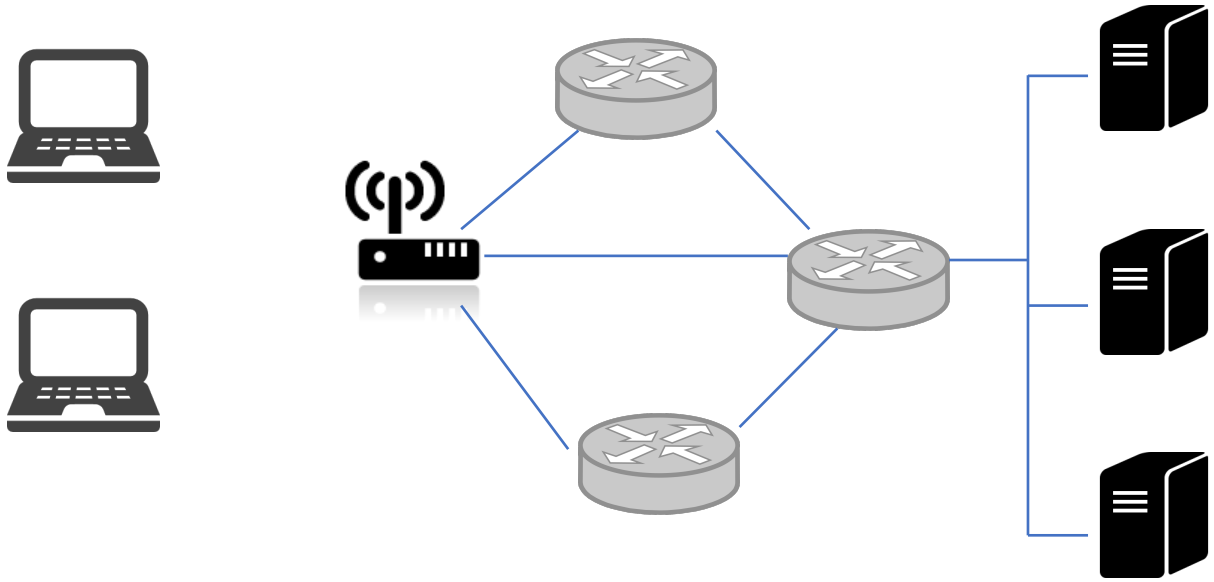
Dr Takfarinas SABER
takfarinas.saber@dcu.ie

CA169
Networks & Internet

IP Addressing

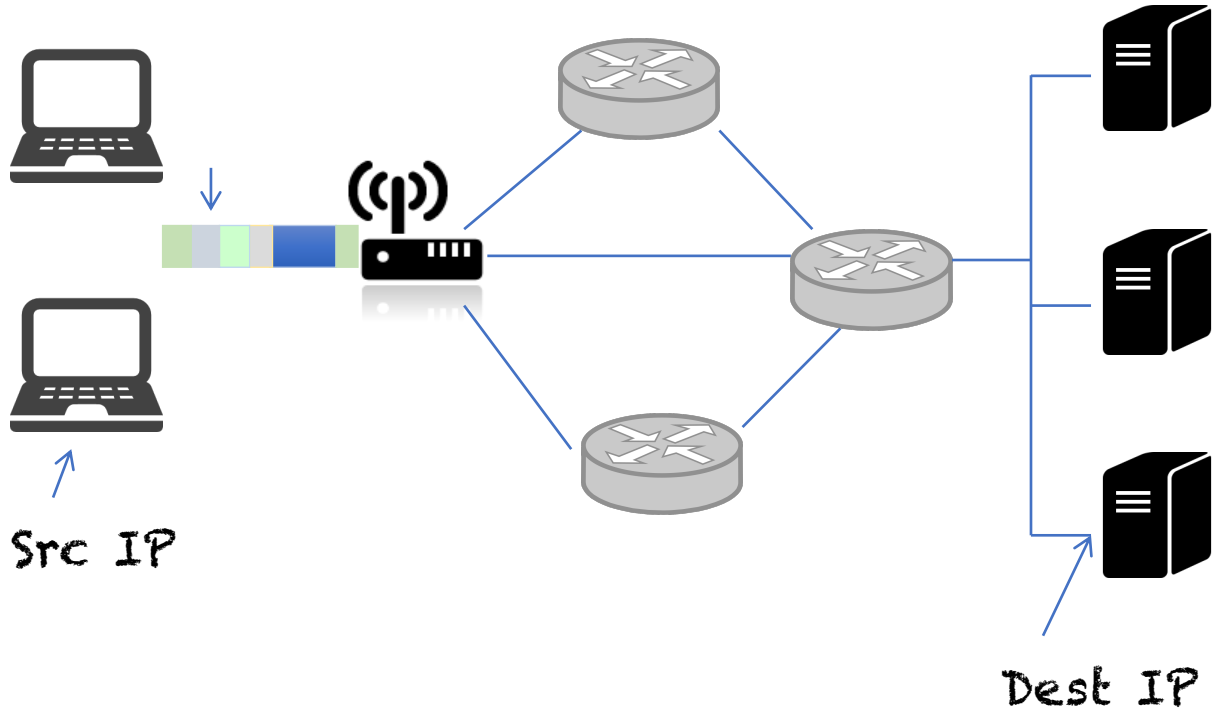
IP Addressing

- IP addressing is an **end to end** addressing
- IP address must be **unique** world wide
- It addresses the intended recipient at all times



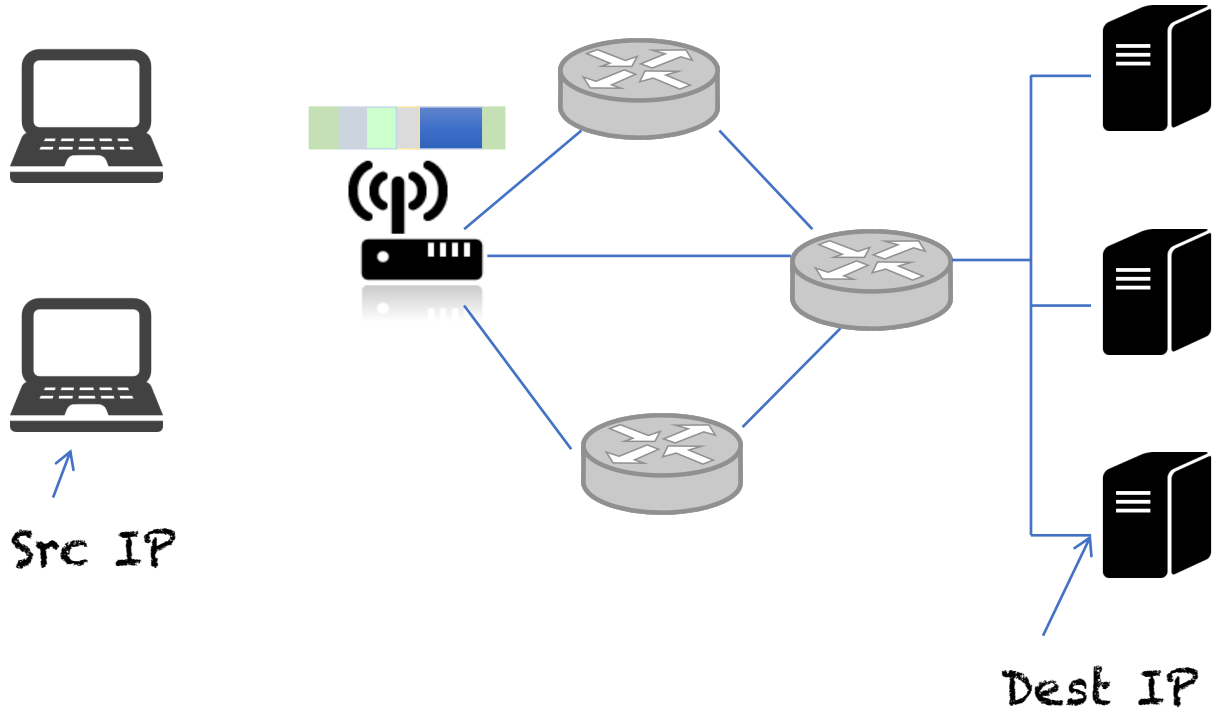
IP Addressing

- IP addressing is an **end to end** addressing
- IP address must be **unique** world wide
- It addresses the intended recipient at all times



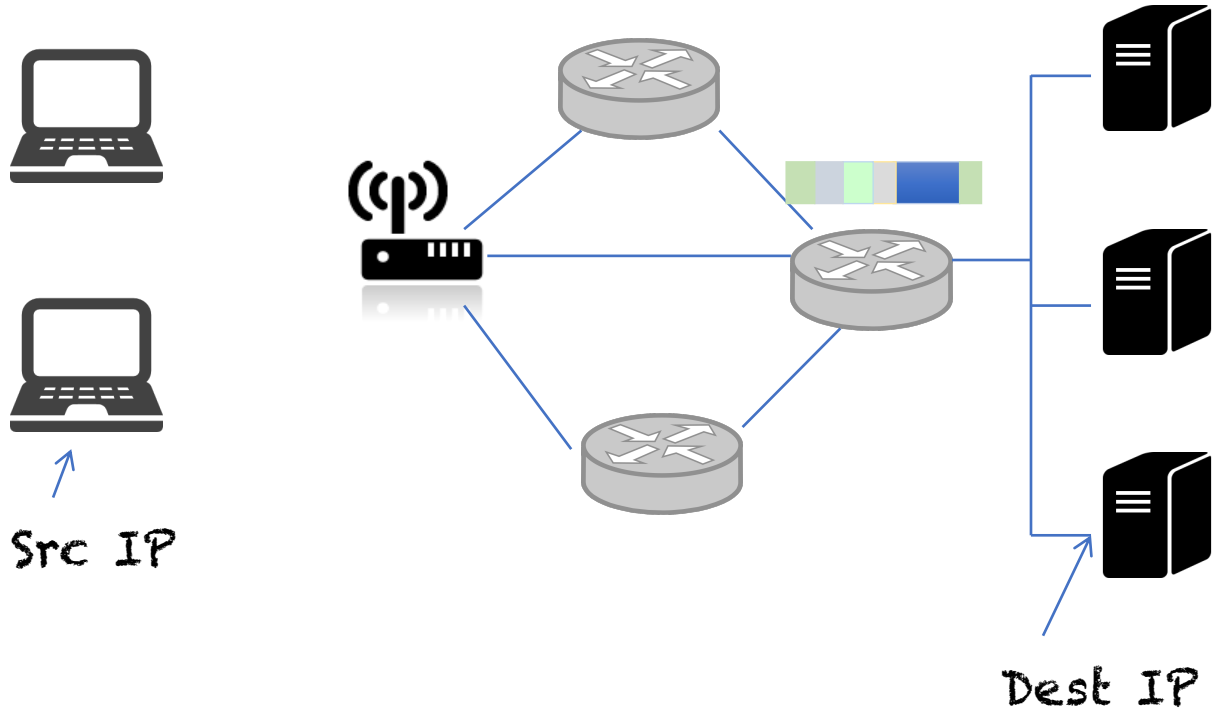
IP Addressing

- IP addressing is an **end to end** addressing
- IP address must be **unique** world wide
- It addresses the intended recipient at all times



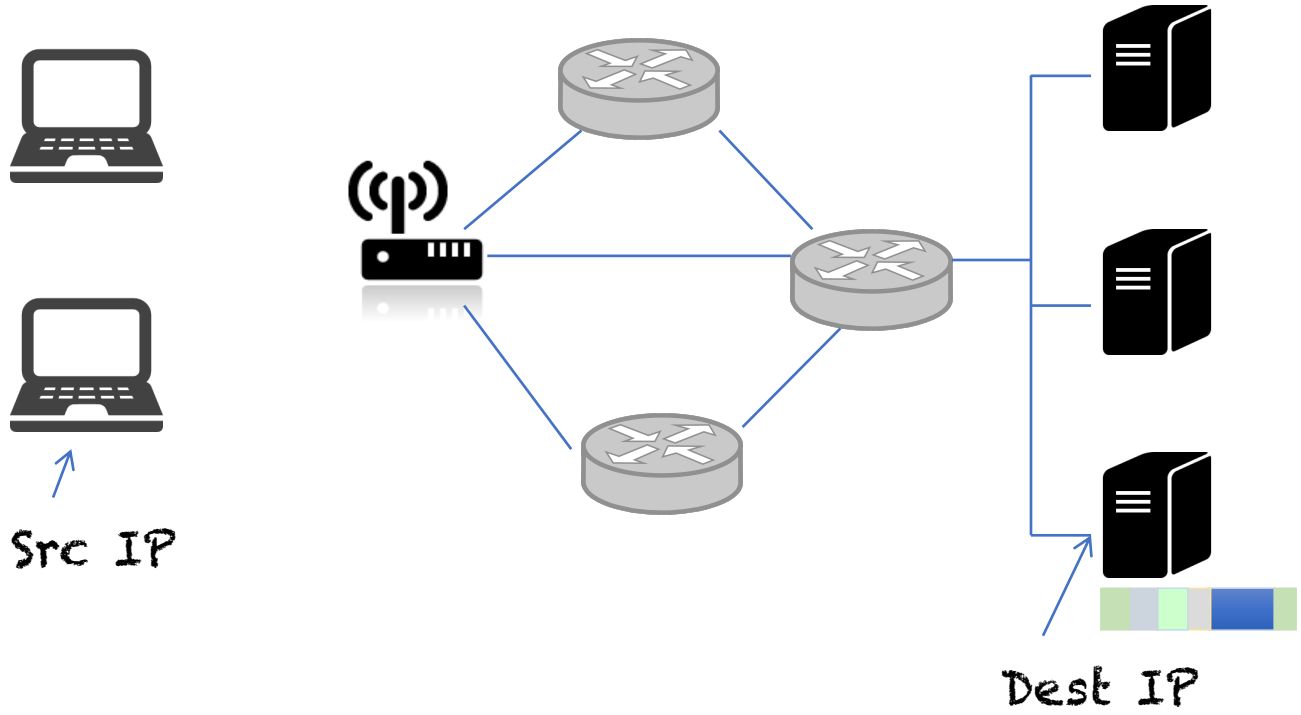
IP Addressing

- IP addressing is an **end to end** addressing
- IP address must be **unique** world wide
- It addresses the intended recipient at all times



IP Addressing

- IP addressing is an **end to end** addressing
- IP address must be **unique** world wide
- It addresses the intended recipient at all times



IP Addressing

- The IP address is a 32-bit Address
- 32 bits can address how many individual devices?

```
00000000.00000000.00000000.00000000
```

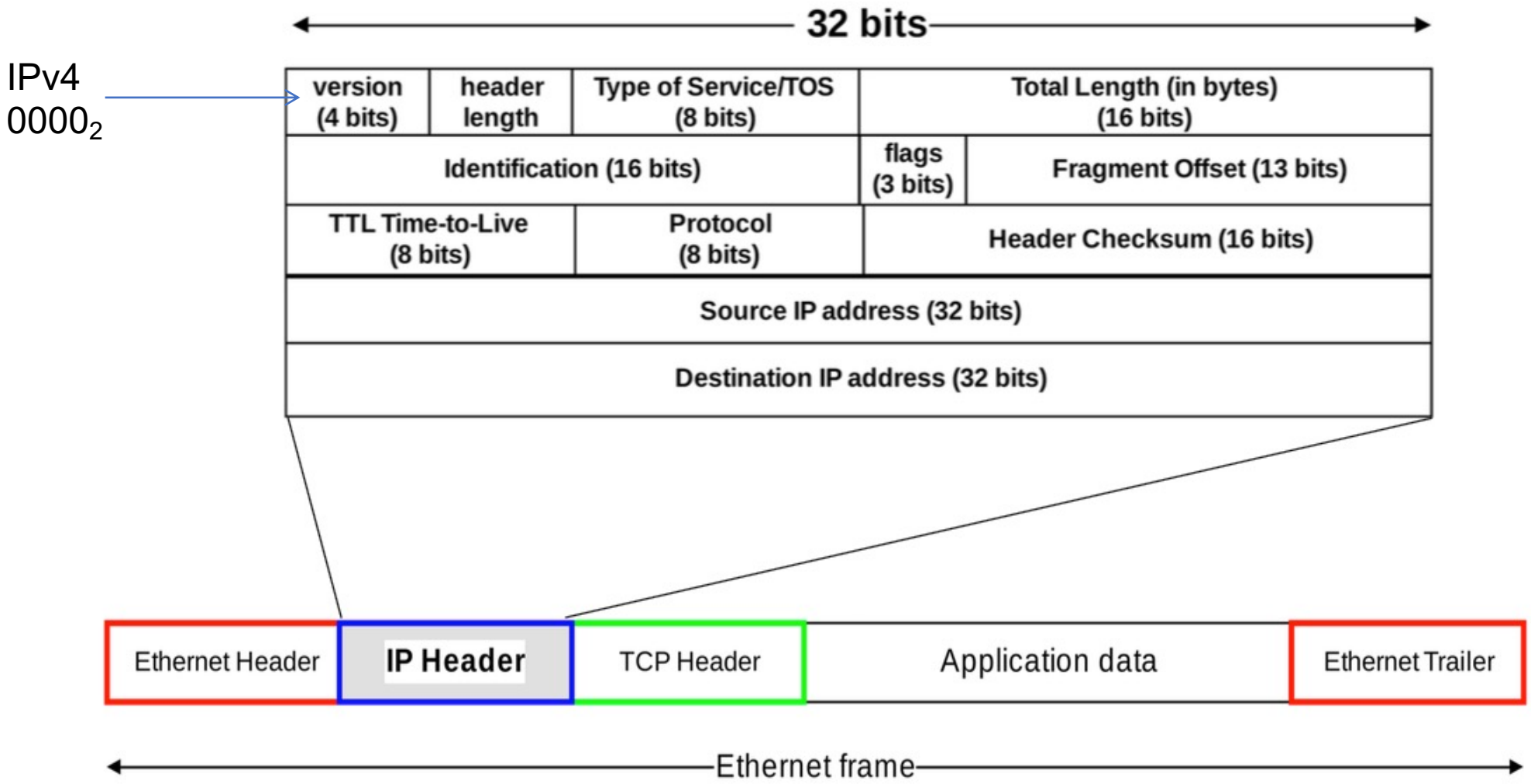


```
11111111.11111111.11111111.11111111
```

- 2^{32} -> 4,294,967,296

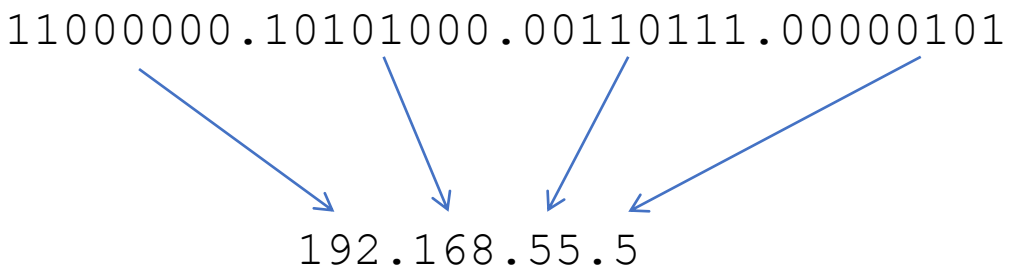
This may seem like a lot but we have already run out of IP addresses

IP Addressing



IP Addressing

- We usually use the “decimal dot notation” for human readable purposes
  - We can look at IP addresses as 4 separate 1 Byte numbers



- IP addresses are **logical** addresses:
  - We can (re-) assign IP addresses to devices as we please

IP Addressing

192.168.40.2

192.168.40.7

192.168.40.92

192.168.40.36

192.168.40.1

If we set up a network, we can assign the IP addresses so they are logically linked!

IP Addressing

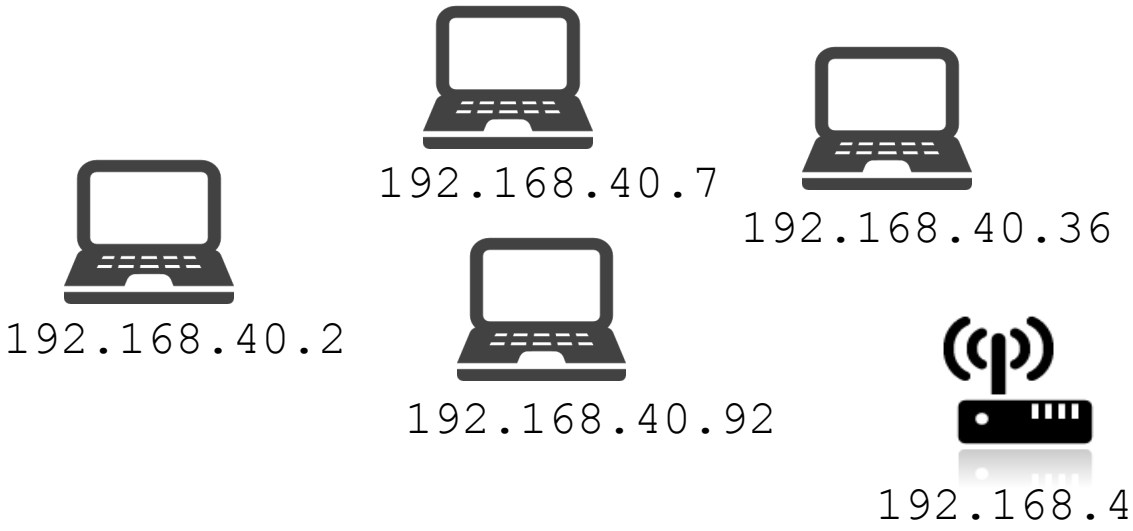
- So……..
- If we can pick our own IP addresses,
- How do we choose IPs that do not conflict with other devices in the world?

➢There is an autority that gives out IP address ranges for ISPs/organisations/universitys to use:

  - Internet Assigned Number Authotity (IANA)

IP Addressing

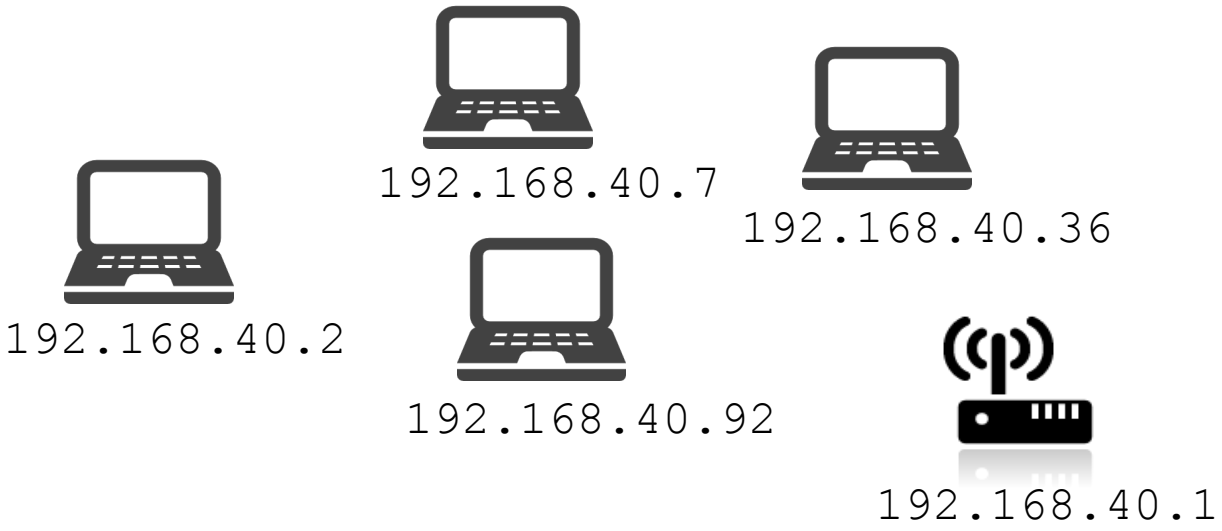
- The Network part and Host part of the IP address are important



- In this example all devices on the network share a part of their IP address

IP Addressing

- The Network part and Host part of the IP address are important.



- 192.168.40 – Addresses the Network they are on (First 3 bytes)
- The last byte is the host address on that network

Special IP addresses

- 127.0.0.1 : Me (a.k.a., localhost)
  - Regardless of my given IP address, 127.0.0.1 will send a message to myself
  - It is used to test the network stack

- Each network has two reserved IP addresses
  - Network Name: all Host bits set to “0”
    - E.g., `192.168.40.0`
  - Broadcast Address: all Host bits set to “1”
    - This will broadcast to all computers on the network with the given prefix
    - `E.g., 192.168.40.255`
- In a dynamic way
  - 0.0.0.0 : My network name
  - 255.255.255.255 : Broadcast to my network

Network and Host

- Each IP address has a Network Prefix and a Host Number

Many networks, each network has many hosts

Lots of networks, each network has a few hosts

Small number of networks, each network has lots of hosts

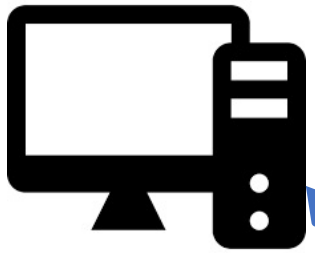
- But what scheme do we use!

We Use them all!!!

Determining the Network!

What is my **Host** IP Address?

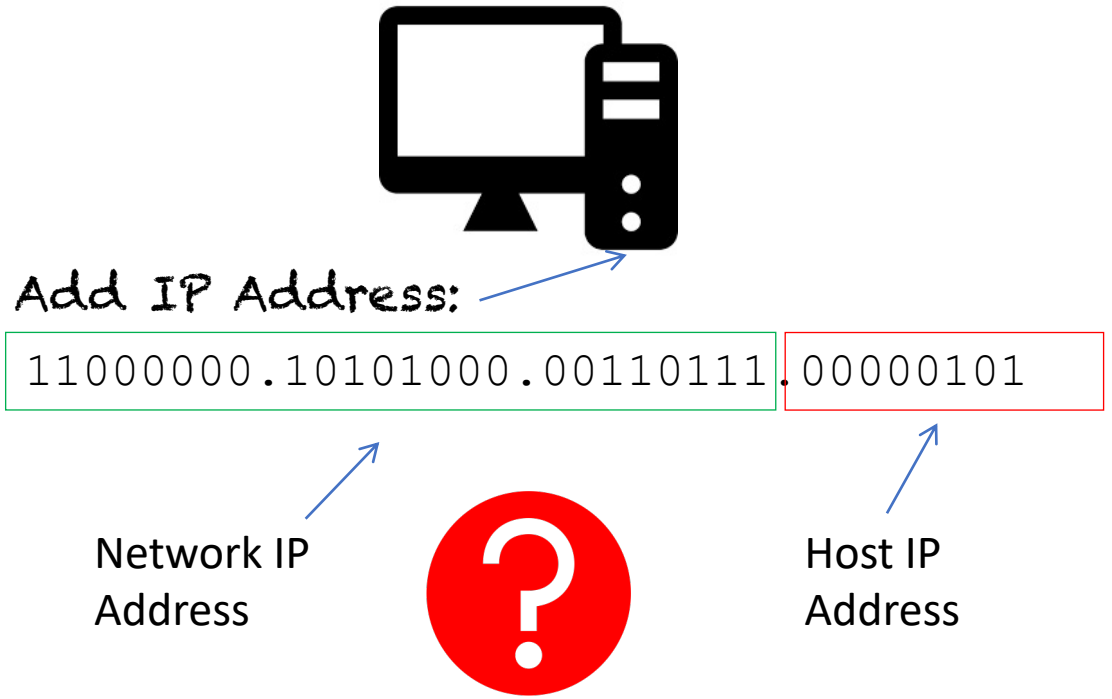
What is my **Network** IP Address?



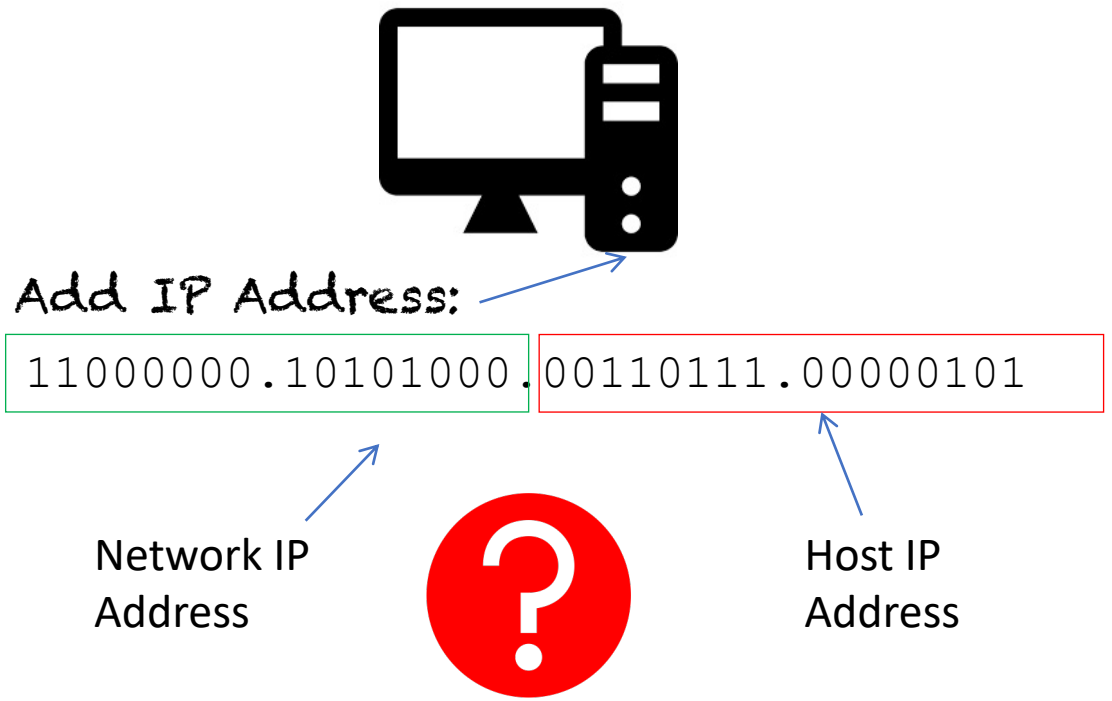
Add IP Address:

11000000.10101000.00110111.00000101

Determining the Network!



Determining the Network!

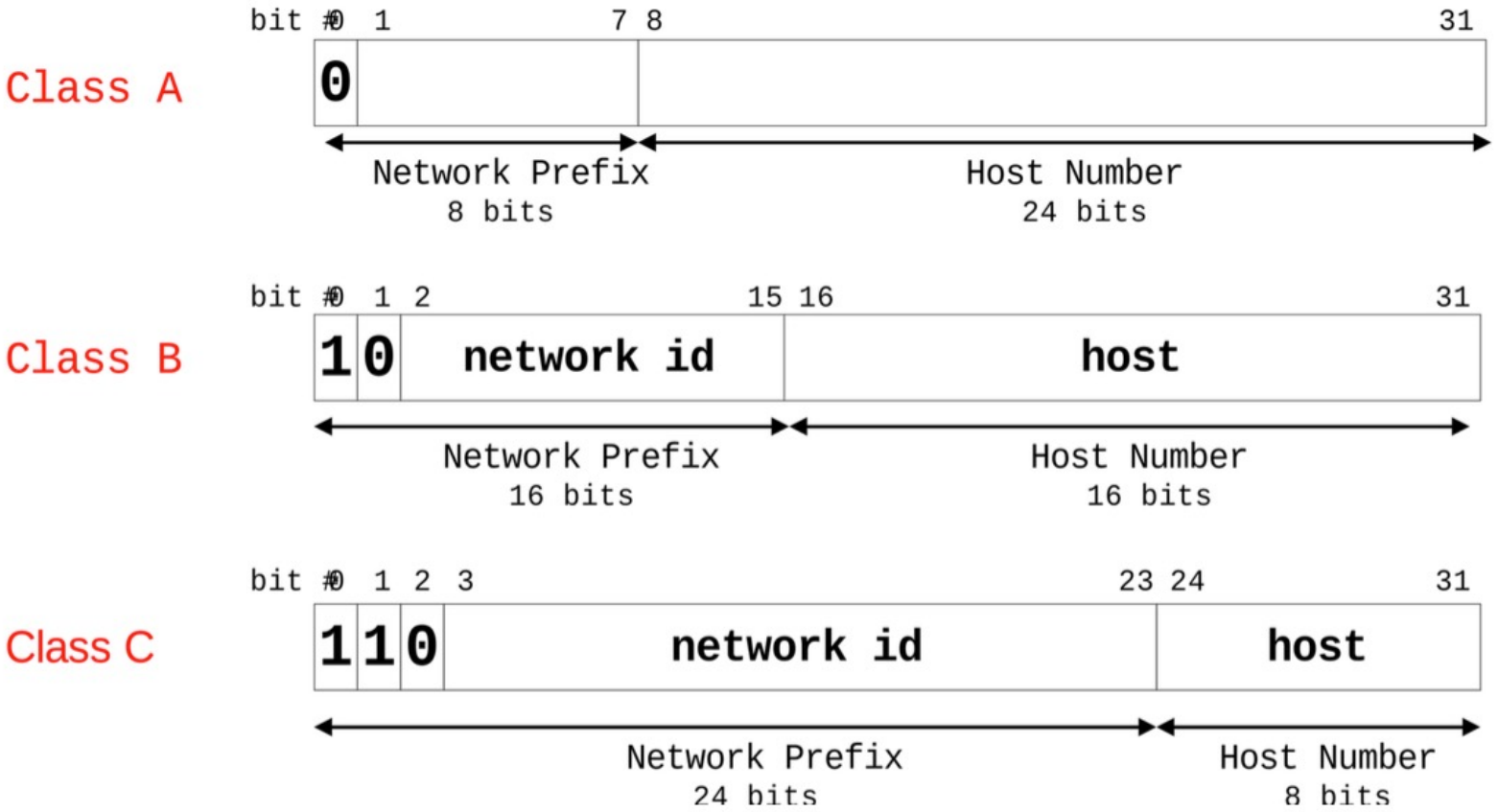


IP Addressing

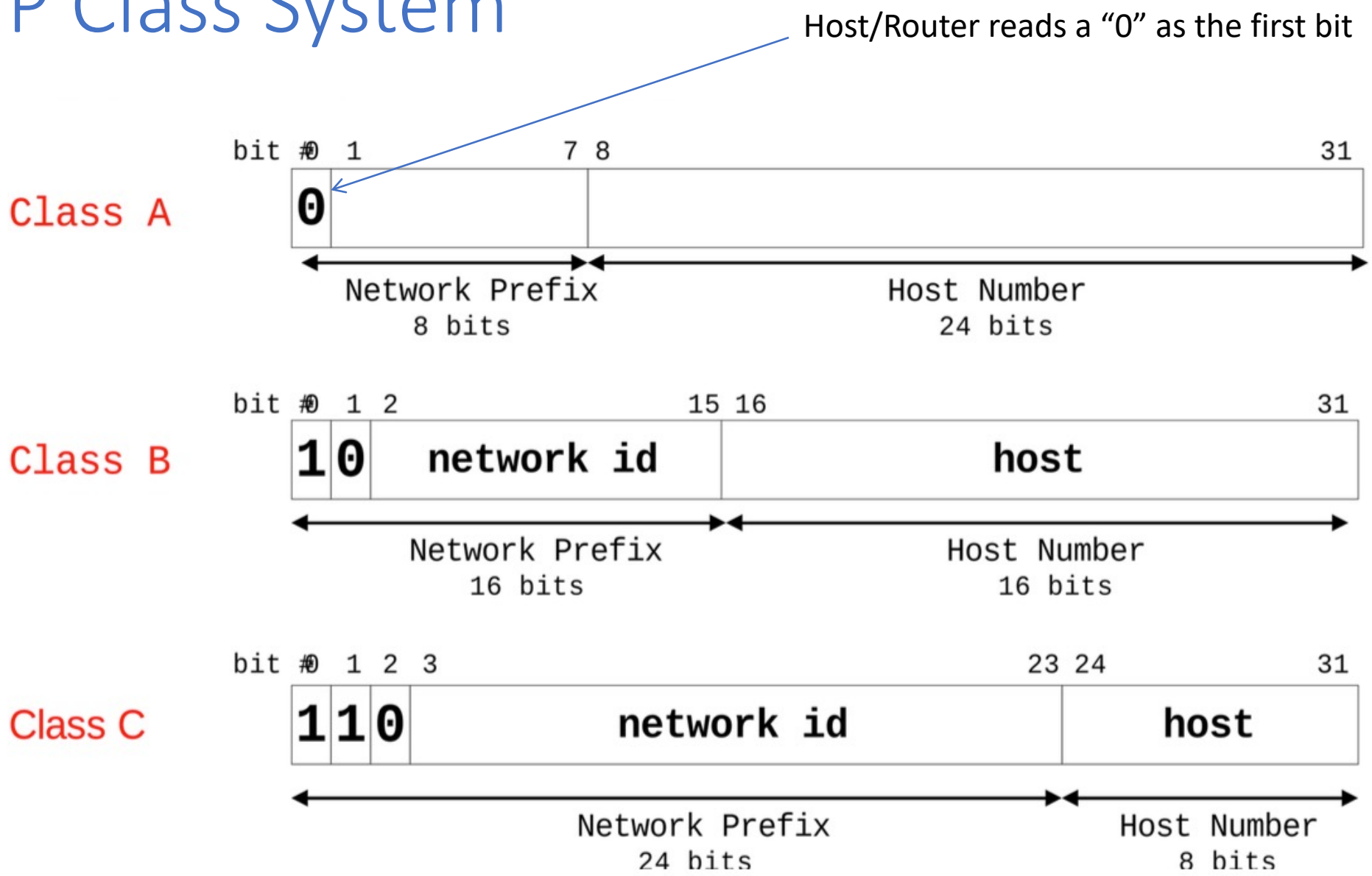
- There are two strategies for defining the network prefix size
  1. Class-based IP Addresses - Old Way
  2. Classless Inter domain Routing (CIDR) - New Way

IP Class System

The OLD WAY of looking at IP addresses!

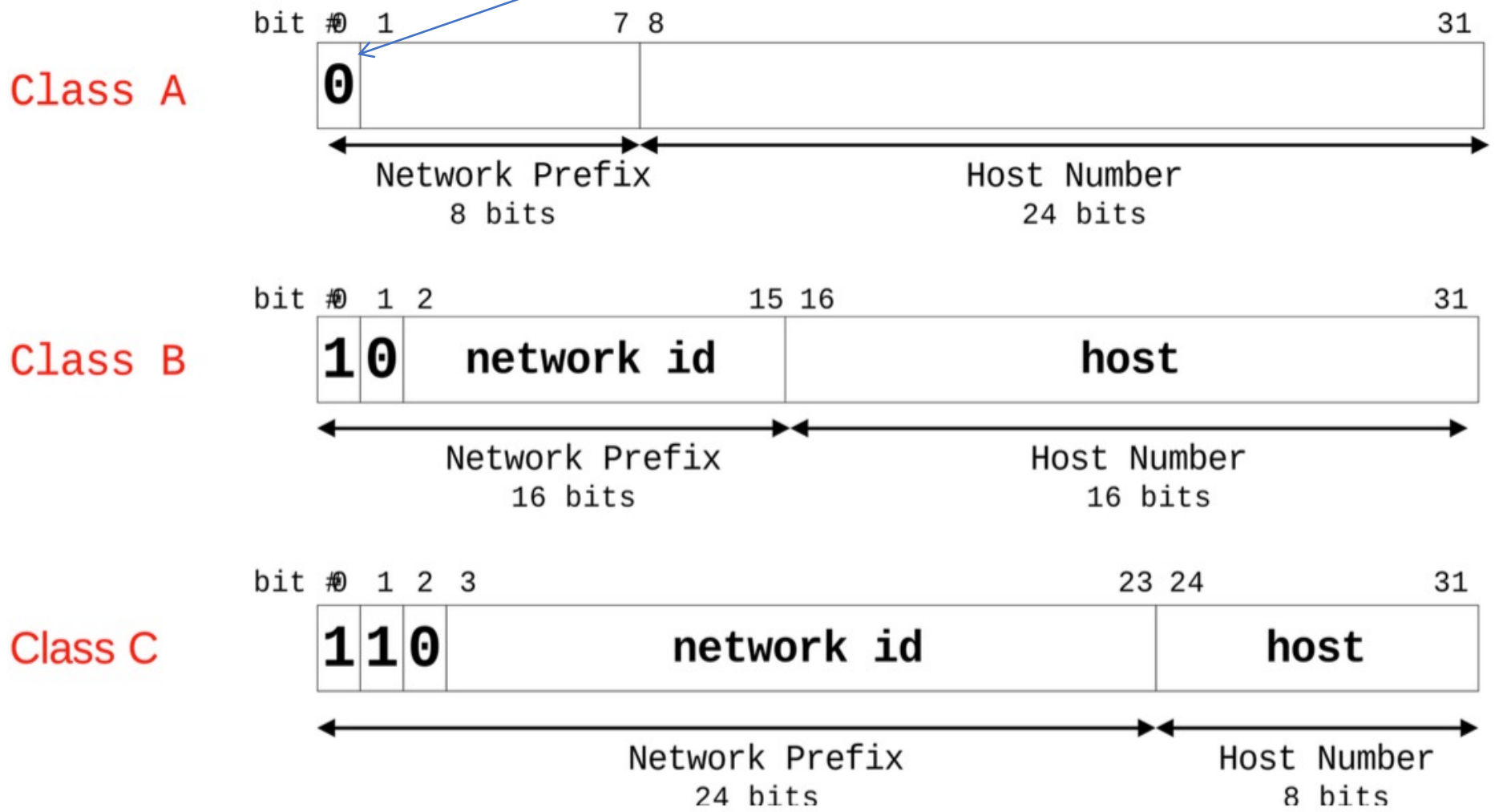


IP Class System

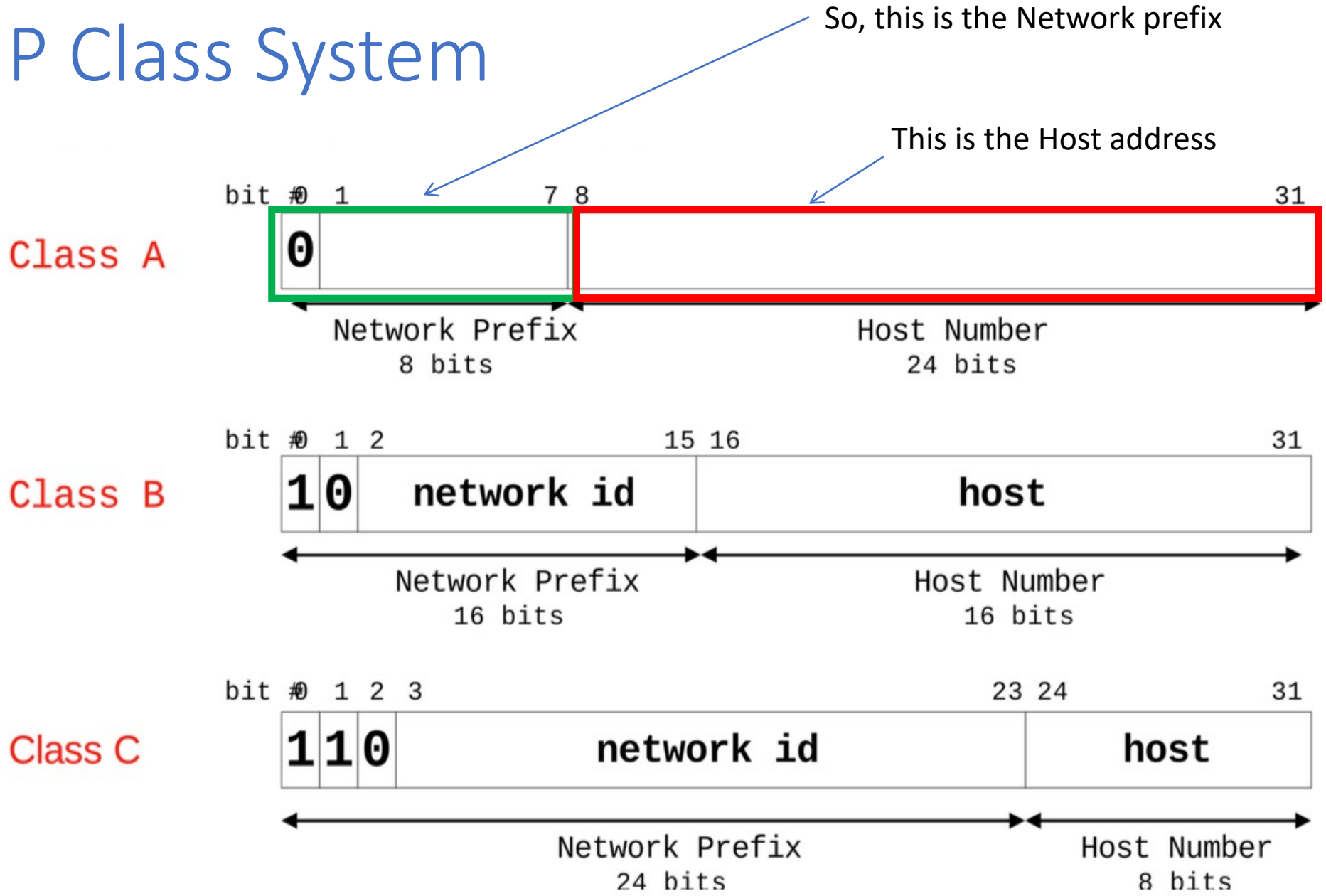


IP Class System

Therefore, it is a class A address



IP Class System



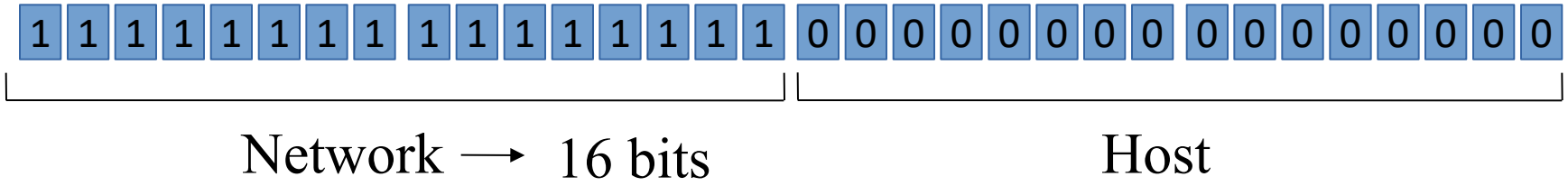
IP Class System

- Problem 1: The class system is inflexible
  - E.g., a company requires 2,000 addresses
  - Class A and B addresses are too big
  - Class C address is insufficient (requires 8 Class C addresses)
- Problem 2: Routing table can become too large with subnetting
- Problem Fix:
  - CIDR

Masking

- The Network mask is also 32 bits long

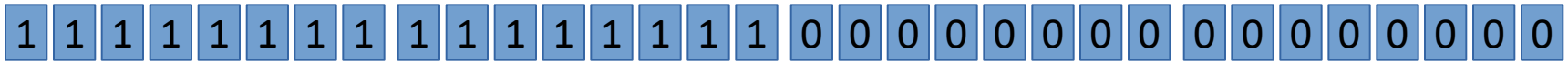
- It is split into sections that denote the “network” and “host” bits
- 1's denote the network, with 0's denoting the host



Masking

- The Network mask is also 32 bits long

- It is split into sections that denote the “network” and “host” bits.
- 1's denote the network, with 0's denoting the host

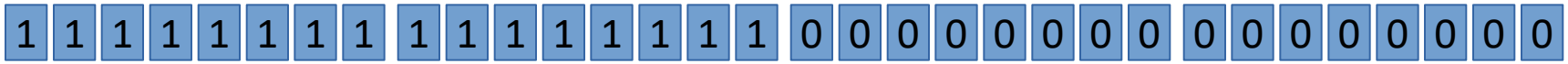


$= /16 \longrightarrow$ Slash Notation

Masking

- The Network mask is also 32 bits long

- It is split into sections that denote the “network” and “host” bits.
- 1's denote the network, with 0's denoting the host



= /16

/24

Masking

- The Network mask is also 32 bits long

- It is split into sections that denote the “network” and “host” bits.
- 1's denote the network, with 0's denoting the host

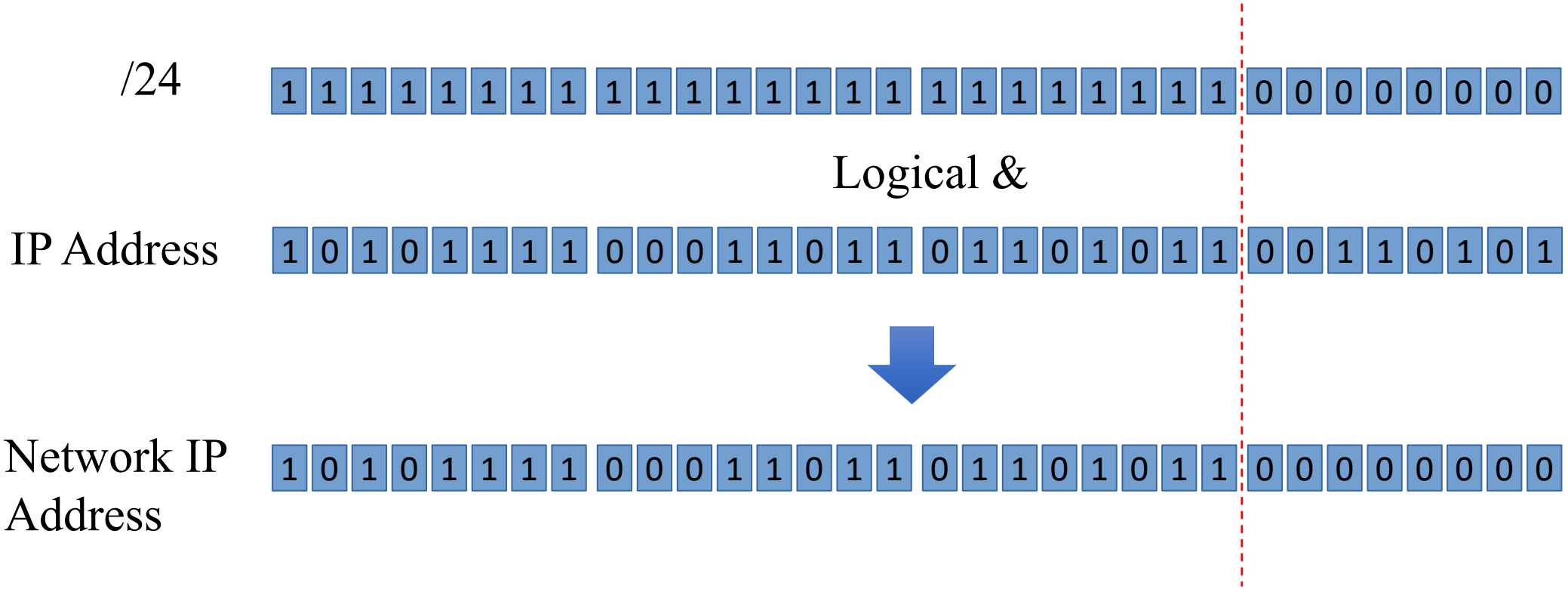
1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0

= /16

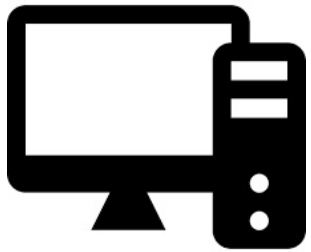
1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 0 0 0 0 0 0 0 0

/24

Using the Mask



With Masks!



Add IP Address:

11000000.10101000.00110111.00000101

And Mask:

11111111.11111111.00000000.00000000

Routing table:

I'm connected to network:
11000000.10101000.00000000.00000000

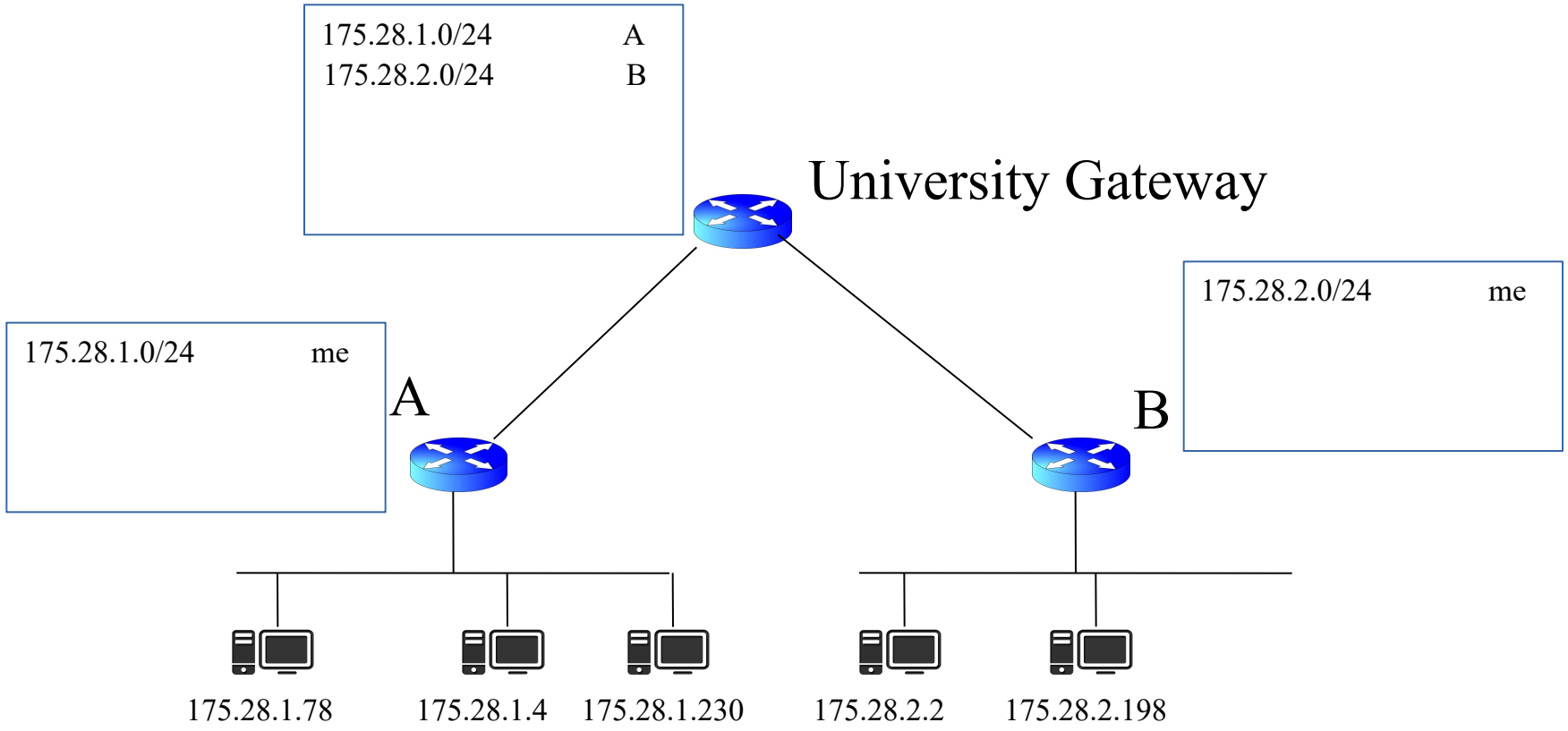
Netmask:
11111111.11111111.00000000.00000000

Network Address =
192.168.0.0 / 16

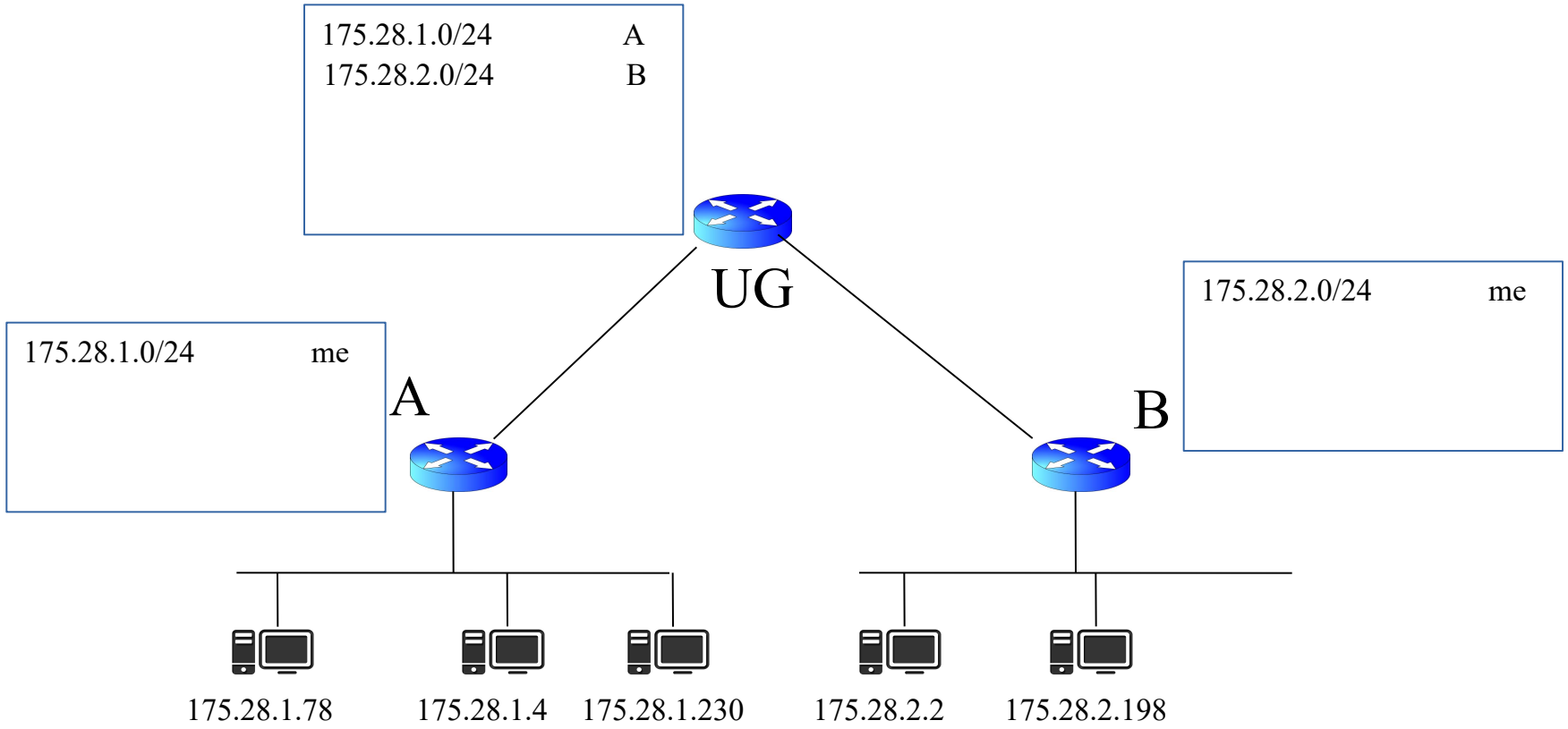
Finding the Correct Route with Masks

- Now that each Host/Router knows the network it is attached to, it can route packets effectively
  - It uses the mask on each line of the routing
  - Applies the mask to the incoming packet (Logical & operation)
  - Compares the network name with the result (equals operation)
    - If they are equal -> route to the destination
    - If they are not equal, continue through the routing table

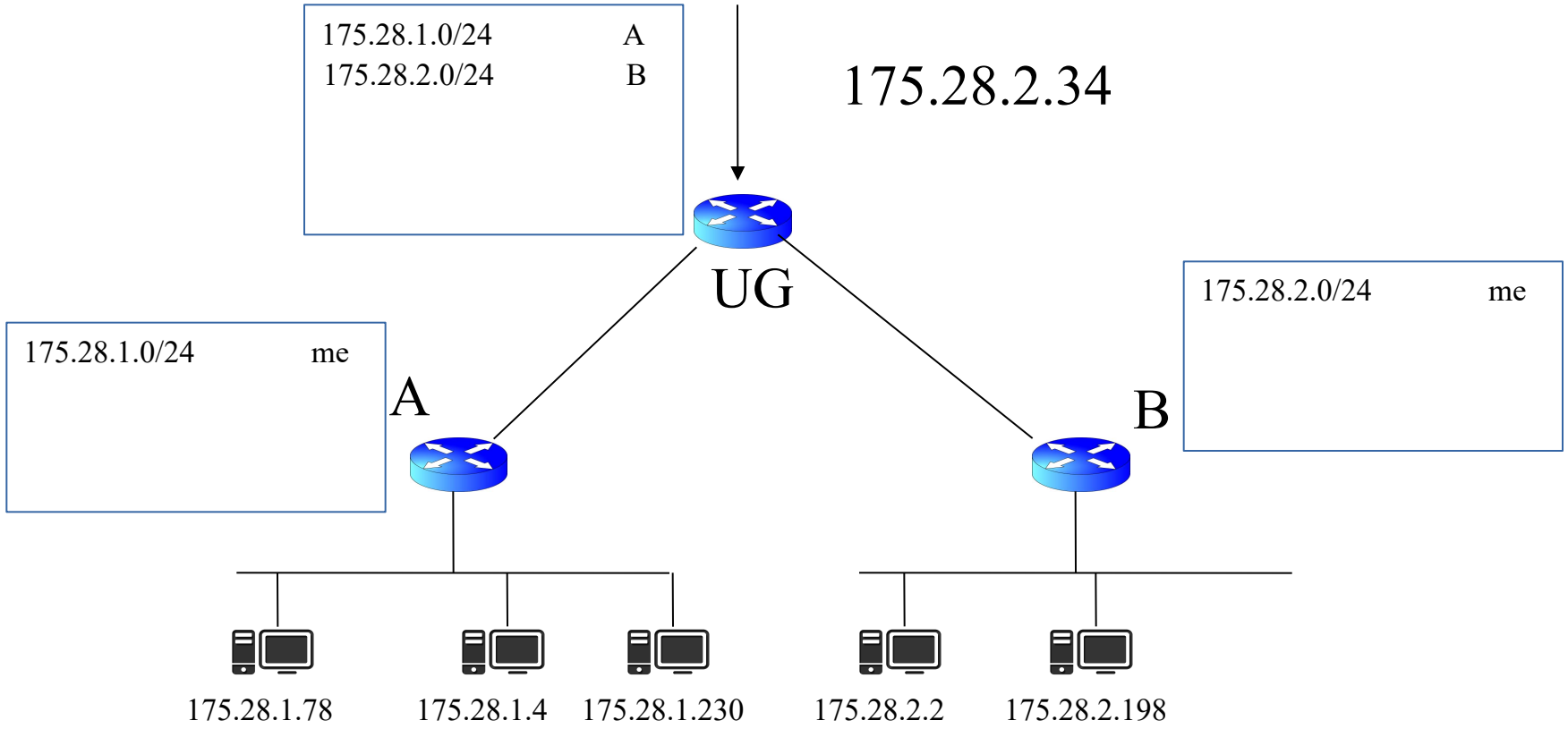
Using Masks!


175.28.1.0/24 A
175.28.2.0/24 B
University Gateway
175.28.1.0/24 me
A
B
175.28.2.0/24 me
175.28.1.78
175.28.1.4
175.28.1.230
175.28.2.2
175.28.2.198

Using Masks!

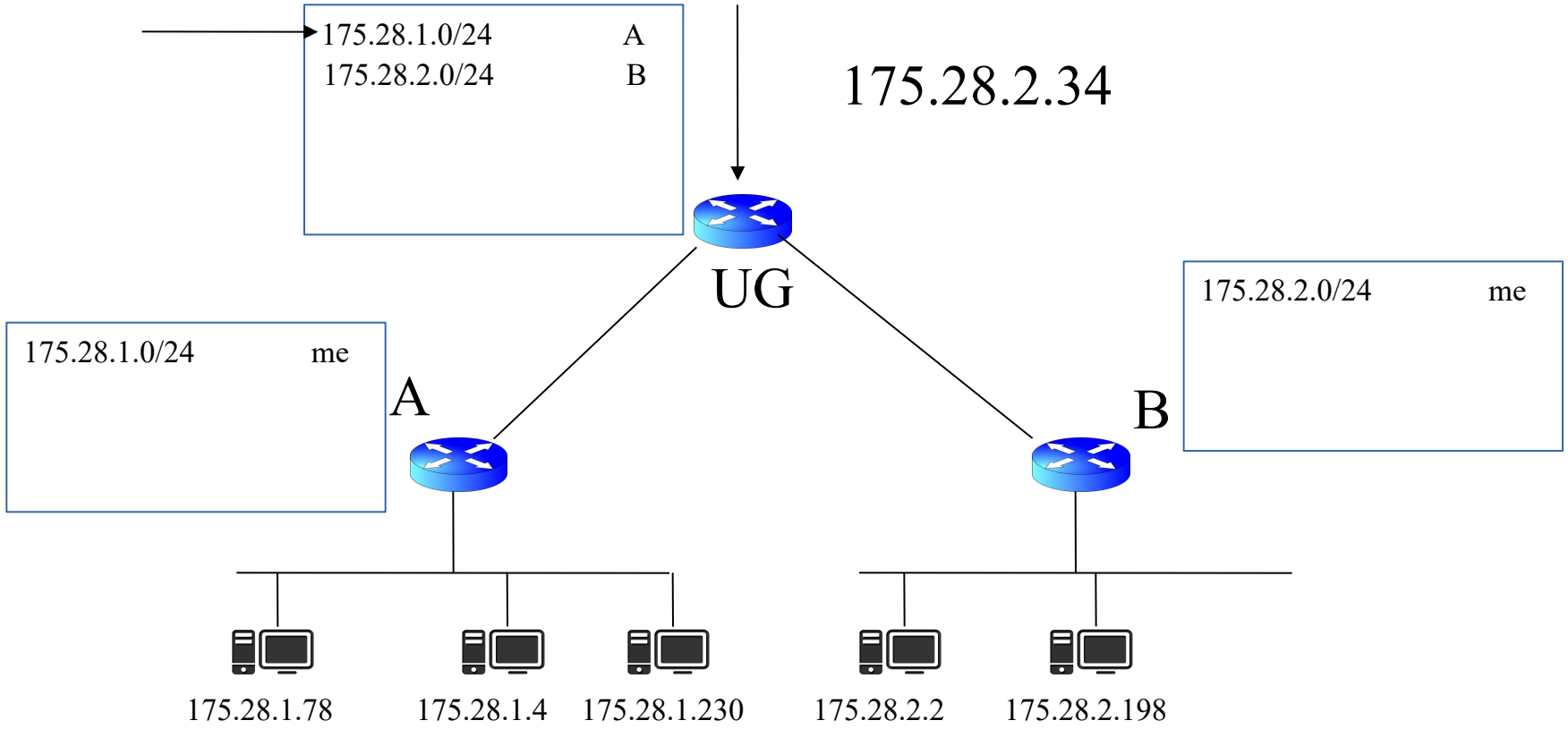

175.28.1.0/24 A
175.28.2.0/24 B
UG
175.28.1.0/24 me
A
B
175.28.2.0/24 me
175.28.1.78
175.28.1.4
175.28.1.230
175.28.2.2
175.28.2.198

Using Masks!



Packet comes in for: 10101111 0011100 00000010 00100010

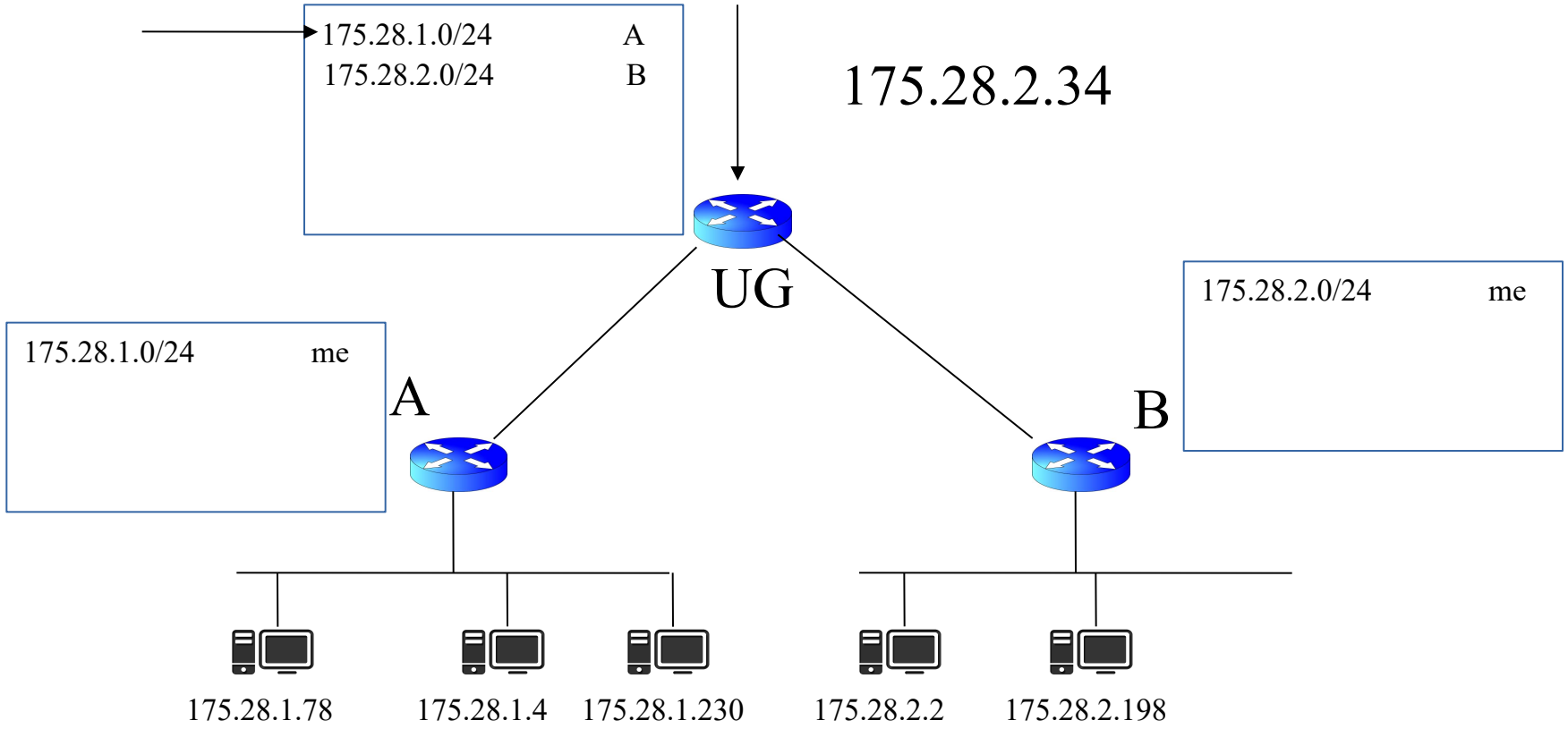
Using Masks!



Packet comes in for: 10101111 0011100 00000010 00100010

Check with 1st mask: 11111111 1111111 11111111 00000000

Using Masks!

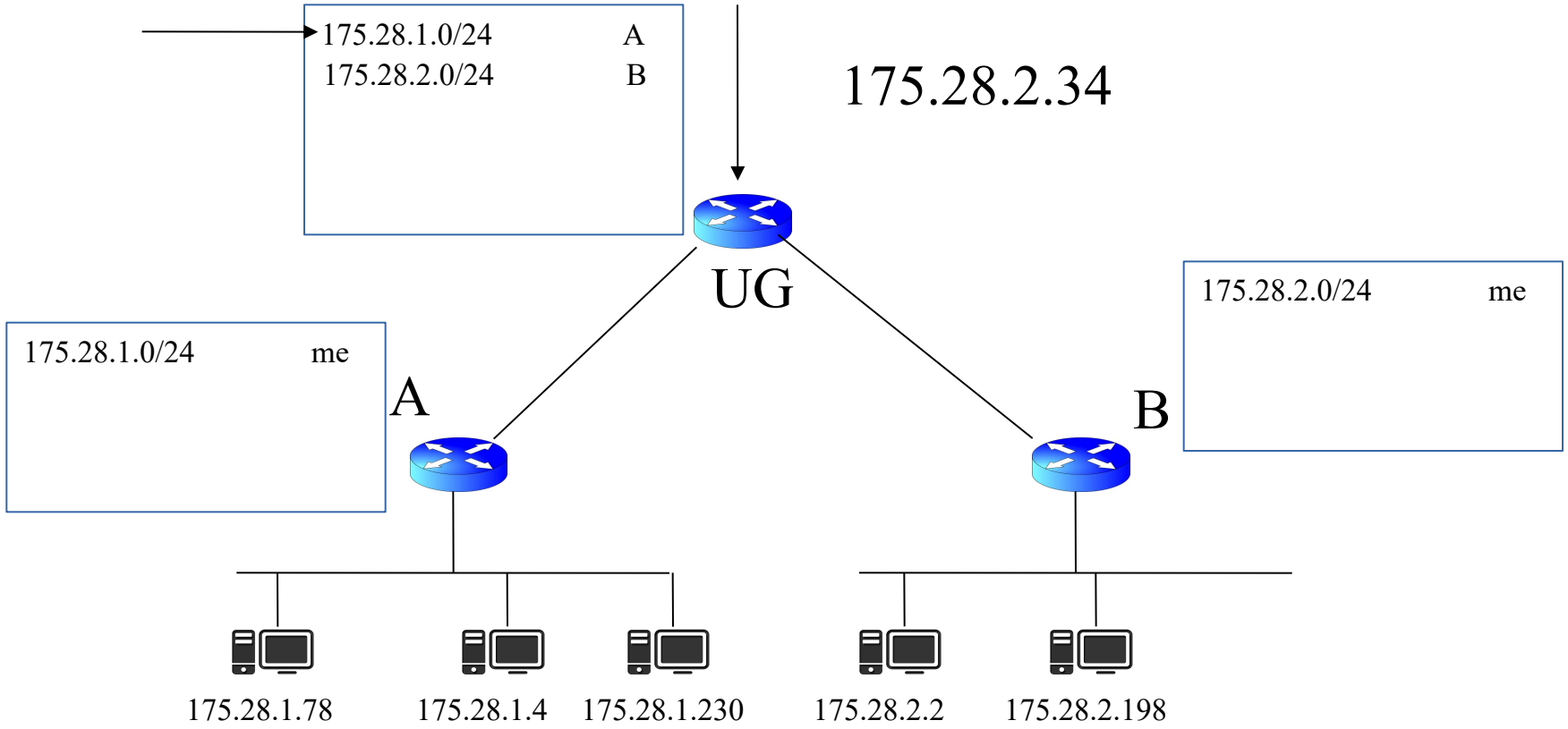


Packet comes in for: 10101111 0011100 00000010 00100010

Check with 1st mask: 11111111 1111111 11111111 00000000

1010111 0011100 00000010 00000000

Using Masks!

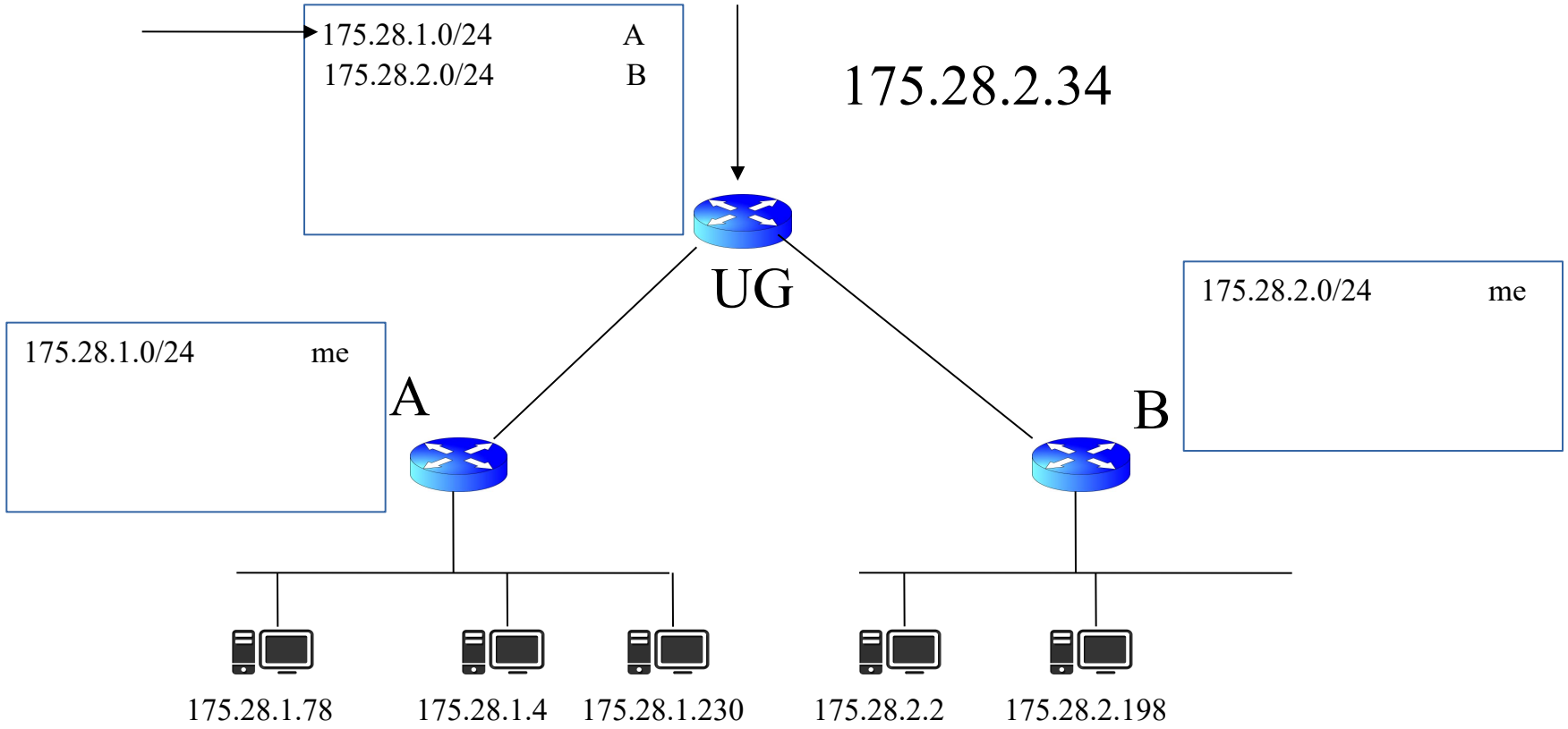


Packet comes in for: 10101111 0011100 00000010 00100010

Check with 1st mask: 11111111 1111111 11111111 00000000

175.28.2.0

Using Masks!

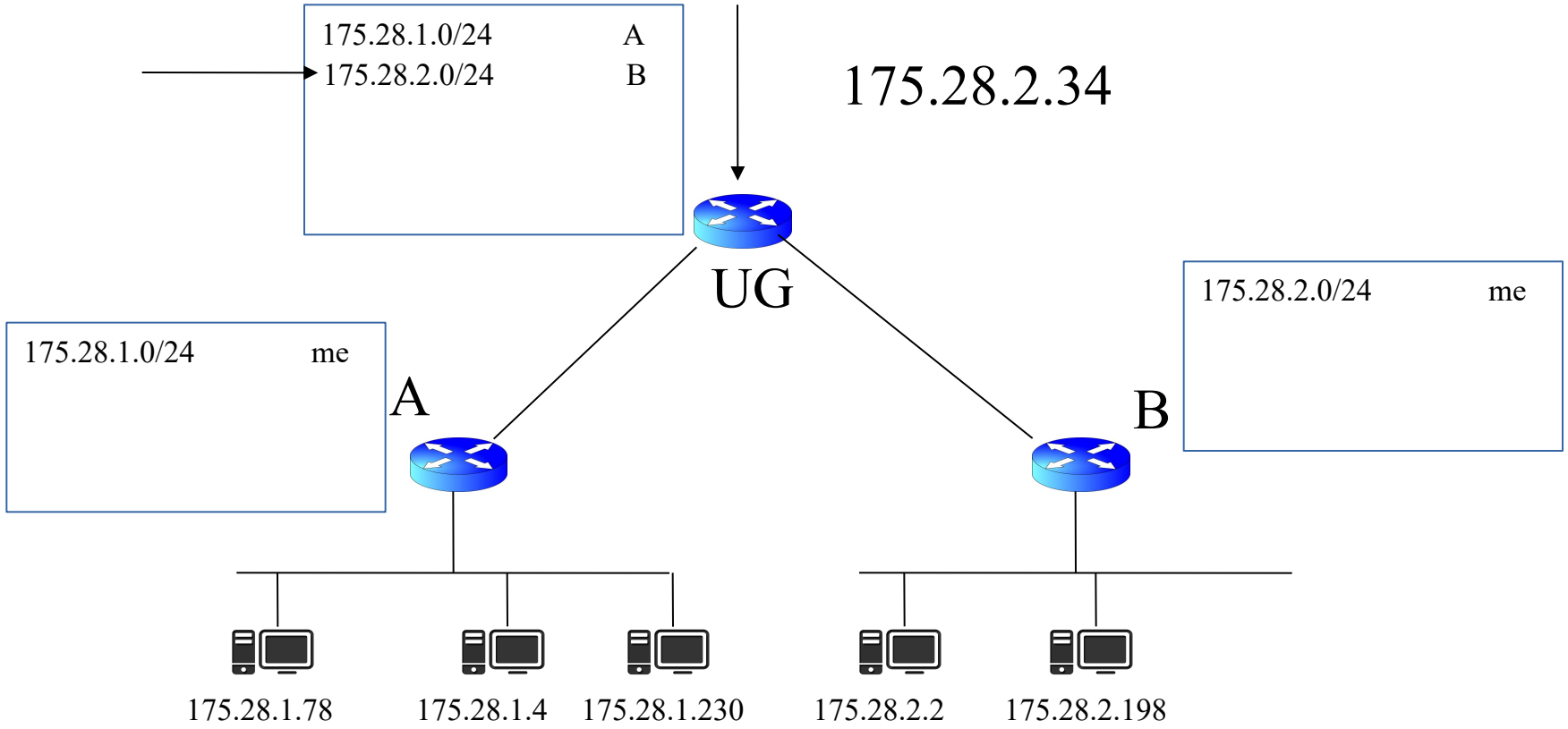


Packet comes in for: 10101111 0011100 00000010 00100010

Check with 1st mask: 11111111 1111111 11111111 00000000

175.28.2.0 → Not a match

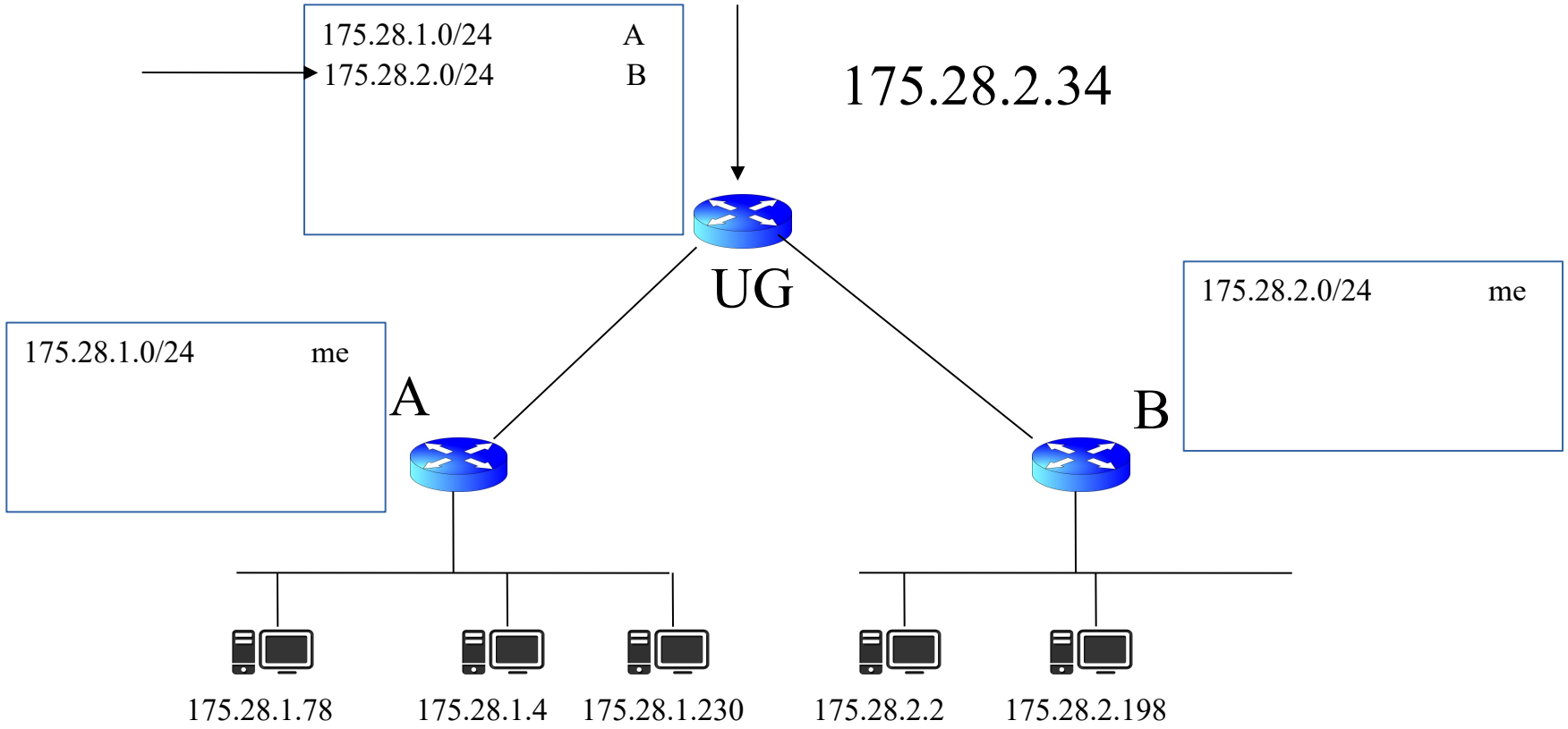
Using Masks!



Packet comes in for: 10101111 0011100 00000010 00100010

Check with 2nd mask: 11111111 1111111 11111111 00000000

Using Masks!

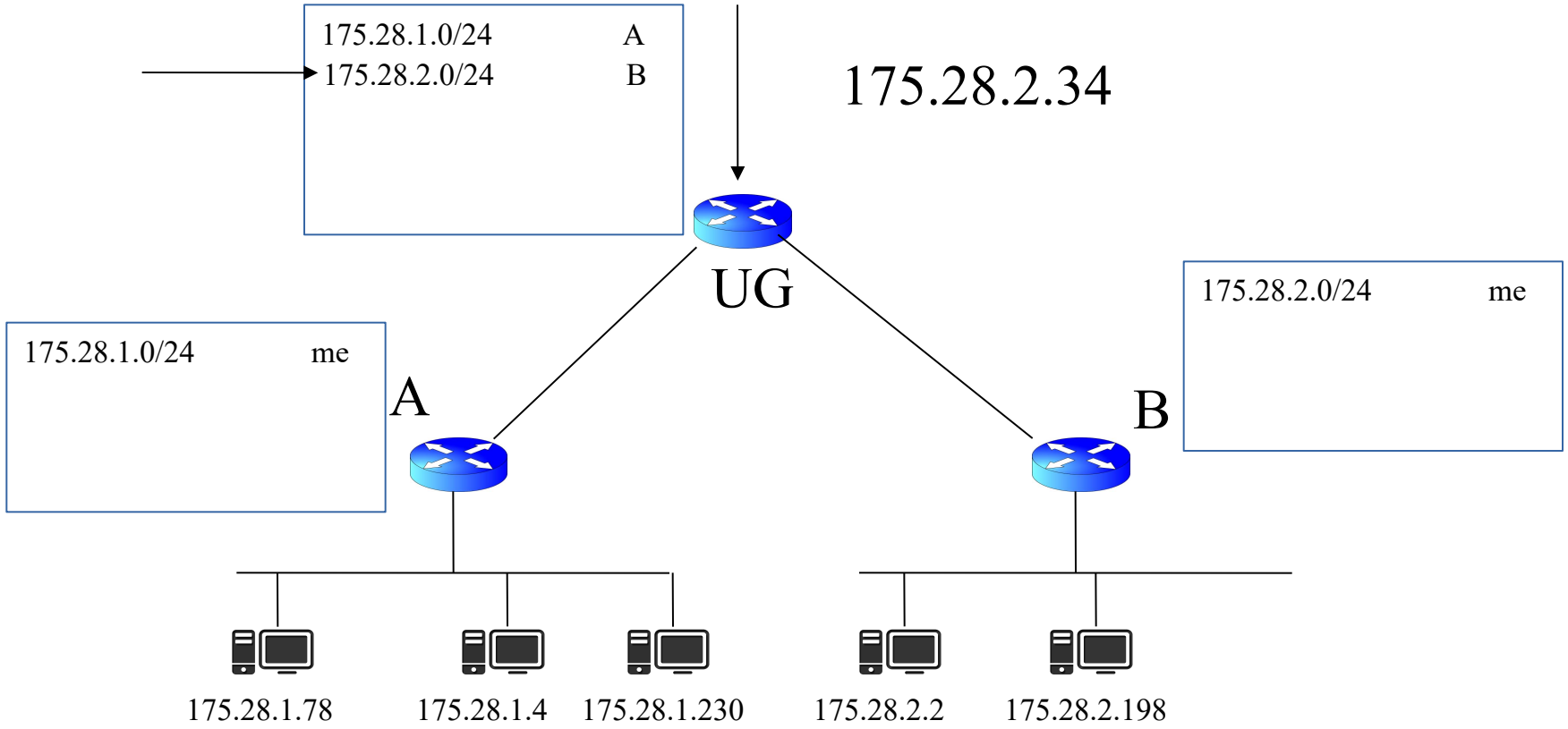


Packet comes in for: 10101111 0011100 00000010 00100010

Check with 2nd mask: 11111111 1111111 11111111 00000000

1010111 0011100 00000010 00000000

Using Masks!

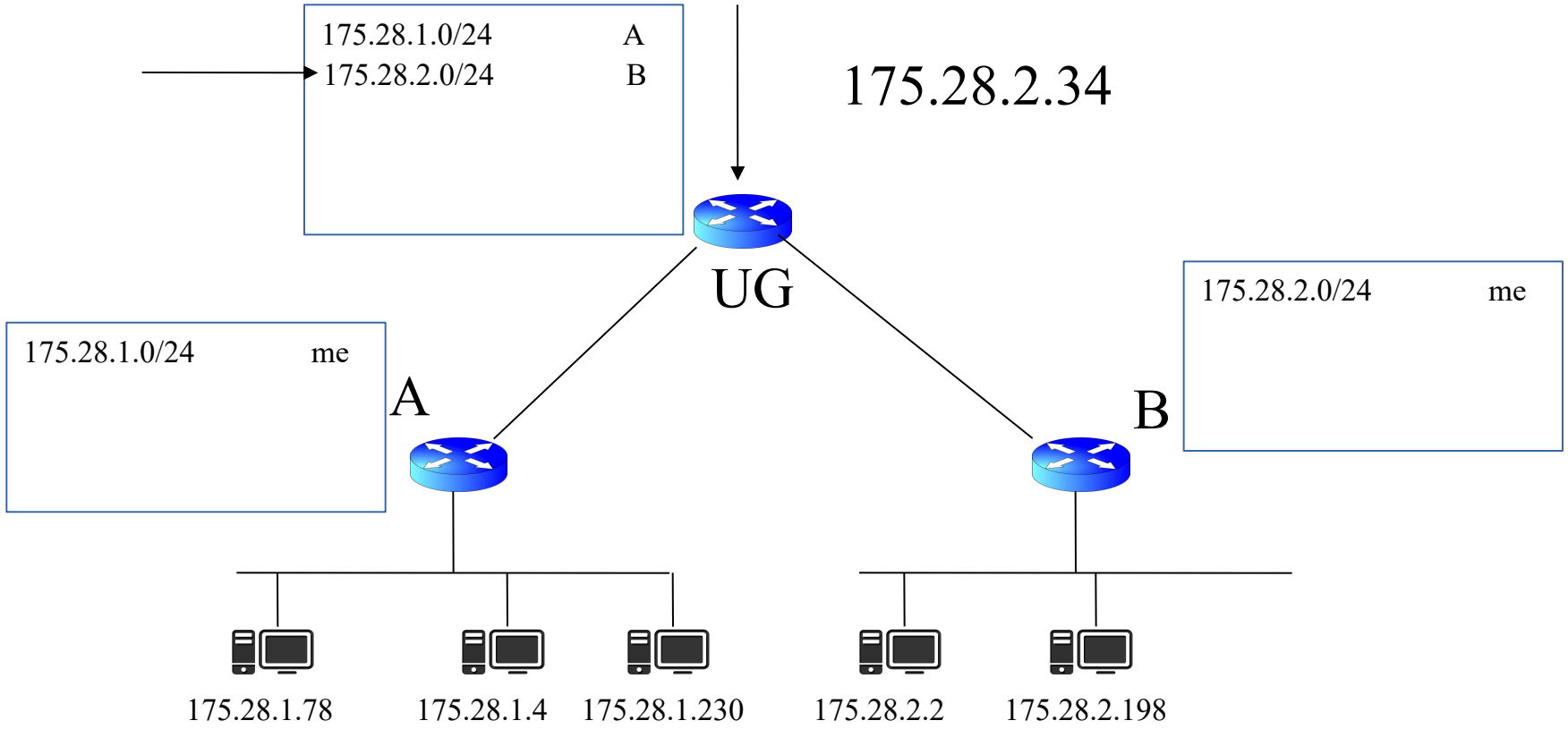


Packet comes in for: 10101111 0011100 00000010 00100010

Check with 2nd mask: 11111111 1111111 11111111 00000000

175.28.2.0

Using Masks!



Packet comes in for: 10101111 0011100 00000010 00100010

Check with 2nd mask: 11111111 1111111 11111111 00000000

175.28.2.0 → match, send to B

Exercise

- Discern both the host and network from the address 175.35.17.124/24
- Determine the:
  - Network Name
  - Broadcast Address
  - Number of existing IP addresses on the network
  - Number of valid Host IP Addresses on the network
- IP address: 175.35.17.124/24
  - Network Name → 175.35.17.0
  - Broadcast Address → 175.35.17.255
  - Existing Addresses → 256
  - Valid Host Addresses → 254

Host part is set to all 0's!

Host part set to all 1's

2^8 different arrangements (unique addresses)

00000000 and 11111111 already used for Network and Broadcast

$2^8 - 2 = 254$ Valid Host addresses!

CIDR - Classless InterDomain Routing

- **Key Concept:**
  - The length of the network id (prefix) in the IP addresses is kept arbitrary
  - Routers advertise the IP address and the length of the prefix

- **Example:** CIDR notation of a network address: **192.0.2.0/18**
  - "18" means that the first 18 bits are the network part of the address (and 14 bits are available for specific host addresses)
- Assume that a site requires a network address with 1000 addresses
- With CIDR, the network is assigned a continuous block of 1024 addresses
  - Hosts: 10 last bits (2^{10} = 1024)
  - Prefix: 22-bit long

CIDR: Prefix Size vs. Network Size

CIDR Block Prefix	# of Existing Addresses	# Valid Host Addresses
/27	2^{32-27} = 32 hosts	30 hosts
/26	2^{32-26} = 64 hosts	62 hosts
/25	2^{32-25} = 128 hosts	126 hosts
/24	2^{32-24} = 256 hosts	254 hosts
/23	2^{32-23} = 512 hosts	510 hosts
/22	2^{32-222} = 1,024 hosts	1,022 hosts
/21	2^{32-21} = 2,048 hosts	2,046 hosts
/20	2^{32-20} = 4,096 hosts	4,094 hosts
/19	2^{32-19} = 8,192 hosts	8,190 hosts
/18	2^{32-18} = 16,384 hosts	16,382 hosts
/17	2^{32-17} = 32,768 hosts	32,766 hosts
/16	2^{32-16} = 65,536 hosts	65,534 hosts
/15	2^{32-15} = 131,072 hosts	131,070 hosts
/14	2^{32-14} = 262,144 hosts	262,142 hosts
/13	2^{32-13} = 524,288 hosts	524,286 hosts

CIDR and Masking

- IP address: 175.35.124.17 / 19
- IP → 10101111.00100001.01111100.00010001
- NetMask → 11111111.11111111.11100000.00000000
- Network : 10101111.00100001.01100000.00000000
  = 175.35.96.0
- Broadcast: 10101111.00100001.01111111.11111111
  = 175.35.127.255

Existing Addresses = $2^{32-19} = 2^{13} = 8192$

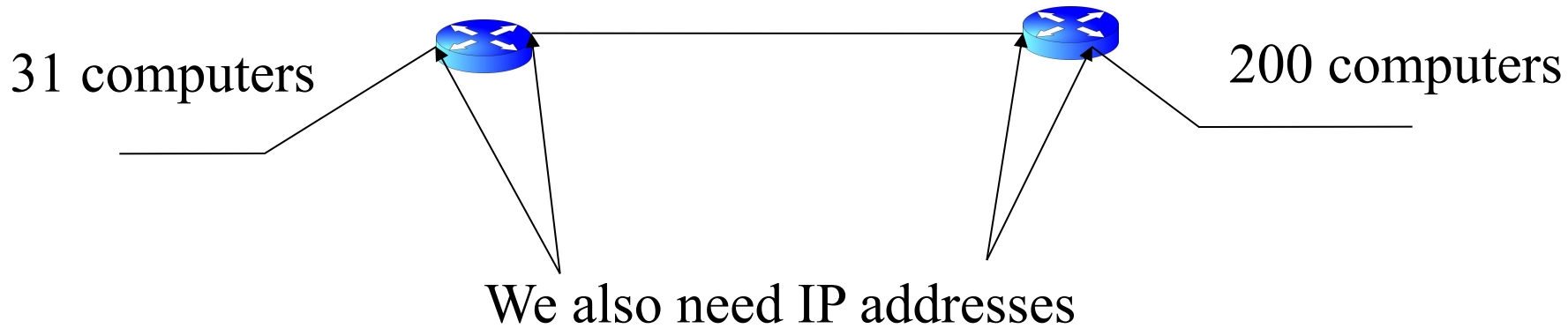
Available Addresses = $2^{32-19} - 2 = 2^{13} - 2 = 8190$

Subnet Design

- You are a network designer!
- You have the IP address range 192.168.0.0/23

  11000000 10101000 00000000 00000000

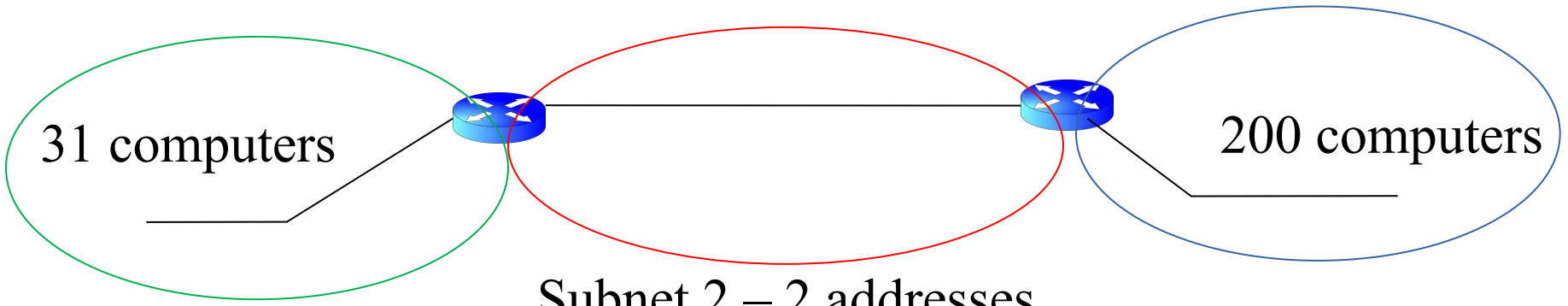
- You have to assign network addresses to 2 departments
  - Department A has 31 computers
  - Department B has 200 computers



Subnet Design

- You are a network designer!
- You have the IP address range 192.168.0.0/23

  11000000 10101000 0000000|0 00000000
- You have to assign network addresses to 2 departments
  - Department A has 31 computers
  - Department B has 200 computers



Subnet 2 – 2 addresses

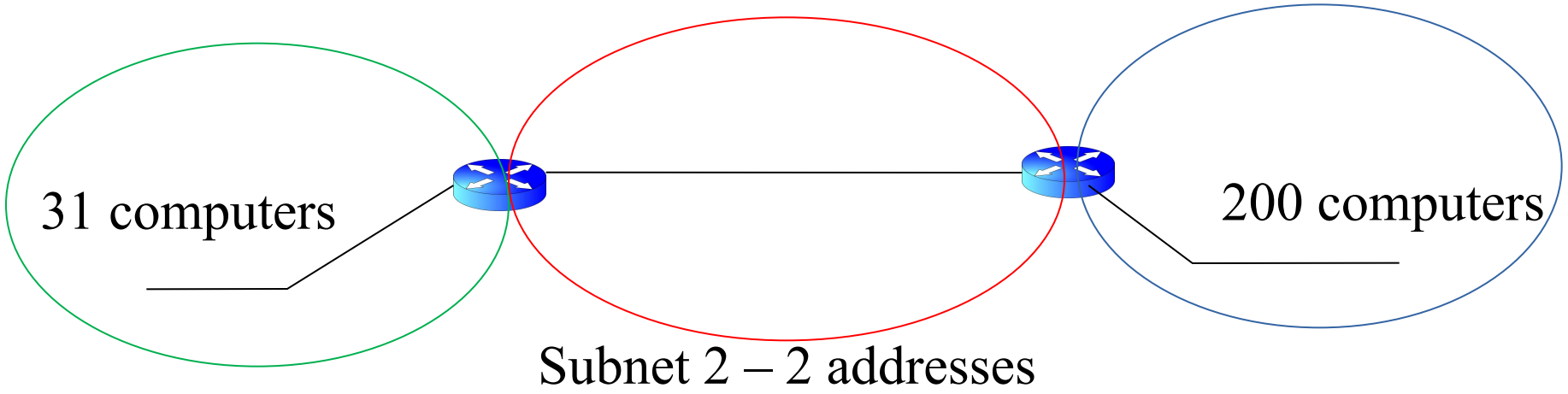
Subnet 1 – 32 addresses

Subnet 3 – 201 addresses

Assigned IP Range: 192.168.0.0/23

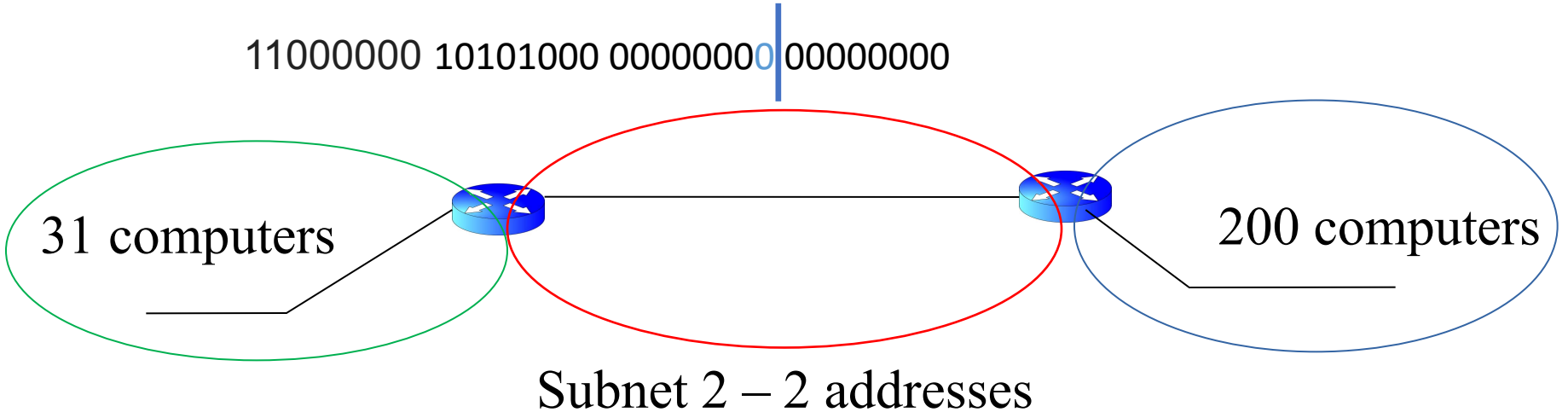
Subnet Design

- 3 subnets – Take the largest first
  - 201 addresses requires 8 bits for host addresses
    - 7 bits = 128 addresses, 126 valid host addresses
    - 8 bits = 256 addresses, 254 valid host addresses



Subnet Design

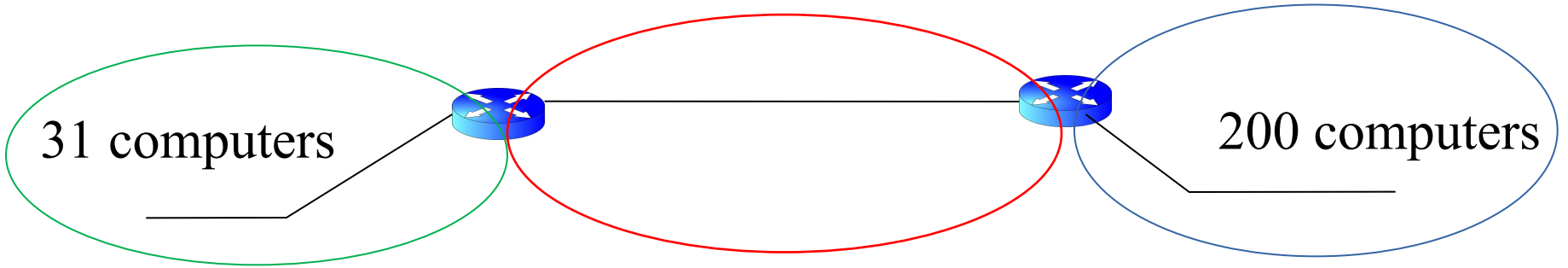
- 3 subnets – Take the largest first
  - 201 addresses requires 8 bits for host addresses
    - 7 bits = 128 addresses, 126 valid host addresses
    - 8 bits = 256 addresses, 254 valid host addresses
  - 192.168.0.0 → 192.168.0.255
  - 192.168.0.0/24



Assigned IP Range: 192.168.0.0/23
Subnet 3: 192.168.0.0/24

Subnet Design

- 3 subnets
  - 32 addresses requires 6 bits for host addresses
    - 5 bits = 32 addresses, 30 valid host addresses
    - 6 bits = 64 addresses, 62 valid host addresses



Subnet 2 – 2 addresses

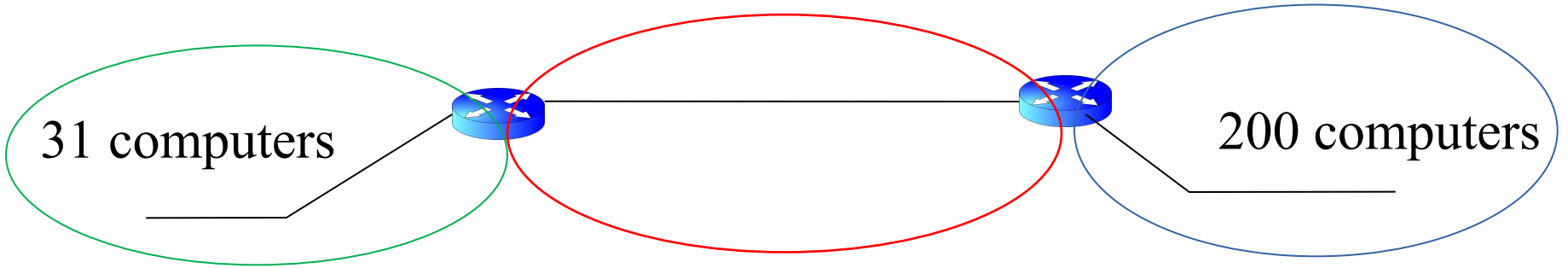
Subnet 1 – 32 addresses

Subnet 3 – 201 addresses

Assigned IP Range: 192.168.0.0/23
Subnet 3: 192.168.0.0/24

Subnet Design

- 3 subnets
  - 32 addresses requires 6 bits for host addresses
    - 5 bits = 32 addresses, 30 valid host addresses
    - 6 bits = 64 addresses, 62 valid host addresses
  - 192.168.0.0 → 192.168.0.255 ---- already used



Subnet 2 – 2 addresses

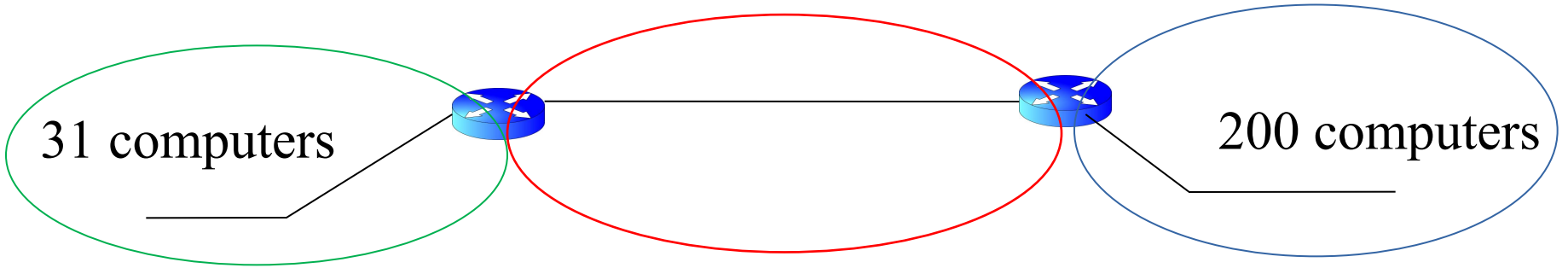
Subnet 1 – 32 addresses

Subnet 3 – 201 addresses

Assigned IP Range: 192.168.0.0/23
Subnet 3: 192.168.0.0/24

Subnet Design

- 3 subnets
  - 32 addresses requires 6 bits for host addresses
    - 5 bits = 32 addresses, 30 valid host addresses
    - 6 bits = 64 addresses, 62 valid host addresses
  - 192.168.1.0



Subnet 2 – 2 addresses

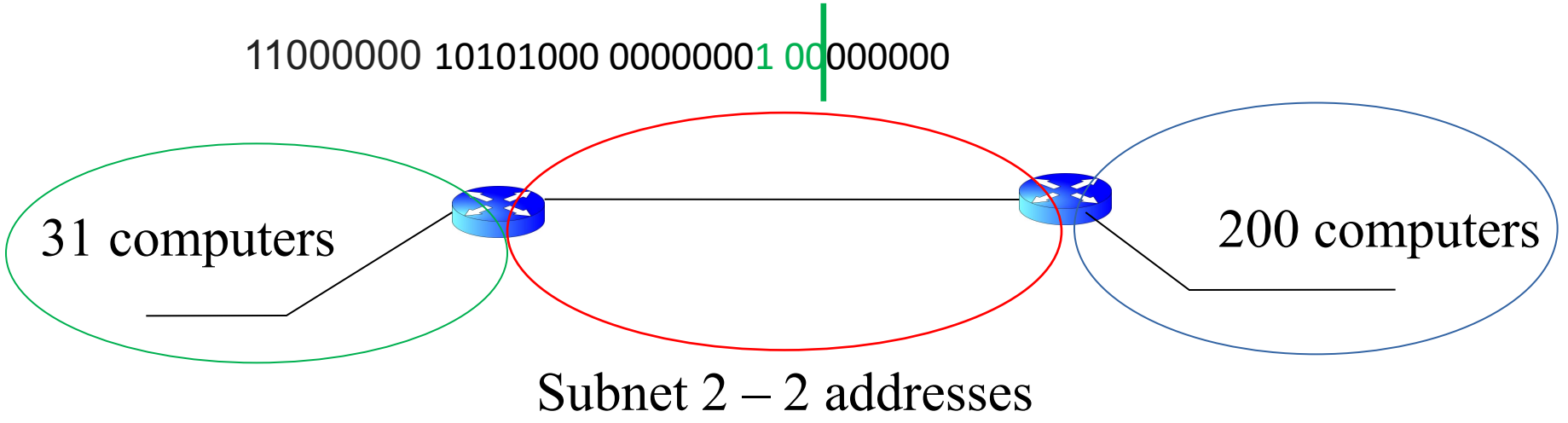
Subnet 1 – 32 addresses

Subnet 3 – 201 addresses

Assigned IP Range: 192.168.0.0/23
Subnet 3: 192.168.0.0/24

Subnet Design

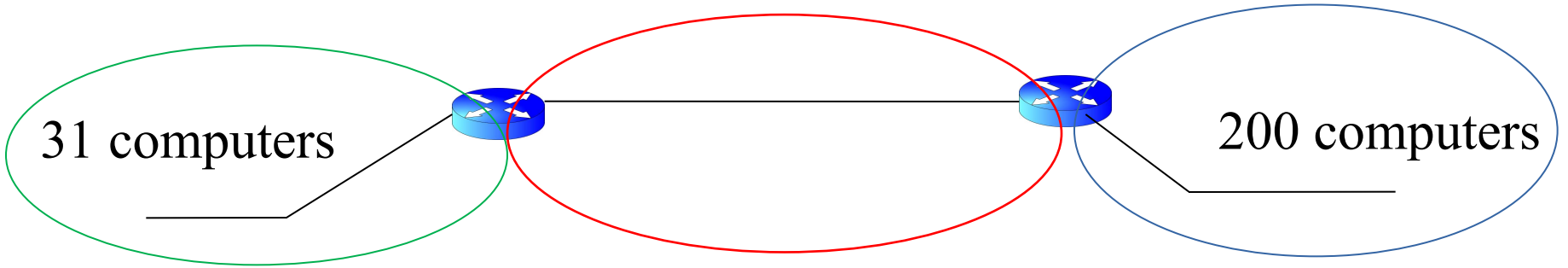
- 3 subnets
  - 32 addresses requires 6 bits for host addresses
    - 5 bits = 32 addresses, 30 valid host addresses
    - 6 bits = 64 addresses, 62 valid host addresses
  - 192.168.1.0 → 192.168.1.63
  - 192.168.1.0/26



Subnet Design

Assigned IP Range: 192.168.0.0/23
Subnet 3: 192.168.0.0/24
Subnet 1: 192.168.1.0/26

- 3 subnets
  - 2 addresses requires 2 bits for host addresses
    - 1 bit = 2 addresses, 0 valid host addresses
    - 2 bits = 4 addresses, 2 valid host addresses



Subnet 2 – 2 addresses

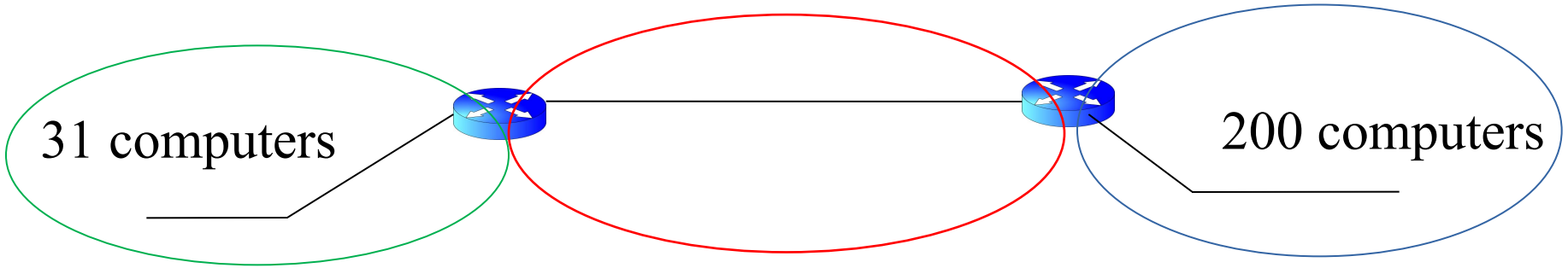
Subnet 1 – 32 addresses

Subnet 3 – 201 addresses

Subnet Design

Assigned IP Range: 192.168.0.0/23
Subnet 3: 192.168.0.0/24
Subnet 1: 192.168.1.0/26

- 3 subnets
  - 2 addresses requires 2 bits for host addresses
    - 1 bit = 2 addresses, 0 valid host addresses
    - 2 bits = 4 addresses, 2 valid host addresses
  - 192.168.0.0 → 192.168.1.63 ----- already used



Subnet 2 – 2 addresses

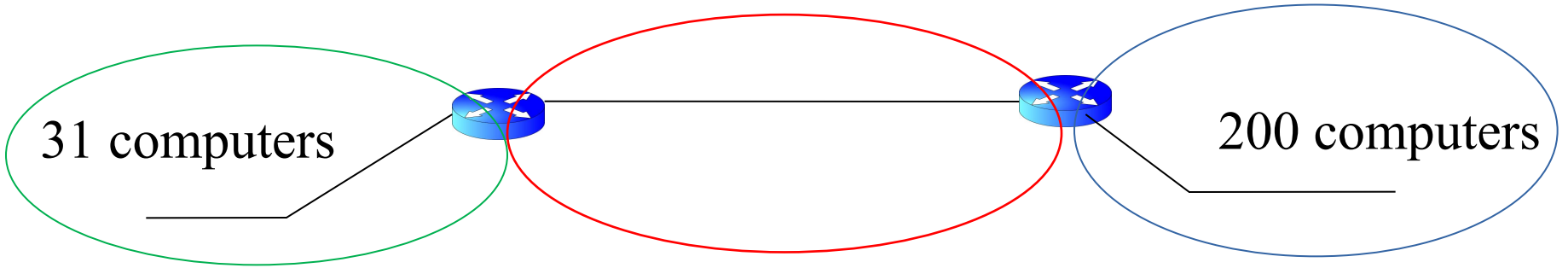
Subnet 1 – 32 addresses

Subnet 3 – 201 addresses

Subnet Design

Assigned IP Range: 192.168.0.0/23
Subnet 3: 192.168.0.0/24
Subnet 1: 192.168.1.0/26

- 3 subnets
  - 2 addresses requires 2 bits for host addresses
    - 1 bit = 2 addresses, 0 valid host addresses
    - 2 bits = 4 addresses, 2 valid host addresses
  - 192.168.1.64



Subnet 2 – 2 addresses

Subnet 1 – 32 addresses

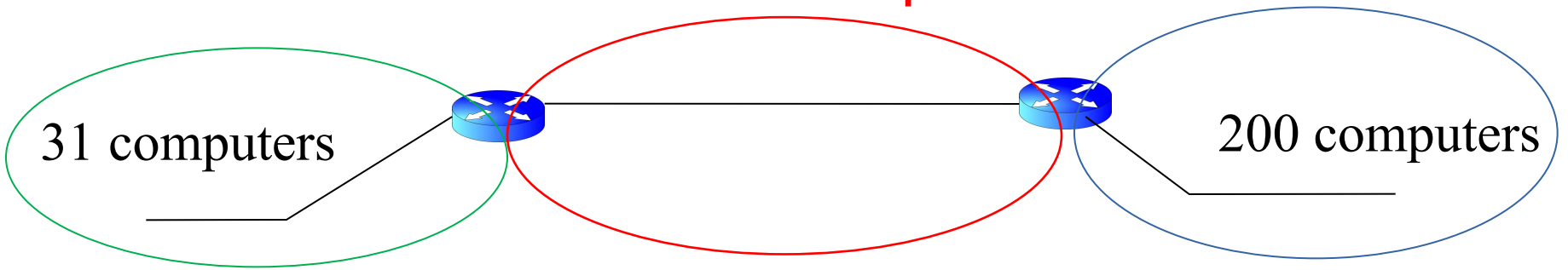
Subnet 3 – 201 addresses

Subnet Design

Assigned IP Range: 192.168.0.0/23
Subnet 3: 192.168.0.0/24
Subnet 1: 192.168.1.0/26

- 3 subnets
  - 2 addresses requires 2 bits for host addresses
    - 1 bit = 2 addresses, 0 valid host addresses
    - 2 bits = 4 addresses, 2 valid host addresses
  - 192.168.1.64 → 192.168.1.67
  - 192.168.1.64/30

11000000 10101000 00000001 01000000



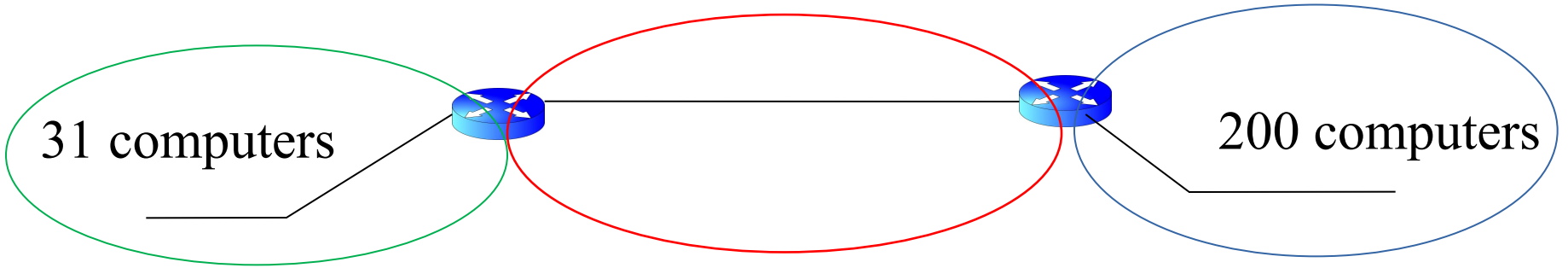
Subnet 2 – 2 addresses

Subnet 1 – 32 addresses

Subnet 3 – 201 addresses

Subnet Design

- Subnet 1: 192.168.1.0/26
- Subnet 2: 192.168.1.64/30
- Subnet 3: 192.168.0.0/24

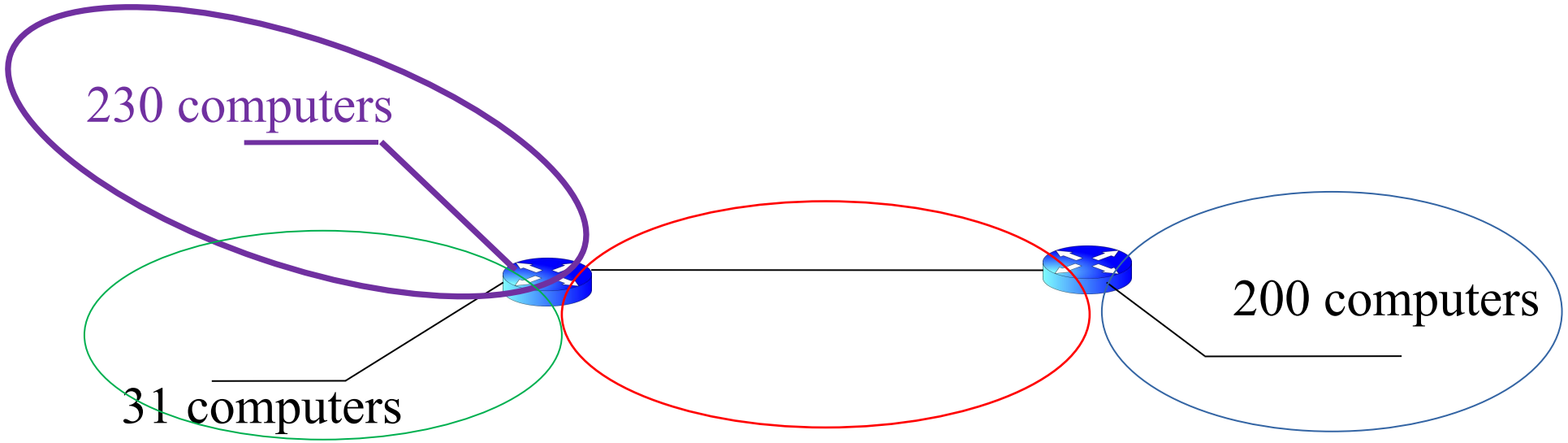


Subnet 2 – 2 addresses

Subnet 1 – 32 addresses

Subnet 3 – 201 addresses

Can We Add More Computers?



Assigned IP Range: 192.168.0.0/23

/23 means 512 Existing addresses

We have in total: 230 + 31+ 200 = 561 computers

So, based only on the number of available IP addresses, it is clear that we cannot add 230 new computers

Problem with IPv4

- We are already running out of IP addresses
- Problem Fixes
  - NAT (Network Address Translation)
    - Allocates IP address freely to all internal devices
    - The outside networks only knows one IPv4 address (assigned by ISP) for a whole internal network
    - Need a device for translating messages between internal and external IPs
  - IPv6:
    - the IPv6 address space is **128**-bits ($\mathbf{2^{128}}$) in size