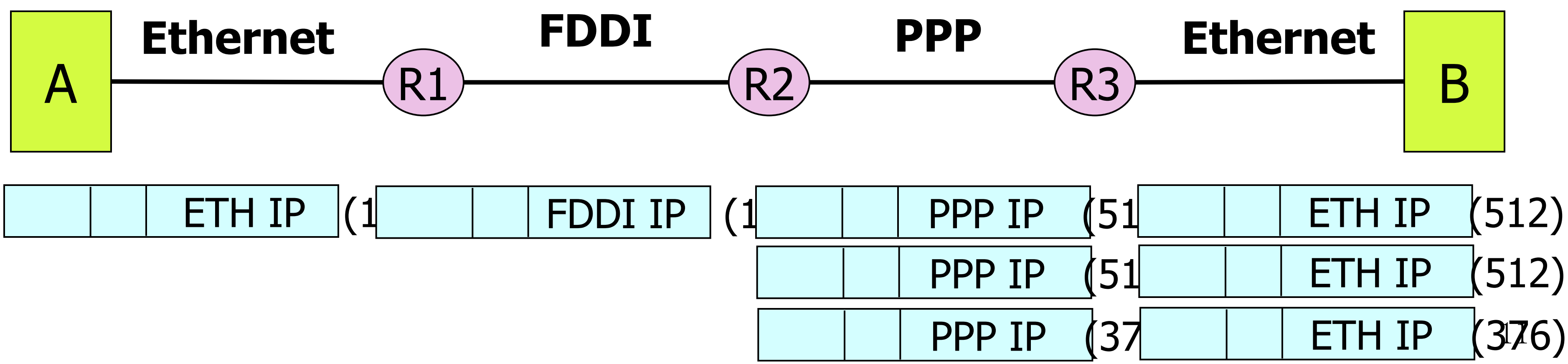
Problem#2: Question

- Show the unfragmented datagram as well as the fragmented datagrams and clearly identify the Header fields used in IP fragmentation.



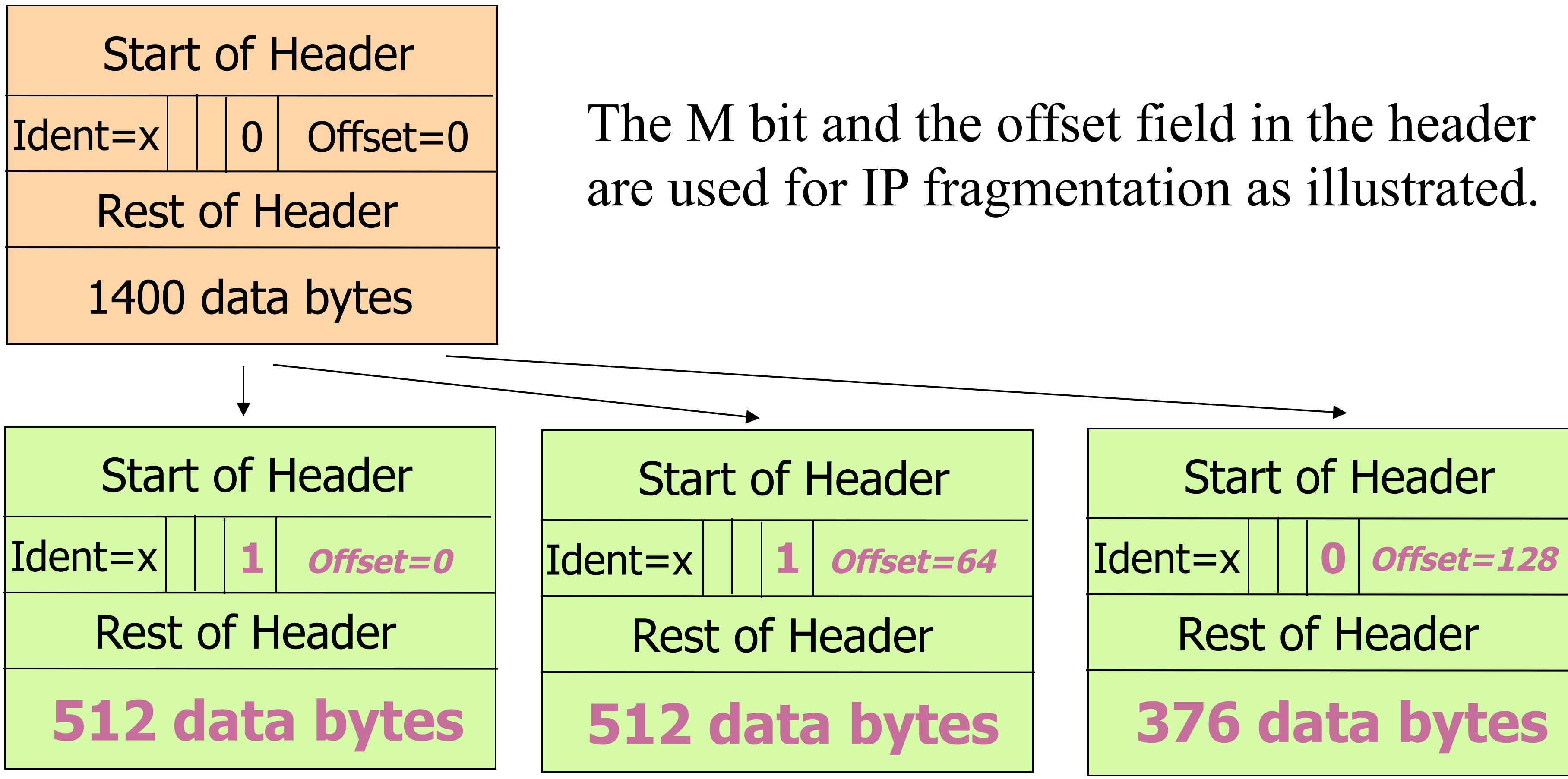
Problem#2: Solution

- The datagram will not be fragmented across the first two networks.
- Since the MTU of the PPP network is less than the size of the datagram (without the IP header), it will be fragmented to 3 datagrams.
- The fragments of the original datagram travel across the 4th network with no further fragmentation and they will reassembled at the endpoint.



Problem#2: Solution
Unfragmented and fragmented datagrams

The M bit and the offset field in the header are used for IP fragmentation as illustrated.



Problem#3: Description

- Suppose a router has built up its routing table. The router can deliver packets directly over interfaces 0 and 1, or it can forward packets to routers R2, R3, or R4. Assume the router does the longest prefix match. Describe what the router does with a packet addressed to each of the following destinations:

(a) 128.96.171.92

(b) 128.96.167.151

(c) 128.96.163.151

(d) 128.96.169.192

(e) 128.96.165.121

Problem#3: Routing Table

SubnetNumber	SubnetMask	NextHop
128.96.170.0	255.255.254.0	Interface 0
128.96.168.0	255.255. 254.0	Interface 1
128.96.166.0	255.255. 254.0	R2
128.96.164.0	255.255. 252.0	R3
(default)		R4

Apply each subnet mask to the given destination IP address and if the corresponding subnet number matches the entry in the SubnetNumber column, use the entry in the Next-hop column. (Find the longest prefix match.)

Problem#3: Solution

SubnetNumber	SubnetMask	NextHop
128.96.170.0	255.255.254.0	Interface 0
128.96.168.0	255.255. 254.0	Interface 1
128.96.166.0	255.255. 254.0	R2
128.96.164.0	255.255. 252.0	R3
(default)		R4

(a) 128.96.171.92. Applying the subnet mask 255.255.254.0.

128. 96. **10101011** . **01011100**

AND

255.255. **11111110** . **00000000**

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128. 96. **10101010** . **00000000** = 128.96.170.0 Next hop: **interface0**

Problem#3: Solution

SubnetNumber	SubnetMask	NextHop
128.96.170.0	255.255.254.0	Interface 0
128.96.168.0	255.255. 254.0	Interface 1
128.96.166.0	255.255. 254.0	R2
128.96.164.0	255.255. 252.0	R3
(default)		R4

(b) 128.96.167.151. Applying the subnet masks 255.255.254.0 & 255.255.252.0

128. 96. **10100111** . **10010111**

AND

255.255. **11111110** . **00000000**

128. 96. **10100110** . **00000000**

= 128.96.166.0 Next hop: **R2**

128. 96. **10100111** . **10010111**

AND

255.255. **11111100** . **00000000**

128. 96. **10100100** . **00000000**

= 128.96.164.0 Next hop: **R3**

Problem#3: Solution

SubnetNumber	SubnetMask	NextHop
128.96.170.0	255.255.254.0	Interface 0
128.96.168.0	255.255. 254.0	Interface 1
128.96.166.0	255.255. 254.0	R2
128.96.164.0	255.255. 252.0	R3
(default)		R4

(c) 128.96.163.151

None of the subnet entries match, hence use default router **R4**.

Problem#3: Solution

SubnetNumber	SubnetMask	NextHop
128.96.170.0	255.255.254.0	Interface 0
128.96.168.0	255.255. 254.0	Interface 1
128.96.166.0	255.255. 254.0	R2
128.96.164.0	255.255. 252.0	R3
(default)		R4

(d) 128.96.169.192. Applying the subnet mask 255.255.254.0.

128. 96. **10101001** . **11000000**

AND

255.255. **11111110** . **00000000**

128. 96. **10101000** . **00000000** = 128.96.168.0 Next hop: **interface1**

Problem#3: Solution

SubnetNumber	SubnetMask	NextHop
128.96.170.0	255.255.254.0	Interface 0
128.96.168.0	255.255. 254.0	Interface 1
128.96.166.0	255.255. 254.0	R2
128.96.164.0	255.255. 252.0	R3
(default)		R4

(e) 128.96.165.121. Applying the subnet mask 255.255.252.0

128. 96. **10100101** . **01111001**

AND

255.255. **11111100** . **00000000**

128. 96. **10100100** . **00000000** = 128.96.164.0 Next hop: **R3**

Problem#4: Description

- Suppose a router has built up its routing table. The router can deliver packets directly over interfaces 0 and 1, or it can forward packets to routers R2, R3, or R4. Describe what the router does with a packet addressed to each of the following destinations:

(a) 128.96.39.10

(b) 128.96.40.12

(c) 128.96.40.151

(d) 192.4.153.17

(e) 192.4.153.90

Problem#4: Routing Table

SubnetNumber	SubnetMask	NextHop
128.96.39.0	255.255.255.128	Interface 0
128.96.39.128	255.255.255.128	Interface 1
128.96.40.0	255.255.255.128	R2
192.4.153.0	255.255.255.192	R3
(default)		R4

Apply each subnet mask to the given destination IP address and if the corresponding subnet number matches the entry in the SubnetNumber column, use the entry in the Next-hop column. (In these tables there is always a unique match.)

Problem#4: Solution

SubnetNumber	SubnetMask	NextHop
128.96.39.0	255.255.255.128	Interface 0
128.96.39.128	255.255.255.128	Interface 1
128.96.40.0	255.255.255.128	R2
192.4.153.0	255.255.255.192	R3
(default)		R4

(a) 128.96.39.10. Applying the subnet mask 255.255.255.128, we get 128.96.39.0. Use **interface0** as the next hop.

(b) 128.96.40.12. Applying the subnet mask 255.255.255.128, we get 128.96.40.0. Use **R2** as the next hop.

Problem#4: Solution

SubnetNumber	SubnetMask	NextHop
128.96.39.0	255.255.255.128	Interface 0
128.96.39.128	255.255.255.128	Interface 1
128.96.40.0	255.255.255.128	R2
192.4.153.0	255.255.255.192	R3
(default)		R4

(c) 128.96.40.151. All subnet masks give 128.96.40.128 as the subnet number. Since there is no match, use the default entry. Next hop is **R4**.

(d) 192.4.153.17. Applying the subnet mask 255.255.255.192, we get 192.4.153.0. Next hop is **R3**.

(e) 192.4.153.90. None of the subnet entries match, hence use default router R4.

Problem#5: Description

- An organization has a class C network 200.1.1 and wants to form subnets for four departments, with hosts as follows:

  A 72 Hosts

  B 35 Hosts

  C 20 Hosts

  D 18 Hosts

  There are 145 hosts in all.

a) Give a possible arrangement of subnet masks to make this possible.

b) Suggest what the organization might do if department D grows to 34 hosts.

Problem#5: Solution, part (a)

A possible arrangement of subnet numbers is as follows.

- A with 72 hosts requires $\log_2 72 = 7$ host bits

  Subnet number: 0/

- B with 35 hosts requires $\log_2 35 = 6$ host bits

  Subnet number: 10/

- C with 20 hosts requires $\log_2 20 = 5$ host bits

  Subnet number: 110/

- D with 18 hosts requires $\log_2 18 = 5$ host bits

  Subnet number: 111/

Problem#5: Solution, part (a)

- Giving each department a single subnet, the nominal subnet sizes are 2^7, 2^6, 2^5, 2^5 respectively (rounding up to the nearest power of 2).
- Subnet numbers are in binary and represent an initial segment of the bits of the last byte of the IP address, anything to the right of the / represents host bits.
- The / thus represents the subnet mask.
- Any individual bit can, by symmetry, be flipped throughout.
- There are several possible bit assignments.
- The essential requirement is that any two distinct subnet numbers remain distinct when the longer one is truncated to the length of the shorter.

Problem#5: Solution, Part (b)

- We have two choices: either assign multiple subnets to single departments or abandon subnets and buy a bridge.
- Here is a solution giving A two subnets of sizes 64 and 32, every other department gets a single subnet of size the next highest power of 2.

  A 01/

  001/

  B 10/

  C 000/

  D 11/