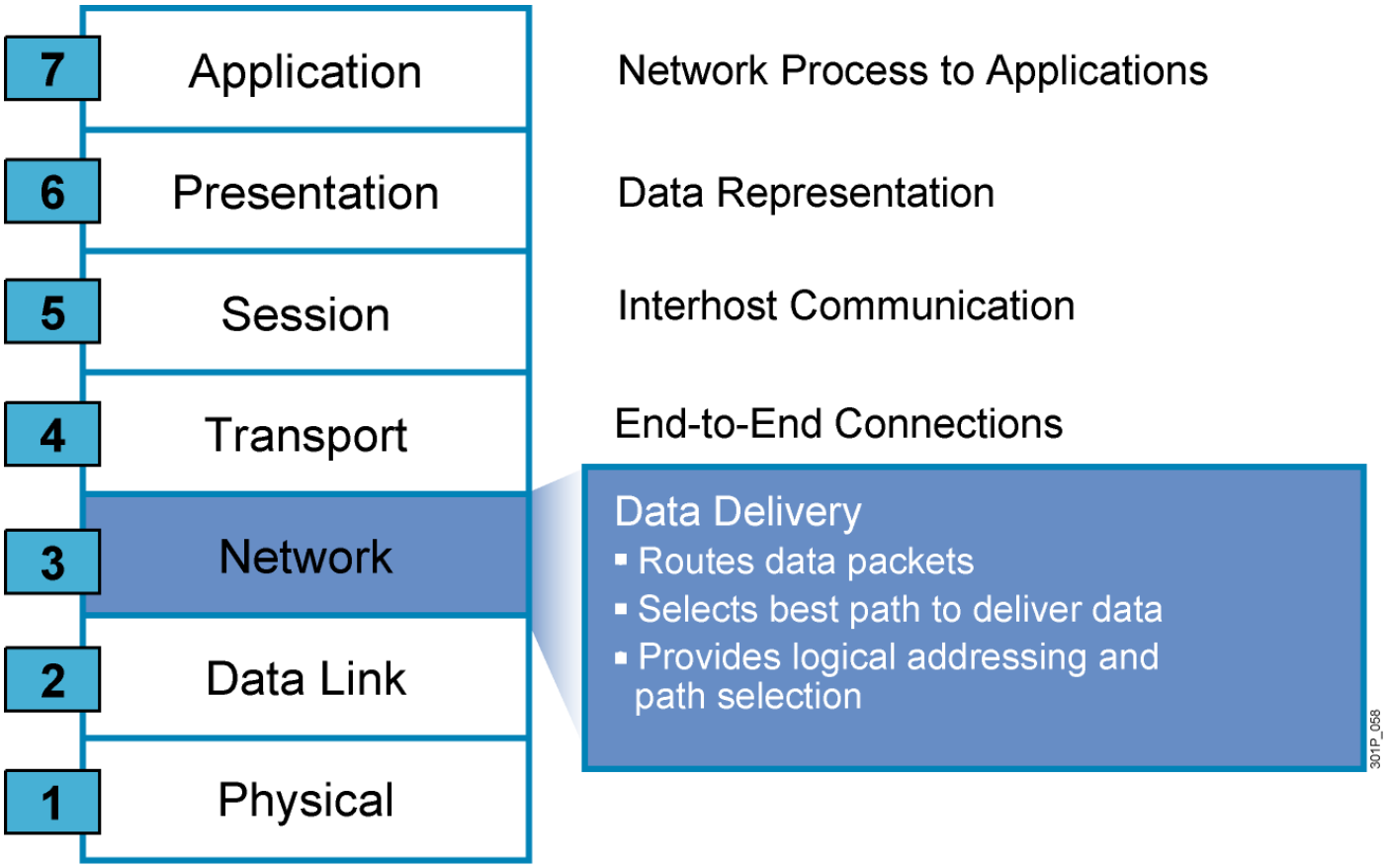
Understanding the TCP/IP Internet Layer

Network Layer



Internet Protocol Characteristics

- Operates at network layer of OSI
- Connectionless protocol
- Packets treated independently
- Hierarchical addressing **Network.Host**
- Best-effort delivery
- No data-recovery features

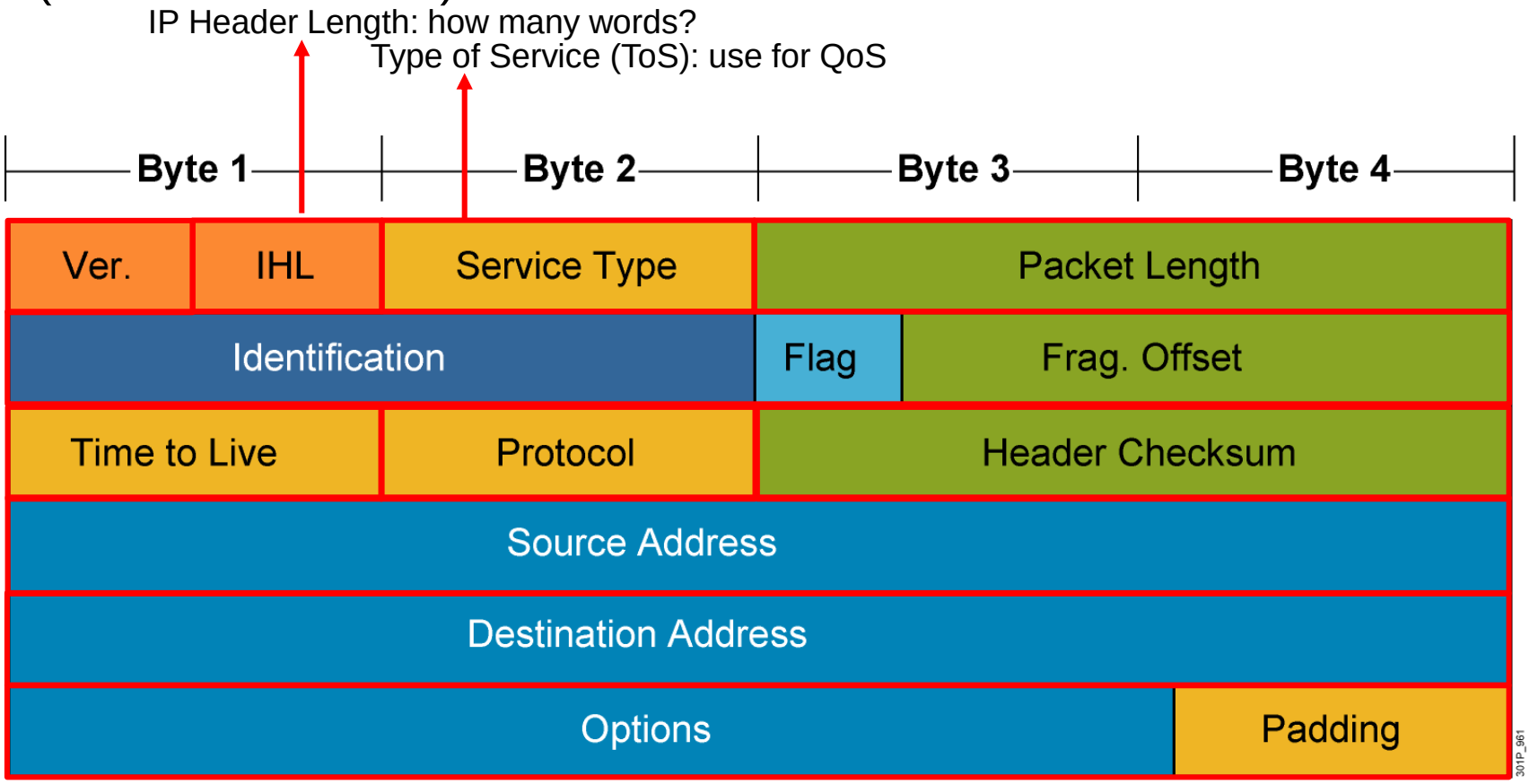
Why IP Addresses?

- They uniquely identify each device on an IP network.
- Every host (computer, networking device, peripheral) must have a unique address.
- Host ID:
  - Identifies the individual host
  - Is assigned by organizations to individual devices

Network.Host

IP PDU Header

(**P**rotocol **D**ata **U**nit)



IP Address Format: Dotted Decimal Notation

	Example			
An IP address is a 32-bit binary number	10101100	00010000	10000000	00010001
For readability, the 32-bit binary number can be divided into four 8-bit octets	10101100	00010000	10000000	00010001
Each octet (or byte) can be converted to decimal	172	16	128	17
The address can be written in dotted decimal notation	172.	16.	128.	17

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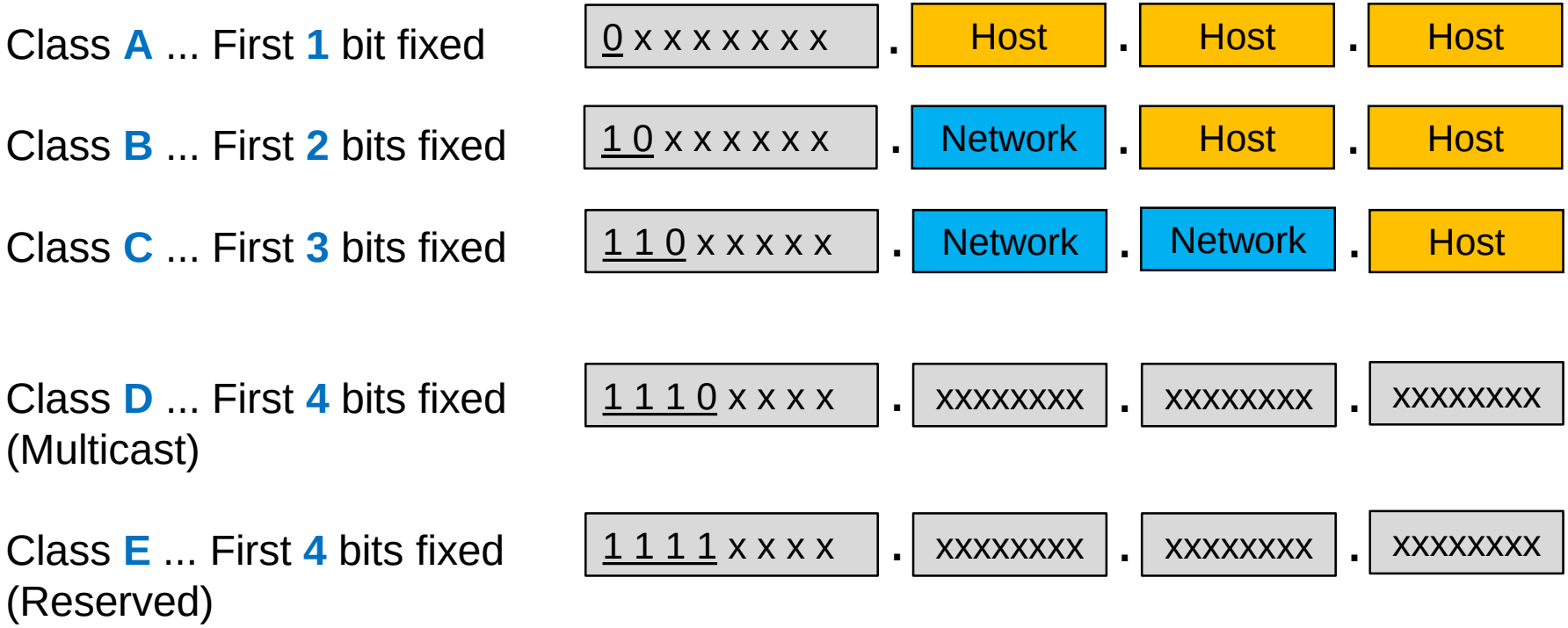
The binary-to-decimal and decimal-to-binary conversion will be detailed later in this course.

IP Address Classes: The First Octet

A B C ... Easy as 1 2 3



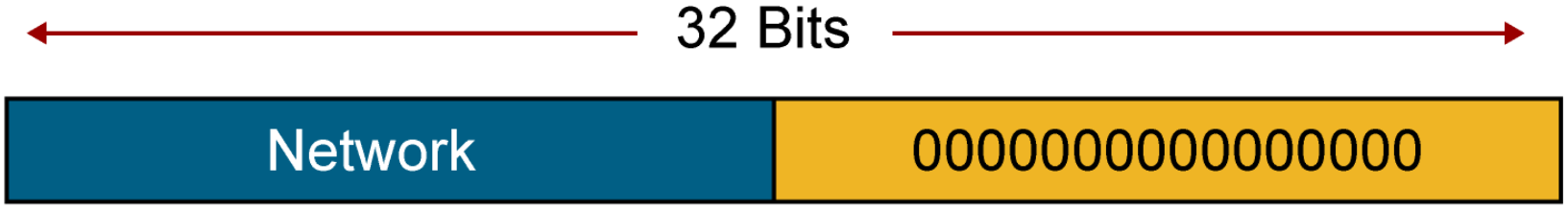
IP Address Ranges

IP Address Class	First Octet Binary Value	First Octet Decimal Value	Possible Number of Hosts
Class A	1-126	00000001 to 01111110*	16,777,214
Class B	128-191	10000000 to 10111111	65,534
Class C	192-223	11000000 to 11011111	254
Class D	224-239	11100000 to 11101111	Multicast
Class E	240-255	11110000 to 11111111*	Reserved for research and experiments

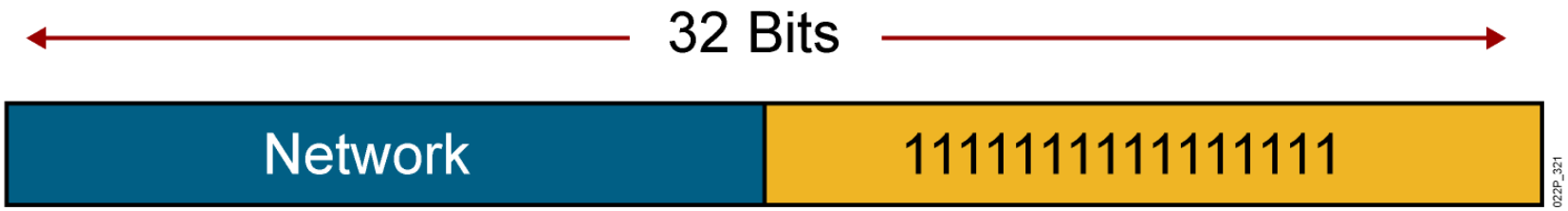
*127 (01111111) is a Class A address reserved for loopback testing and cannot be assigned to a network.

Reserved Address

- Network Addresses



- Broadcast Addresses (Directed Broadcast)

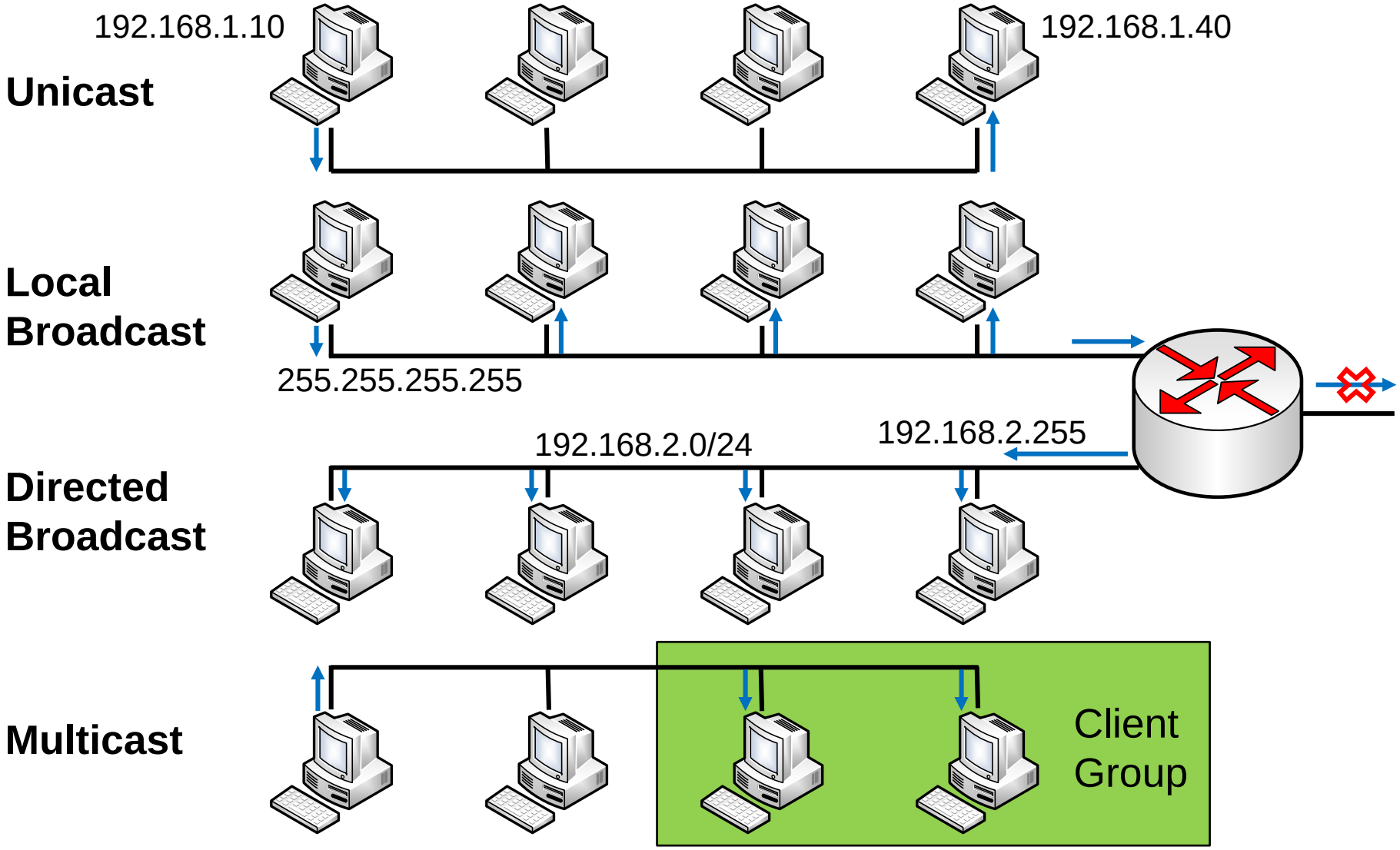


- Local Broadcast Address

  11111111.11111111.11111111.11111111

  → 255.255.255.255

Communication Methods



Public IP Addresses

Class	Public IP Ranges
A	1.0.0.0 to 9.255.255.255 11.0.0.0 to 126.255.255.255
B	128.0.0.0 to 172.15.255.255 172.32.0.0 to 191.255.255.255
C	192.0.0.0 to 192.167.255.255 192.169.0.0 to 223.255.255.255

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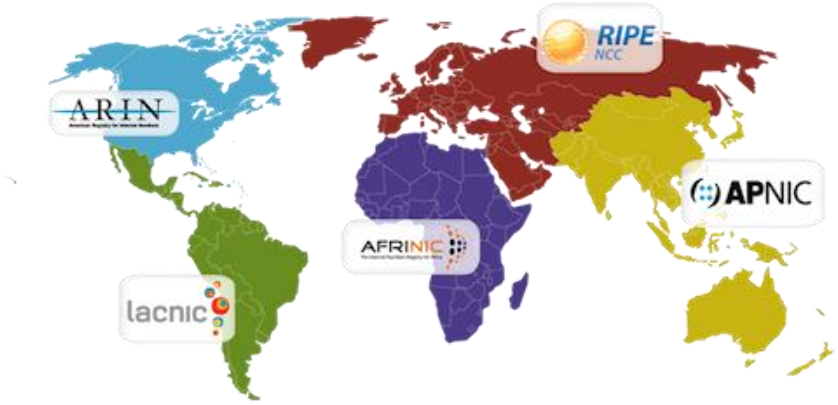
IANA (**I**nternet **A**ssigned **N**umbers **A**uthority)
→ **RIR** (**R**egional **I**nternet **R**egistry)

- AFRINIC (Africa Region)
- APNIC (Asia/Pacific Region)
- ARIN (Canada, USA, and many Caribbean and North Atlantic islands)
- LACNIC (Latin American and Caribbean regions)
- RIPE NCC (Europe, the Middle East and parts of Central Asia)



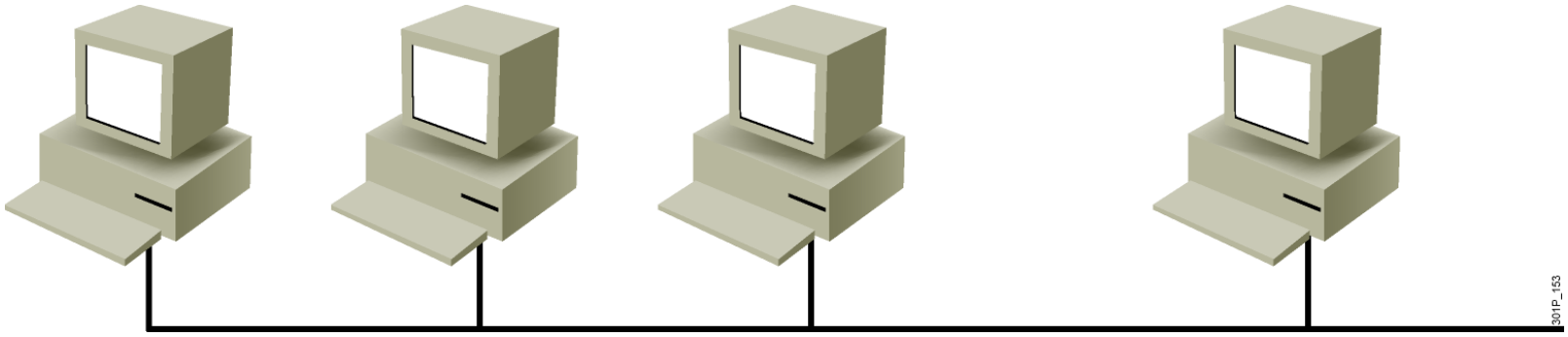
Private IP Addresses

Class	Private Address Range
A	10.0.0.0 to 10.255.255.255
B	172.16.0.0 to 172.31.255.255
C	192.168.0.0 to 192.168.255.255

LAN Connections

Constructing a Network Addressing Scheme

Flat Topology

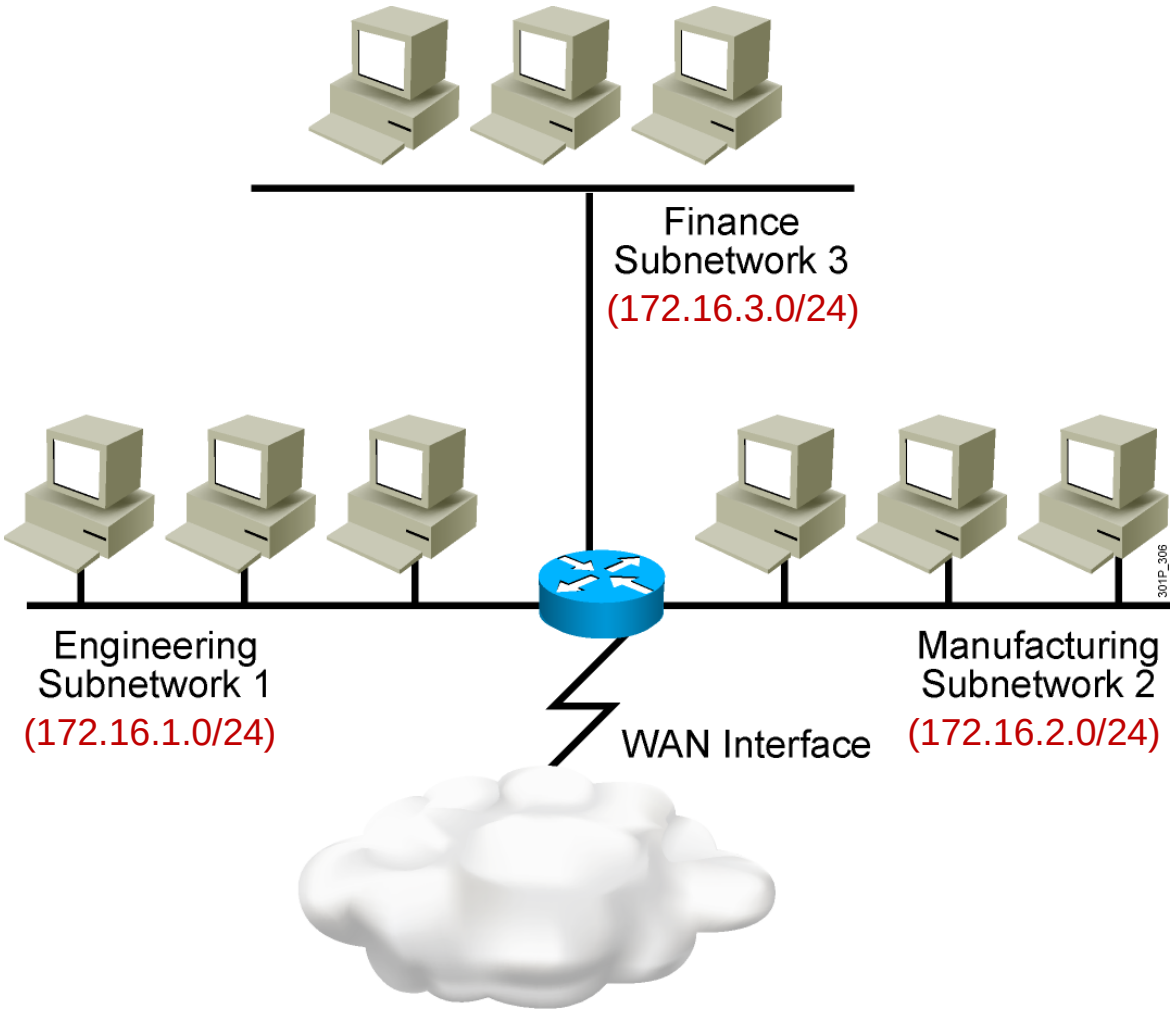


Problems

- All devices share the same bandwidth.
- All devices share the same broadcast domain.
- It is difficult to apply a security policy.

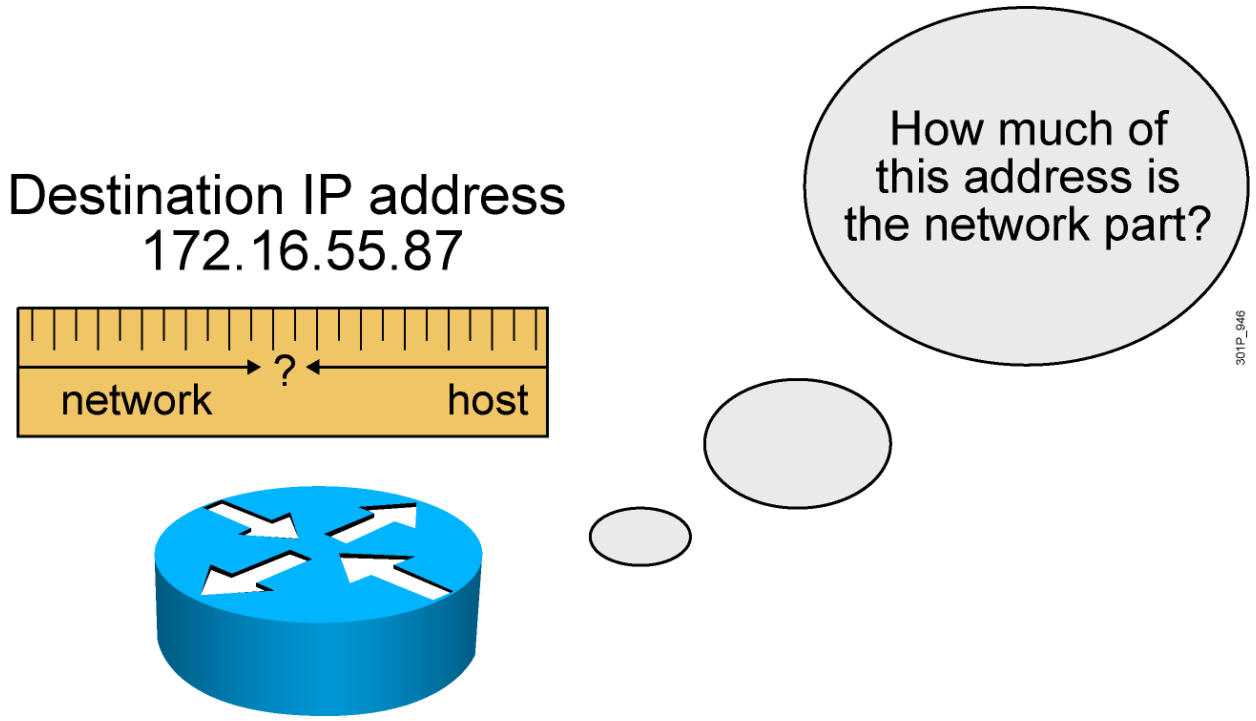
Subnetworks

- Smaller networks are easier to manage.
- Overall traffic is reduced.
- You can more easily apply network security policies.



What a Subnet Mask Does

- **Tells the router the number of bits to look at when routing**
- **Defines the number of bits that are significant**
- **Used as a measuring tool, not to hide anything**



Octet Values of a Subnet Mask

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

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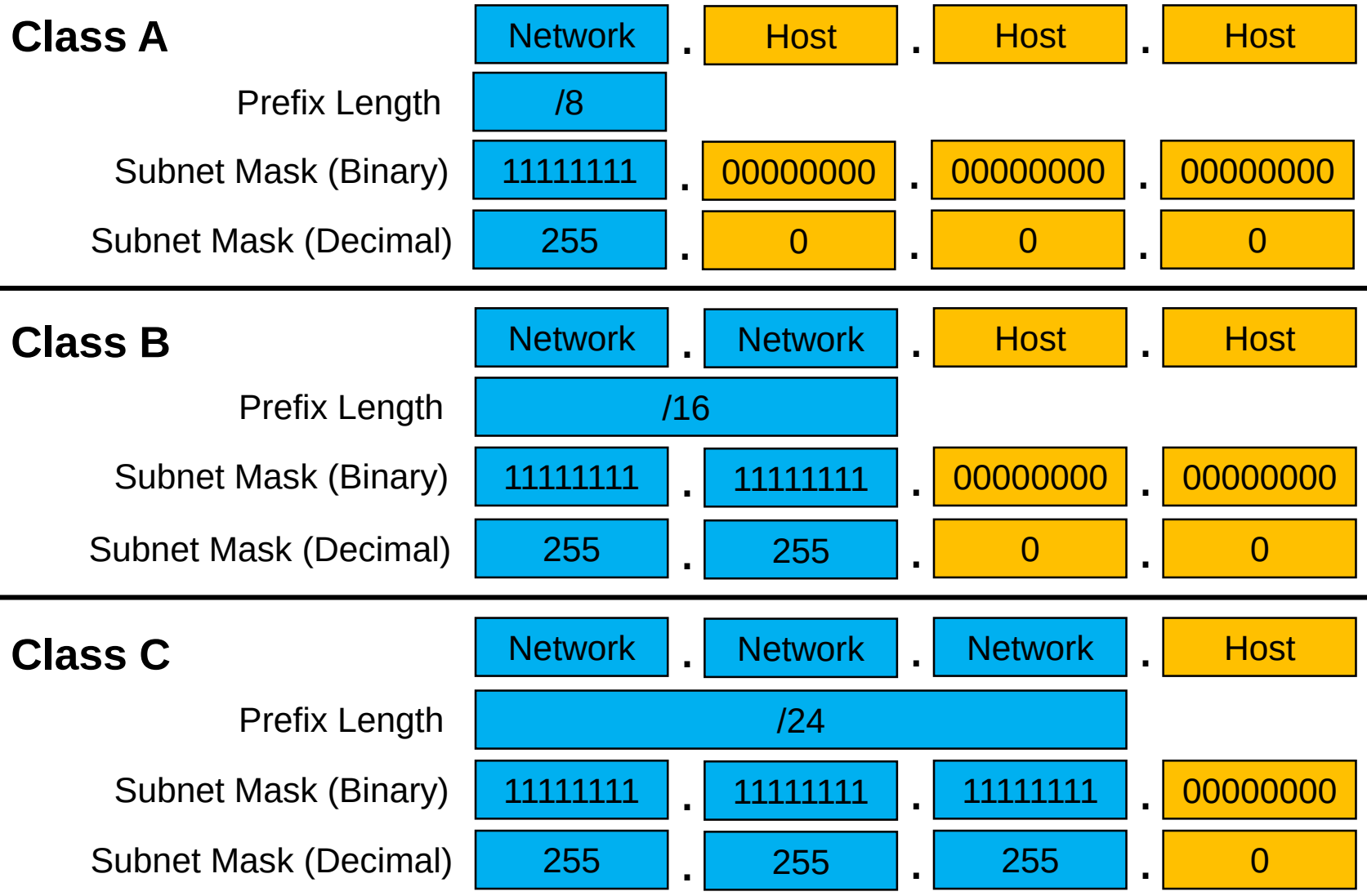
Subnet masks, like IP addresses, are represented in the dotted decimal format like 255.255.255.0

Prefix-Length vs Subnet Mask of Major Networks



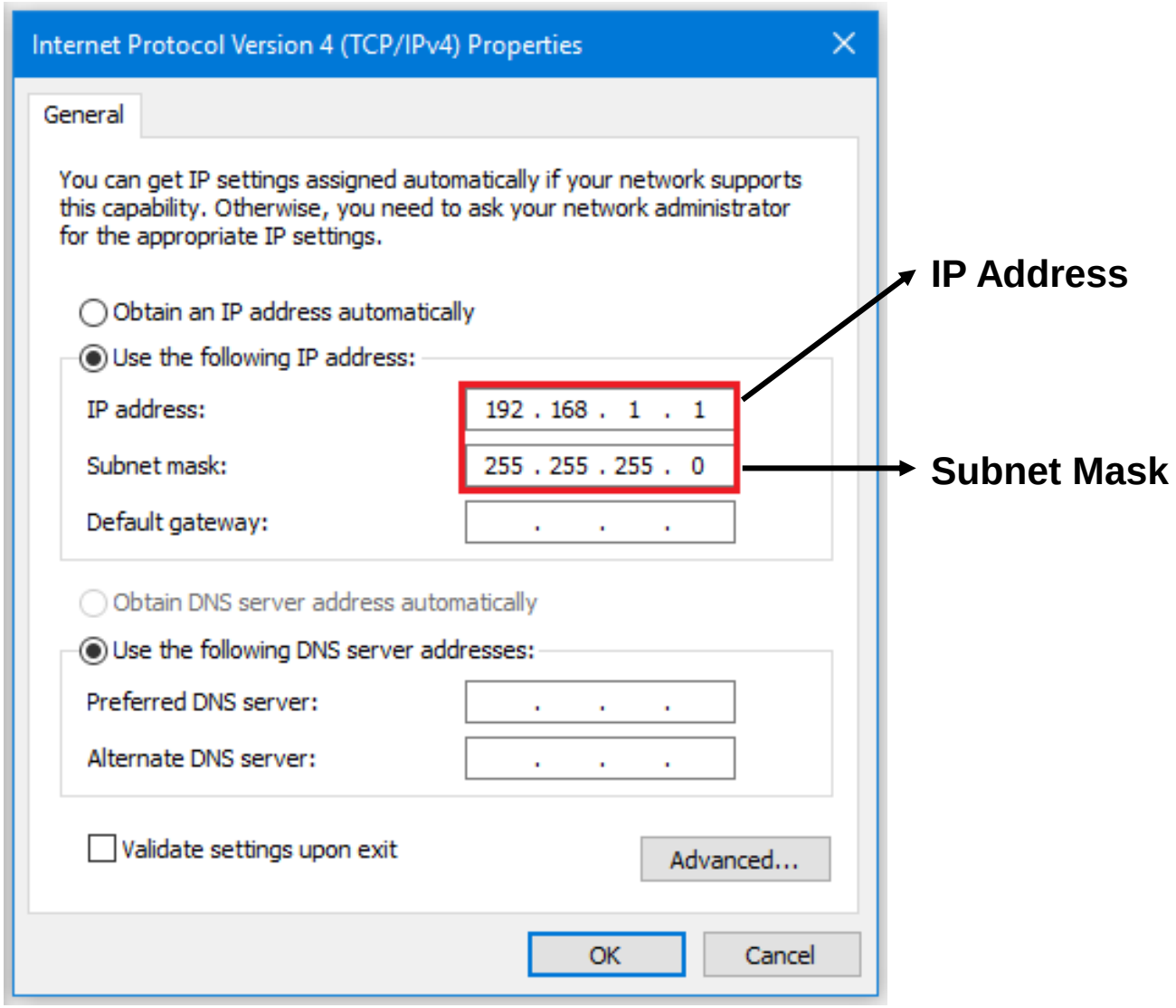
Default Subnet Masks

Example Class A address (decimal):	10.0.0.0
Example Class A address (binary):	00001010.00000000.00000000.00000000
Default Class A mask (binary):	11111111.00000000.00000000.00000000
Default Class A mask (decimal):	255.0.0.0
Default classful prefix length:	/8

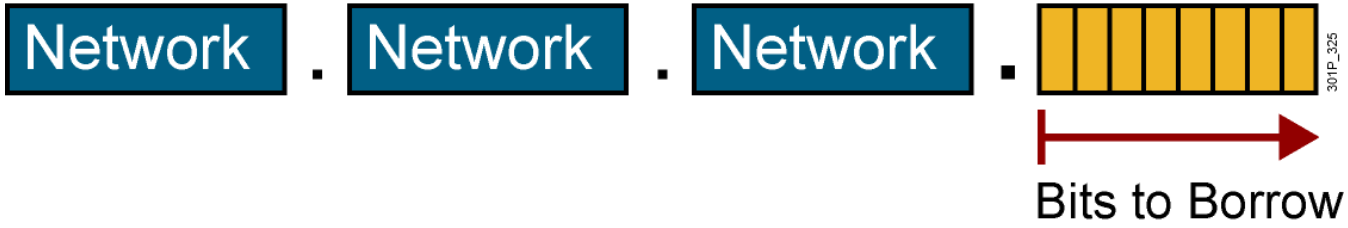
Example Class B address (decimal):	172.16.0.0
Example Class B address (binary):	10101100.00010000.00000000.00000000
Default Class B mask (binary):	11111111.11111111.00000000.00000000
Default Class B mask (decimal):	255.255.0.0
Default classful prefix length:	/16

Example Class C address (decimal):	192.168.42.0
Example Class C address (binary):	11000000.10101000.00101010.00000000
Default Class C mask (binary):	11111111.11111111.11111111.00000000
Default Class C mask (decimal):	255.255.255.0
Default classful prefix length:	/24

Setup IP Address for Windows



Possible Subnets and Hosts for a Class C Network



Number of Bits Borrowed (s)	Number of Subnets Possible (2^s)	Number of Bits Remaining in Host ID (8 - s = h)	Number of Hosts Possible Per Subnet ($2^h - 2$)
1	2	7	126
2	4	6	62
3	8	5	30
4	16	4	14
5	32	3	6
6	64	2	2
7	128	1	2

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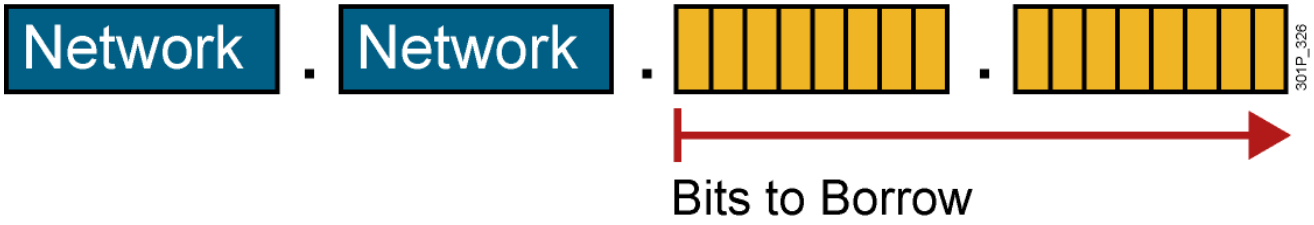
Possible Subnets and Hosts for a Class B Network



Number of Bits Borrowed (s)	Number of Subnets Possible (2^s)	Number of Bits Remaining in Host ID ($16 - s = h$)	Number of Hosts Possible Per Subnet ($2^h - 2$)
1	2	15	32,766
2	4	14	16,382
3	8	13	8,190
4	16	12	4,094
5	32	11	2,046
6	64	10	1,022
7	128	9	510
…	…	…	…

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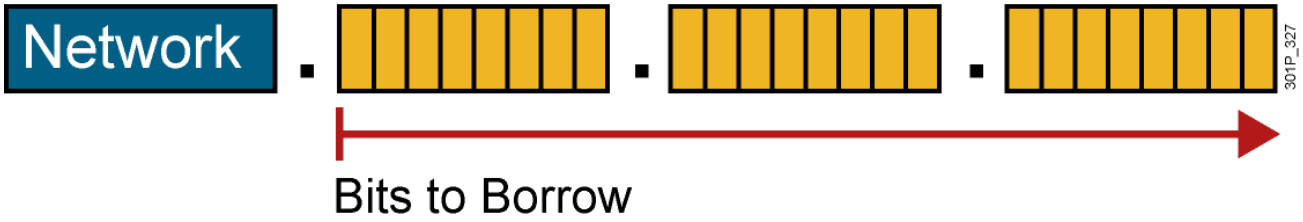
Possible Subnets and Hosts for a Class A Network



Number of Bits Borrowed (s)	Number of Subnets Possible (2^s)	Number of Bits Remaining in Host ID ($24 - s = h$)	Number of Hosts Possible Per Subnet ($2^h - 2$)
1	2	23	8,388,606
2	4	22	4,194,302
3	8	21	2,097,150
4	16	20	1,048,574
5	32	19	524,286
6	64	18	262,142
7	128	17	131,070
…	…	…	…

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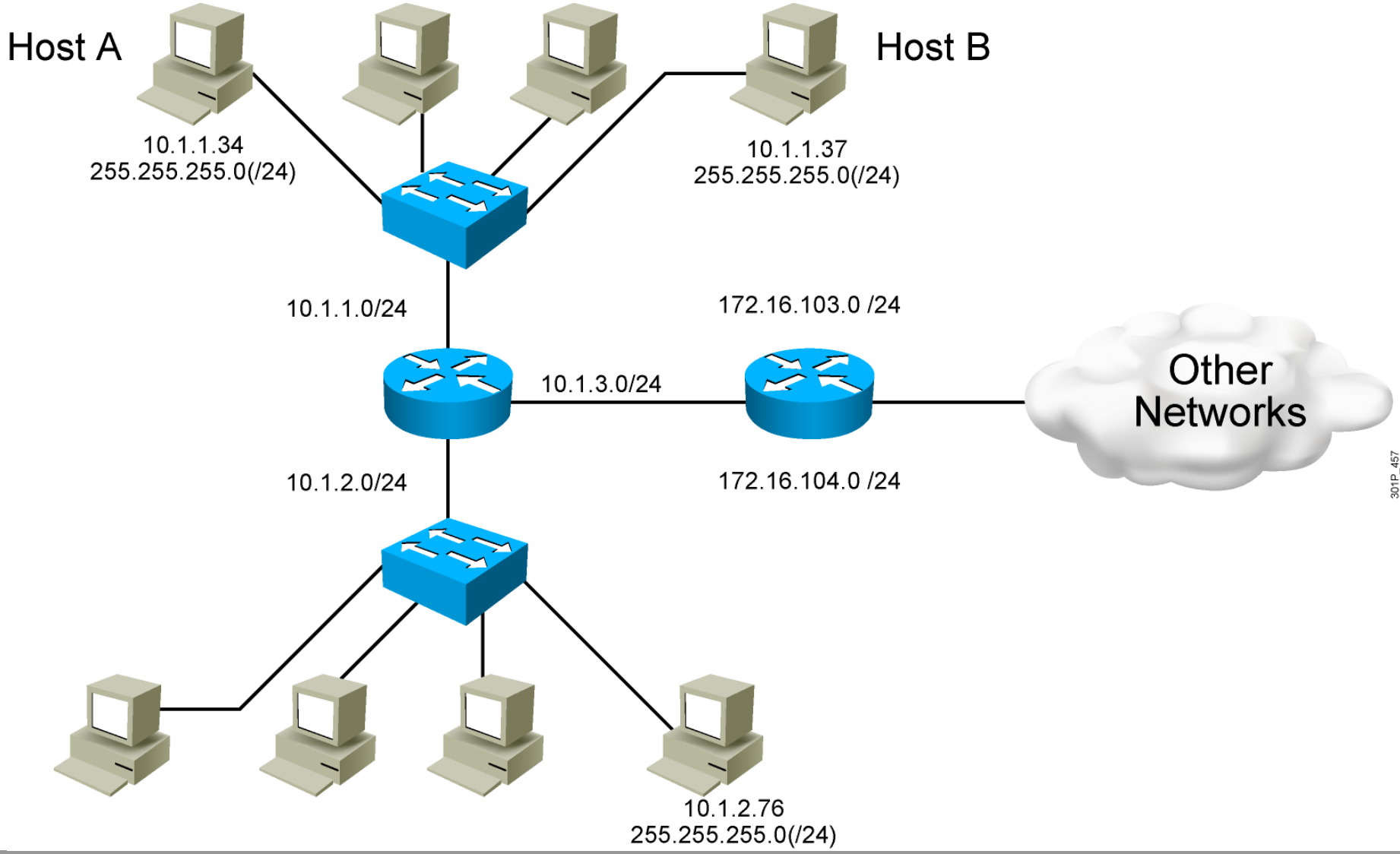
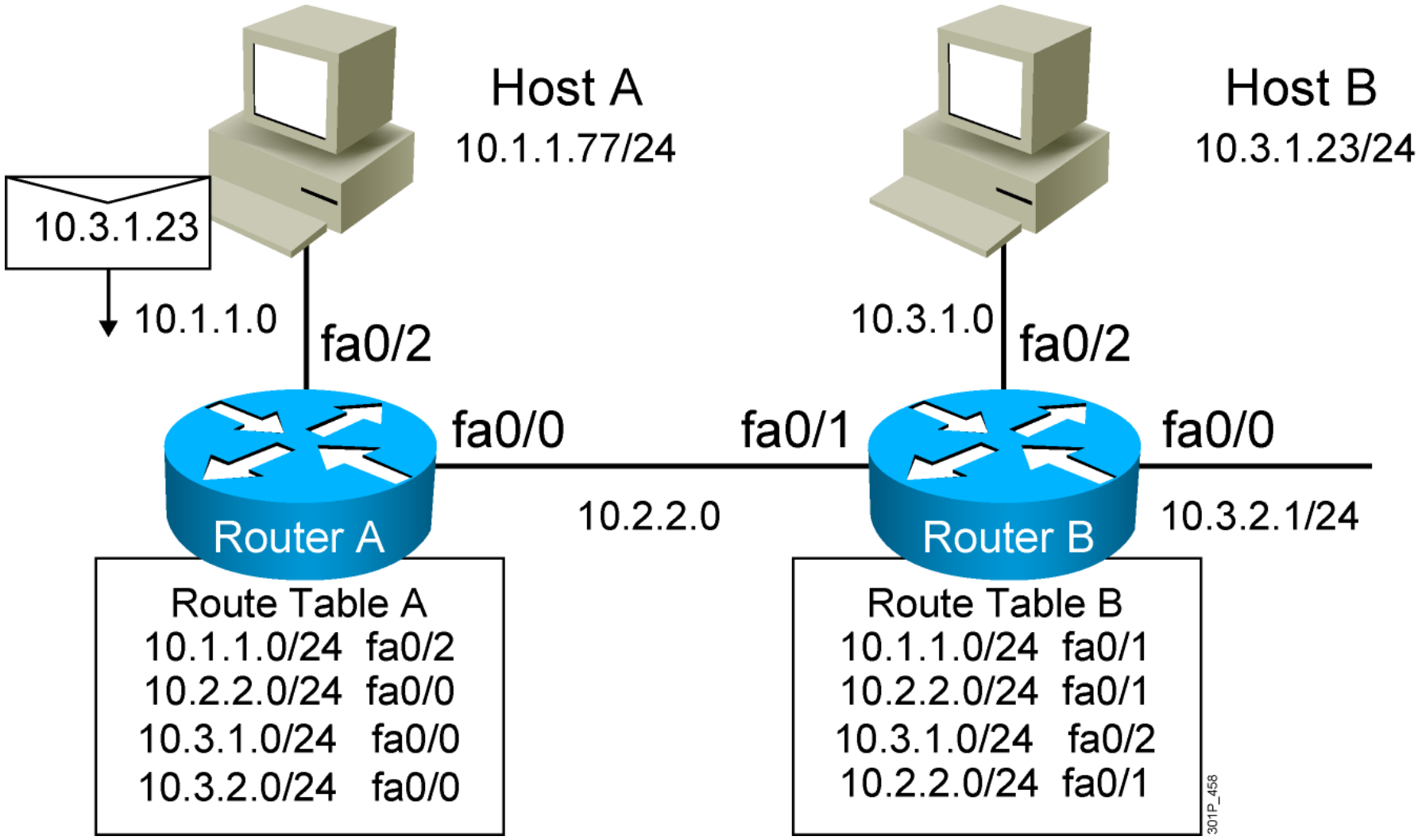
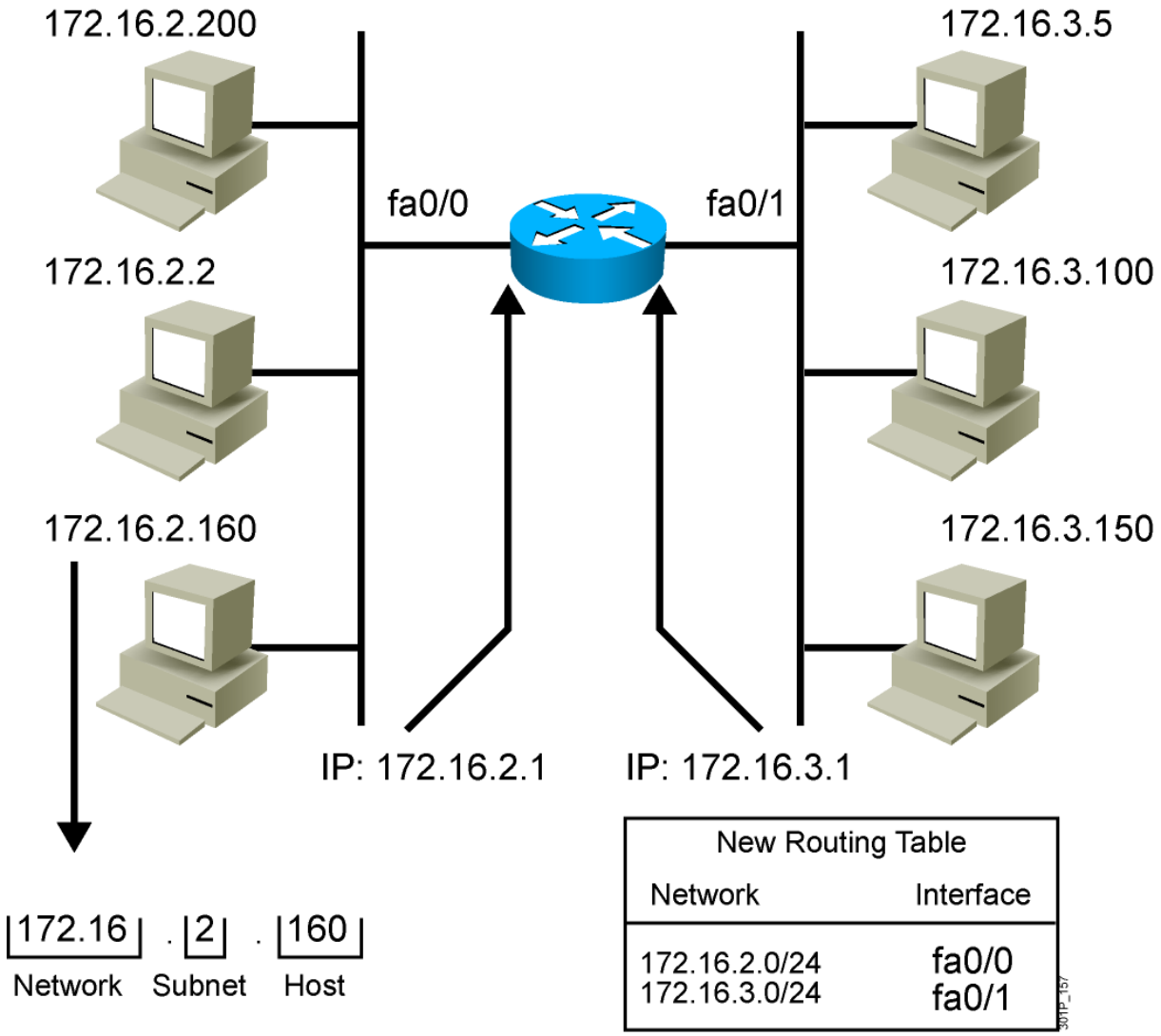
End System Subnet Mask Operation



How Routers Use Subnet Masks



Applying the Subnet Address Scheme



Eight Easy Steps for Determining Subnet Addresses

IP Address: 192.168.221.37 Subnet Mask /29

Step	Description	Example
1.	Write the octet that is being split in binary.	Fourth octet: 00100101
2.	Write the mask or classful prefix length in binary.	Assigned mask: 255.255.255.248 (/29) Fourth octet: 11111000
3.	Draw a line to delineate the significant bits in the assigned IP address. Cross out the mask so you can view the significant bits in the IP address.	Split octet (binary): 00100101 Split mask (binary): 11111000

Eight Easy Steps for Determining Subnet Addresses (Cont.)

Step	Description	Example
4.	Copy the significant bits four times.	00100 000 (network address) 00100 001 (first address in subnet) 00100 110 (last address in subnet) 00100 111 (broadcast address)?
5.	In the first line, define the network address by placing all zeros in the significant bits.	
6.	In the last line, define the broadcast address by placing all ones in the significant bits.	
7.	In the middle lines, define the first and last host number.	
8.	Increment the subnet bits by one.	00101 000 (next subnet)

Completed Subnet Addresses

Network address: 192.168.221.32
Subnet mask: 255.255.255.248
First subnet: 192.168.221.32
First host address: 192.168.221.33
Last host address: 192.168.221.38
Broadcast address: 192.168.221.39
Next subnet: 192.168.221.40

Example: Applying a Subnet Mask for a Class C Address

IP Address 192.168.5.139 Subnet Mask 255.255.255.224

IP Address	192	168	5	139	
IP Address					(Binary)
Subnet Mask					
Subnetwork					(Binary)
Subnetwork					(Decimal)
First Host					
Last Host					
Directed Broadcast					
Next Subnet					

Example: Applying a Subnet Mask for a Class C Address (cont.)

IP Address 192.168.5.139 Subnet Mask 255.255.255.224

IP Address	192	168	5	139	
IP Address	11000000	10101000	00000101	10001011	
Subnet Mask	11111111	11111111	11111111	11100000	/27
Subnetwork	11000000	10101000	00000101	10000000	
Subnetwork	192	168	5	128	
First Host	192	168	5	10000001=129	
Last Host	192	168	5	10011110=158	
Directed Broadcast	192	168	5	10011111=159	
Next Subnet	192	168	5	10100000=160	

Example: Applying a Subnet Mask for a Class B Address

IP Address 172.16.139.46 Subnet Mask /20

IP Address	172	16	139	46	
IP Address					(Binary)
Subnet Mask					
Subnetwork					(Binary)
Subnetwork					(Decimal)
First Host					
Last Host					
Directed Broadcast					
Next Subnet					

Example: Applying a Subnet Mask for a Class B Address (cont.)

IP Address 172.16.139.46 Subnet Mask /20

IP Address	172	16	139	46	
IP Address	10101100	00010000	10001011	00101110	
Subnet Mask	11111111	11111111	11110000	00000000	/20
Subnetwork	10101100	00010000	10000000	00000000	
Subnetwork	172	16	128	0	
First Host	172	16	10000000	00000001=128.1	
Last Host	172	16	10001111	11111110=143.254	
Directed Broadcast	172	16	10001111	11111111=143.255	
Next Subnet	172	16	10010000	00000000=144.0	

Example: Applying a Subnet Mask for a Class A Address

IP Address 10.172.16.211 Subnet Mask /18

IP Address	10	172	16	211	
IP Address					(Binary)
Subnet Mask					
Subnetwork					(Binary)
Subnetwork					(Decimal)
First Host					
Last Host					
Directed Broadcast					
Next Subnet					

Example: Applying a Subnet Mask for a Class A Address (cont.)

IP Address 10.172.16.211 Subnet Mask /18

IP Address	10	172	16	211	
IP Address	00001010	10101100	00010000	11010011	
Subnet Mask	11111111	11111111	11000000	00000000	/18
Subnetwork	00001010	10101100	00000000	00000000	
Subnetwork	10	172	0	0	
First Host	10	172	00000000	00000001=0.1	
Last Host	10	172	00111111	11111110=63.254	
Directed Broadcast	10	172	00111111	11111111=63.255	
Next Subnet	10	172	01000000	00000000=64.0	

Summary

- **IP network addresses consist of two parts: the network ID and the host ID.**
- **IPv4 addresses have 32 bits that are divided into octets and are generally shown in dotted decimal form (for example, 192.168.54.18).**
- **When written in a binary format, the first bit of a Class A address is always 0, the first 2 bits of a Class B address are always 10, and the first 3 bits of a Class C address are always 110.**

Summary (Cont.)

Follow these steps to determine the subnetwork and host addresses using a subnet mask:

1. **Write the octet being split in binary.**
2. **Write the mask in binary and draw a line to delineate the significant bits.**
3. **Cross out the mask so you can view the significant bits.**
4. **Copy the subnet bits four times.**
5. **Define the network address by placing all zeroes in the host bits.**
6. **Define the broadcast address by placing all ones in the host bits.**
7. **Define the first and last host numbers.**
8. **Increment the subnet bits by one.**


CISCO