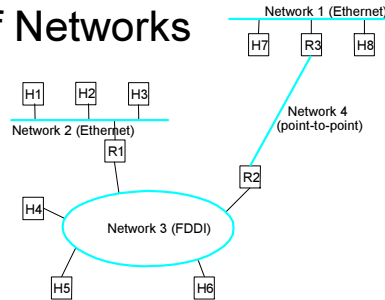
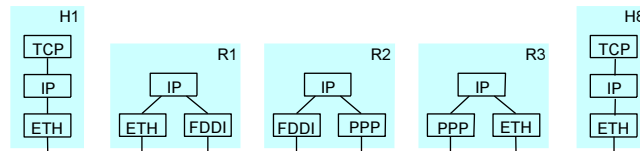


IP Internet

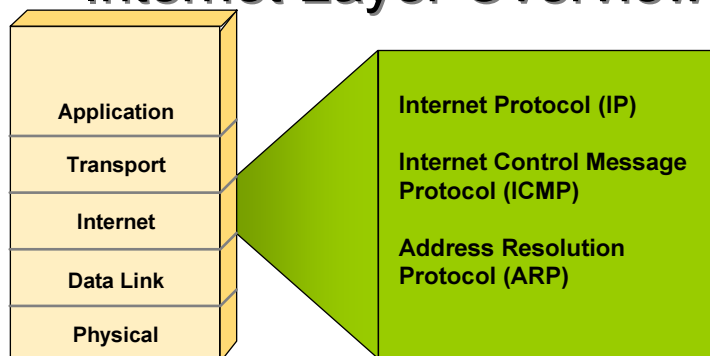
- Concatenation of Networks



- Protocol Stack

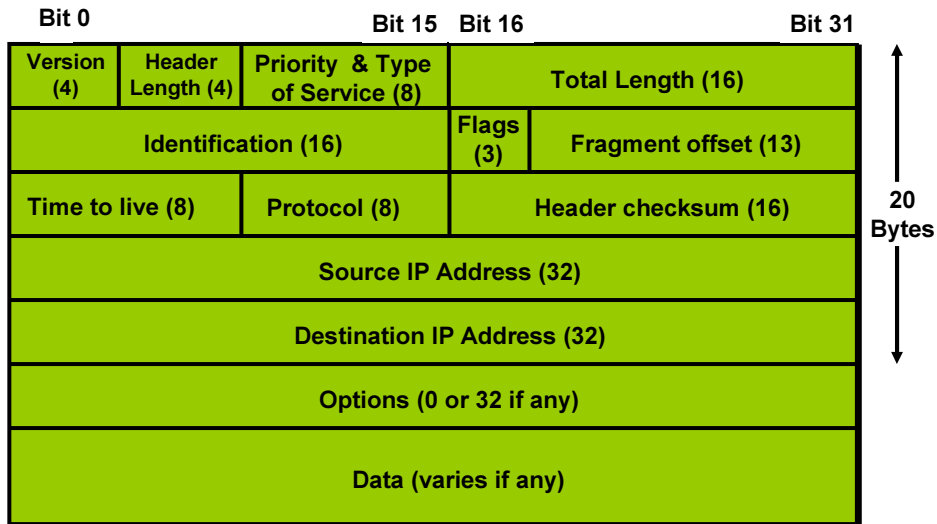


Internet Layer Overview

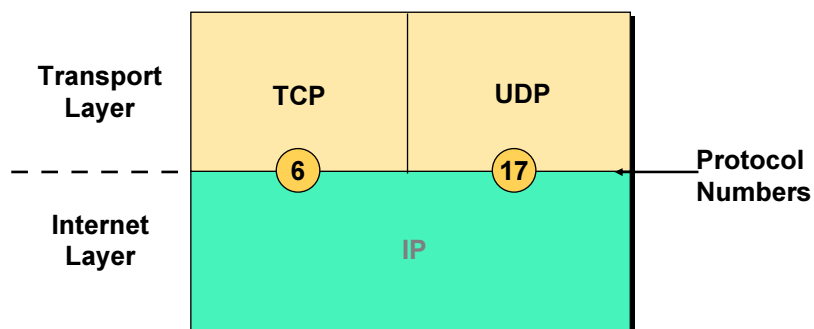


- OSI network layer corresponds to the TCP/IP internet layer
- Connectionless (datagram-based)
- Best-effort delivery (unreliable service)
 - packets are lost
 - packets are delivered out of order
 - duplicate copies of a packet are delivered
 - packets can be delayed for a long time

IP Datagram

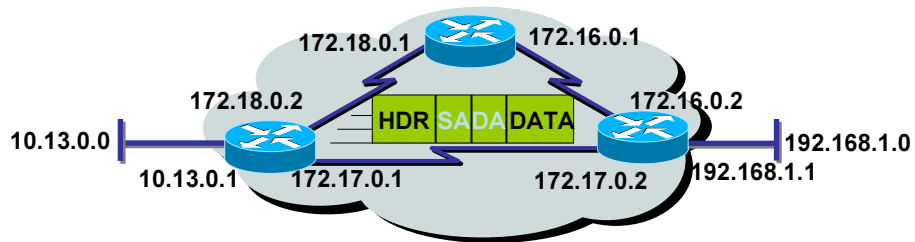


Protocol Field



- Determines destination upper-layer protocol

Introduction to TCP/IP Addresses



- Unique addressing allows communication between end stations
- Path choice is based on location

IP Addressing

| | | | | |
|-----------------|-------------|----------|----------|----------|
| | ← 32 bits → | | | |
| Dotted Decimal | Network | | Host | |
| Maximum | 255 | 255 | 255 | 255 |
| Binary | 11111111 | 11111111 | 11111111 | 11111111 |
| Example Decimal | 172 | 16 | 122 | 204 |
| Example Binary | 10101100 | 00010000 | 01111010 | 11001100 |

IP Address Classes

- Class A:

| 8 bits | 8 bits | 8 bits | 8 bits |
|---------|--------|--------|--------|
| Network | Host | Host | Host |
- Class B:

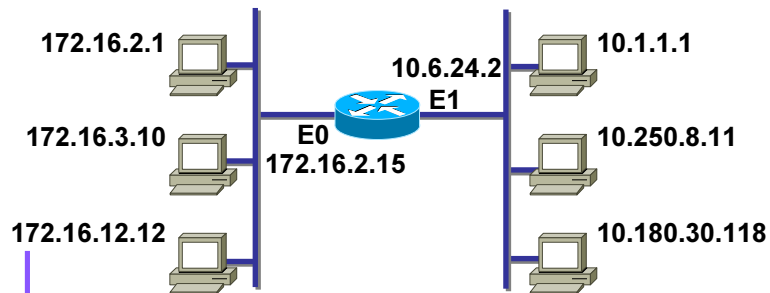
| 8 bits | 8 bits | 8 bits | 8 bits |
|---------|---------|--------|--------|
| Network | Network | Host | Host |
- Class C:

| 8 bits | 8 bits | 8 bits | 8 bits |
|---------|---------|---------|--------|
| Network | Network | Network | Host |
- Class D: Multicast
- Class E: Research

IP Address Classes

| | | | | | |
|-----------------|-----------------|-----------------|-----------------|-----------------|----|
| Bits: | 1 | 8 9 | 16 17 | 24 25 | 32 |
| Class A: | 0NNNNNNN | Host | Host | Host | |
| | Range (1-126) | | | | |
| Bits: | 1 | 8 9 | 16 17 | 24 25 | 32 |
| Class B: | 10NNNNNNN | Network | Host | Host | |
| | Range (128-191) | | | | |
| Bits: | 1 | 8 9 | 16 17 | 24 25 | 32 |
| Class C: | 110NNNNN | Network | Network | Host | |
| | Range (192-223) | | | | |
| Bits: | 1 | 8 9 | 16 17 | 24 25 | 32 |
| Class D: | 1110MMMM | Multicast Group | Multicast Group | Multicast Group | |
| | Range (224-239) | | | | |

Host Addresses



172.16 . 12 . 12
Network Host

| Routing Table | |
|---------------|-----------|
| Network | Interface |
| 172.16.0.0 | E0 |
| 10.0.0.0 | E1 |

Determining Available Host Addresses

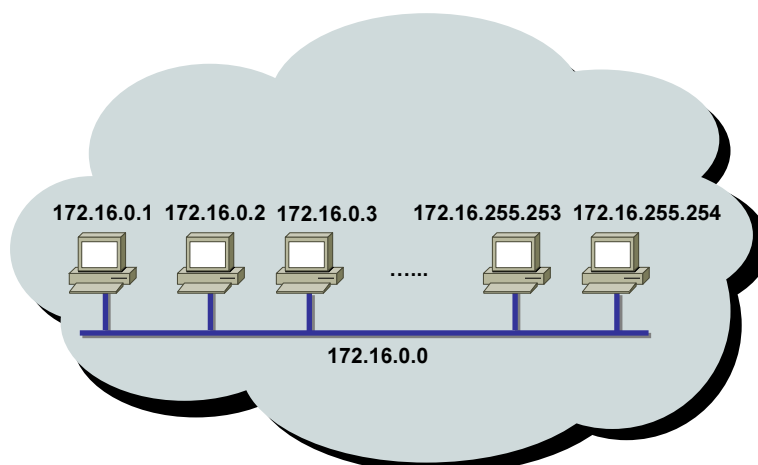
| Network | | Host | |
|-------------------|----|--|-------|
| 172 | 16 | 0 | 0 |
| 10101100 00010000 | | <div> <div>15 14 13 12 11 10 9 8 7 6 5 4 3 2 1 N</div> <div>00000000 00000000</div> <div>00000000 00000001</div> <div>00000000 00000011</div> <div>⋮</div> <div>11111111 11111101</div> <div>11111111 11111110</div> <div>11111111 11111111</div> </div> | |
| | | | 1 |
| | | | 2 |
| | | | 3 |
| | | | ⋮ |
| | | | 65534 |
| | | | 65535 |
| | | | 65536 |
| | | | - 2 |
| | | | 65534 |

$$2^N - 2 = 2^{16} - 2 = 65534$$

IP Address Classes Exercise

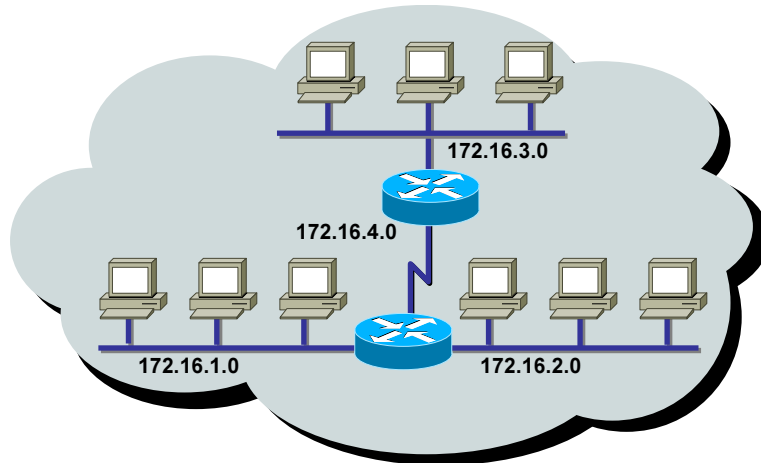
| Address | Class | Network | Host |
|----------------|-------|---------|------|
| 10.2.1.1 | | | |
| 128.63.2.100 | | | |
| 201.222.5.64 | | | |
| 192.6.141.2 | | | |
| 130.113.64.16 | | | |
| 256.241.201.10 | | | |

Addressing without Subnets



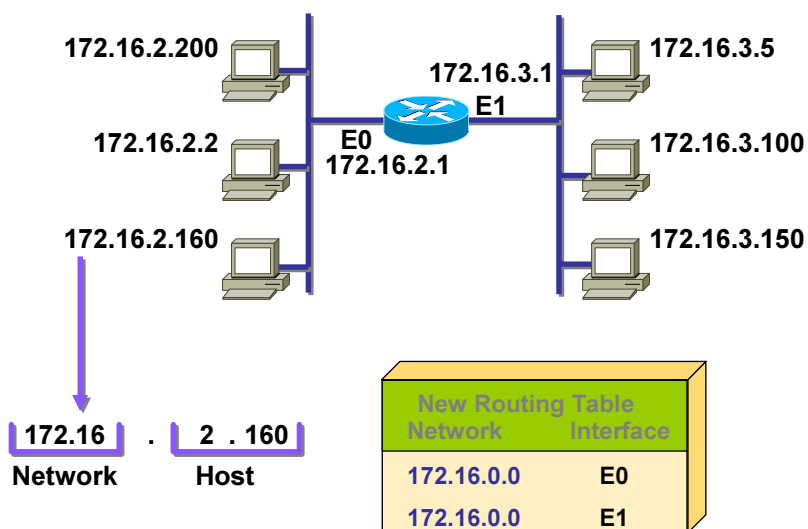
- Network 172.16.0.0

Addressing with Subnets

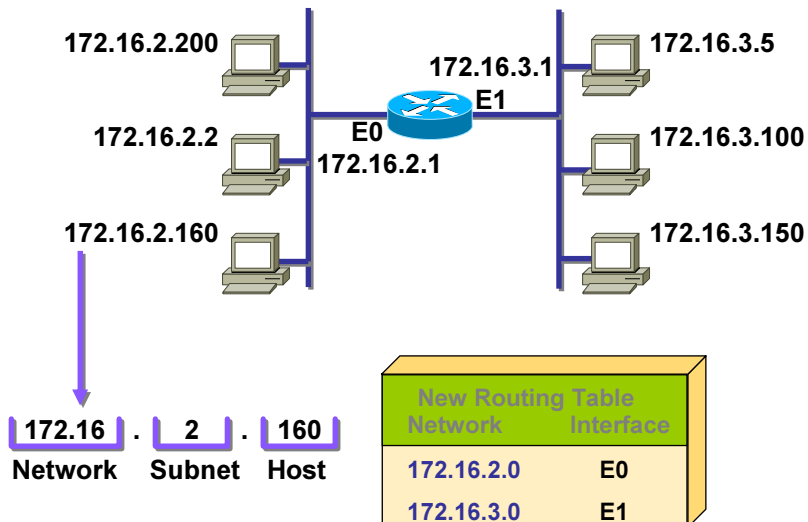


- Network 172.16.0.0

Subnet Addressing



Subnet Addressing



Subnet Mask

| | | | | |
|---|----------|----------|----------|----------|
| | Network | | Host | |
| IP Address | 172 | 16 | 0 | 0 |
| | Network | | Host | |
| Default Subnet Mask | 255 | 255 | 0 | 0 |
| | 11111111 | 11111111 | 00000000 | 00000000 |
| Also written as "/16" where 16 represents the number of 1s in the mask. | | | | |
| | Network | | Subnet | Host |
| 8-bit Subnet Mask | 255 | 255 | 255 | 0 |
| Also written as "/24" where 24 represents the number of 1s in the mask. | | | | |

Decimal Equivalents of Bit Patterns

| 128 | 64 | 32 | 16 | 8 | 4 | 2 | 1 | | |
|-----|----|----|----|---|---|---|---|---|-----|
| ↓ | ↓ | ↓ | ↓ | ↓ | ↓ | ↓ | ↓ | | |
| 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | = | 128 |
| 1 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | = | 192 |
| 1 | 1 | 1 | 0 | 0 | 0 | 0 | 0 | = | 224 |
| 1 | 1 | 1 | 1 | 0 | 0 | 0 | 0 | = | 240 |
| 1 | 1 | 1 | 1 | 1 | 0 | 0 | 0 | = | 248 |
| 1 | 1 | 1 | 1 | 1 | 1 | 0 | 0 | = | 252 |
| 1 | 1 | 1 | 1 | 1 | 1 | 1 | 0 | = | 254 |
| 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | = | 255 |

Subnet Mask without Subnets

| | Network | | Host | |
|----------------|----------|----------|----------|----------|
| 172.16.2.160 | 10101100 | 00010000 | 00000010 | 10100000 |
| 255.255.0.0 | 11111111 | 11111111 | 00000000 | 00000000 |
| | 10101100 | 00010000 | 00000000 | 00000000 |
| Network Number | 172 | 16 | 0 | 0 |

- Subnets not in use—the default

Subnet Mask with Subnets

| | Network | | Subnet | Host |
|---------------|----------|----------|----------|----------|
| 172.16.2.160 | 10101100 | 00010000 | 00000010 | 10100000 |
| 255.255.255.0 | 11111111 | 11111111 | 11111111 | 00000000 |
| | 10101100 | 00010000 | 00000010 | 00000000 |

128
192
224
240
248
252
254
255

Network
Number

| | | | |
|-----|----|---|---|
| 172 | 16 | 2 | 0 |
|-----|----|---|---|

- Network number extended by eight bits

Subnet Mask with Subnets (cont.)

| | Network | | Subnet | Host |
|-----------------|----------|----------|----------|----------|
| 172.16.2.160 | 10101100 | 00010000 | 00000010 | 10100000 |
| 255.255.255.192 | 11111111 | 11111111 | 11111111 | 11000000 |
| | 10101100 | 00010000 | 00000010 | 10000000 |

128
192
224
240
248
252
254
255

Network
Number

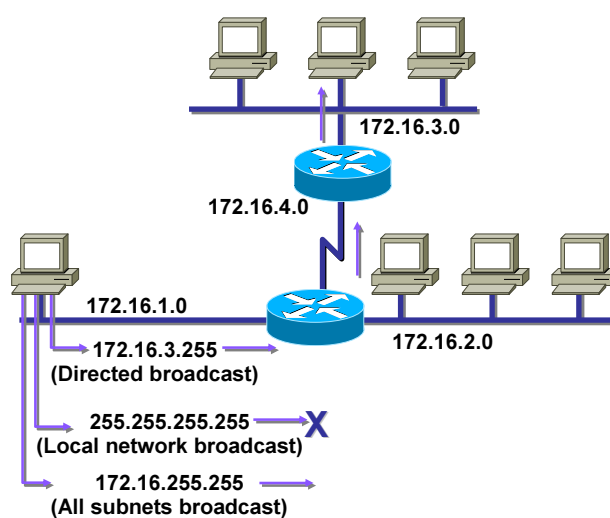
| | | | |
|-----|----|---|-----|
| 172 | 16 | 2 | 128 |
|-----|----|---|-----|

- Network number extended by ten bits

Subnet Mask Exercise

| Address | Subnet Mask | Class | Subnet |
|-------------|---------------|-------|--------|
| 172.16.2.10 | 255.255.255.0 | | |
| 10.6.24.20 | 255.255.240.0 | | |
| 10.30.36.12 | 255.255.255.0 | | |

Broadcast Addresses



Addressing Summary Example

| | | | |
|-----|----|---|-----|
| 172 | 16 | 2 | 160 |
|-----|----|---|-----|

| | | | | | | |
|-----------------|----------|----------|----------|----------|-----------|---|
| 172.16.2.160 | 10101100 | 00010000 | 00000010 | 10100000 | Host | 1 |
| 255.255.255.192 | | | | | Mask | |
| | | | | | Subnet | 4 |
| | | | | | Broadcast | |
| | | | | | First | |
| | | | | | Last | |

Addressing Summary Example

| | | | |
|-----|----|---|-----|
| 172 | 16 | 2 | 160 |
|-----|----|---|-----|

| | | | | | | |
|-----------------|----------|----------|----------|----------|-----------|---|
| 172.16.2.160 | 10101100 | 00010000 | 00000010 | 10100000 | Host | 1 |
| 255.255.255.192 | 11111111 | 11111111 | 11111111 | 11000000 | Mask | 2 |
| | | | | | Subnet | |
| | | | | | Broadcast | |
| | | | | | First | |
| | | | | | Last | |

Addressing Summary Example

| | 172 | 16 | 2 | 160 | |
|-----------------|----------|----------|----------|----------|-----------|
| | | | | | 3 |
| 172.16.2.160 | 10101100 | 00010000 | 00000010 | 10100000 | Host 1 |
| 255.255.255.192 | 11111111 | 11111111 | 11111111 | 11000000 | Mask 2 |
| | | | | | Subnet |
| | | | | | Broadcast |
| | | | | | First |
| | | | | | Last 7 |

Addressing Summary Example

| | 172 | 16 | 2 | 160 | |
|-----------------|----------|----------|----------|----------|-----------|
| | | | | | 3 |
| 172.16.2.160 | 10101100 | 00010000 | 00000010 | 10100000 | Host 1 |
| 255.255.255.192 | 11111111 | 11111111 | 11111111 | 11000000 | Mask 2 |
| | | | | 10000000 | Subnet 4 |
| | | | | | Broadcast |
| | | | | | First |
| | | | | | Last |

Addressing Summary Example

| | 172 | 16 | 2 | 160 | |
|-----------------|----------|----------|----------|----------|-------------|
| | | | | | 3 |
| 172.16.2.160 | 10101100 | 00010000 | 00000010 | 10100000 | Host 1 |
| 255.255.255.192 | 11111111 | 11111111 | 11111111 | 11000000 | Mask 2 |
| | | | | 10000000 | Subnet 4 |
| | | | | 10111111 | Broadcast 5 |
| | | | | | First 6 |
| | | | | | Last |

Addressing Summary Example

| | 172 | 16 | 2 | 160 | |
|-----------------|----------|----------|----------|----------|-------------|
| | | | | | 3 |
| 172.16.2.160 | 10101100 | 00010000 | 00000010 | 10100000 | Host 1 |
| 255.255.255.192 | 11111111 | 11111111 | 11111111 | 11000000 | Mask 2 |
| | | | | 10000000 | Subnet 4 |
| | | | | 10111111 | Broadcast 5 |
| | | | | 10000001 | First 6 |
| | | | | | Last |

Addressing Summary Example

| | 172 | 16 | 2 | 160 | | |
|-----------------|----------|----------|----------|----------|-----------|---|
| | | | | | | 3 |
| 172.16.2.160 | 10101100 | 00010000 | 00000010 | 10100000 | Host | 1 |
| 255.255.255.192 | 11111111 | 11111111 | 11111111 | 11000000 | Mask | 2 |
| | | | | 10000000 | Subnet | 4 |
| | | | | 10111111 | Broadcast | 5 |
| | | | | 10000001 | First | 6 |
| | | | | 10111110 | Last | 7 |

Addressing Summary Example

| | 172 | 16 | 2 | 160 | | |
|-----------------|----------|----------|----------|----------|-----------|---|
| | | | | | | 3 |
| 172.16.2.160 | 10101100 | 00010000 | 00000010 | 10100000 | Host | 1 |
| 255.255.255.192 | 11111111 | 11111111 | 11111111 | 11000000 | Mask | 2 |
| | 10101100 | 00010000 | 00000010 | 10000000 | Subnet | 4 |
| | 10101100 | 00010000 | 00000010 | 10111111 | Broadcast | 5 |
| | 10101100 | 00010000 | 00000010 | 10000001 | First | 6 |
| | 10101100 | 00010000 | 00000010 | 10111110 | Last | 7 |

Addressing Summary Example

| | 172 | 16 | 2 | 160 | |
|-----------------|----------|----------|----------|----------|-------------|
| | | | | | 3 |
| 172.16.2.160 | 10101100 | 00010000 | 00000010 | 10100000 | Host 1 |
| 255.255.255.192 | 11111111 | 11111111 | 11111111 | 11000000 | Mask 2 |
| 172.16.2.128 | 10101100 | 00010000 | 00000010 | 10000000 | Subnet 4 |
| 172.16.2.191 | 10101100 | 00010000 | 00000010 | 10111111 | Broadcast 5 |
| 172.16.2.129 | 10101100 | 00010000 | 00000010 | 10000001 | First 6 |
| 172.16.2.190 | 10101100 | 00010000 | 00000010 | 10111110 | Last 7 |

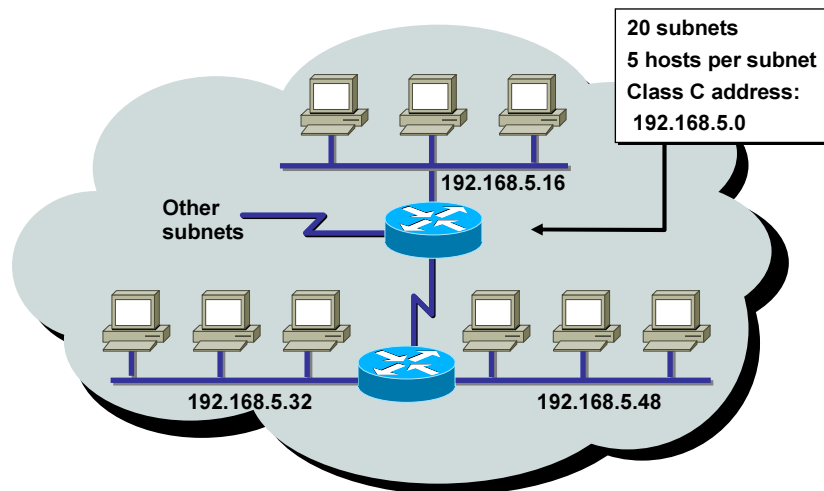
Class B Subnet Example

IP Host Address: 172.16.2.121
Subnet Mask: 255.255.255.0

| | Network | Network | Subnet | Host |
|----------------|----------|----------|----------|----------|
| 172.16.2.121: | 10101100 | 00010000 | 00000010 | 01111001 |
| 255.255.255.0: | 11111111 | 11111111 | 11111111 | 00000000 |
| Subnet: | 10101100 | 00010000 | 00000010 | 00000000 |
| Broadcast: | 10101100 | 00010000 | 00000010 | 11111111 |

- Subnet Address = 172.16.2.0
- Host Addresses = 172.16.2.1–172.16.2.254
- Broadcast Address = 172.16.2.255
- Eight bits of subnetting

Subnet Planning



Class C Subnet Planning Example

IP Host Address: 192.168.5.121
Subnet Mask: 255.255.255.248

| | Network | Network | Network | Subnet | Host |
|------------------|----------|----------|----------|----------|------|
| 192.168.5.121: | 11000000 | 10101000 | 00000101 | 01111001 | |
| 255.255.255.248: | 11111111 | 11111111 | 11111111 | 11111000 | |
| Subnet: | 11000000 | 10101000 | 00000101 | 01111000 | |
| Broadcast: | 11000000 | 10101000 | 00000101 | 01111111 | |

- Subnet Address = 192.168.5.120
- Host Addresses = 192.168.5.121–192.168.5.126
- Broadcast Address = 192.168.5.127
- Five Bits of Subnetting

Broadcast Addresses Exercise

| Address | Subnet Mask | Class | Subnet | Broadcast |
|---------------|-----------------|-------|--------|-----------|
| 201.222.10.60 | 255.255.255.248 | | | |
| 15.16.193.6 | 255.255.248.0 | | | |
| 128.16.32.13 | 255.255.255.252 | | | |
| 153.50.6.27 | 255.255.255.128 | | | |