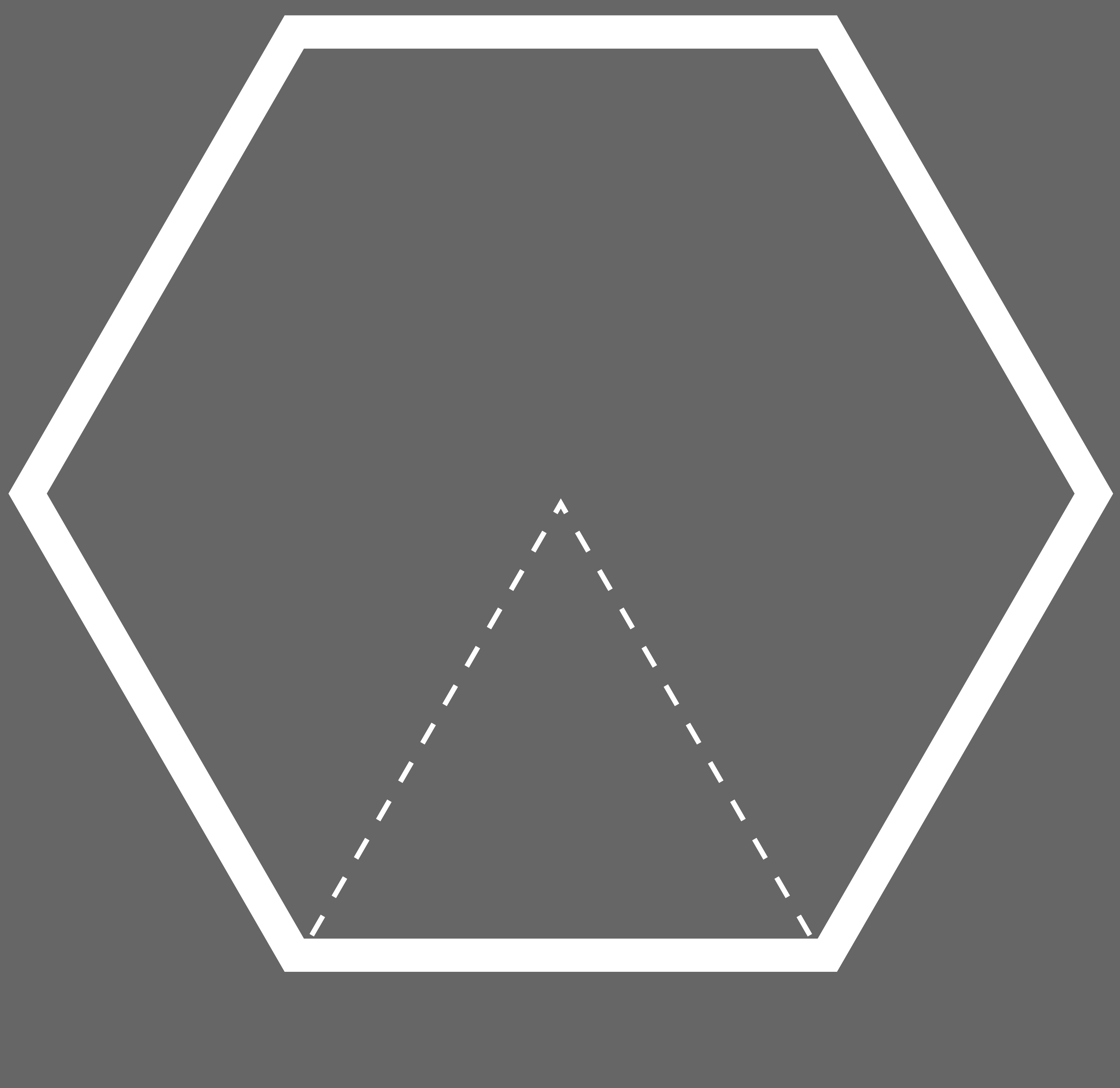
SUBNETTING

A FIELD MANUAL



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Introduction

Who Is This Book For?

This book serves as a helpful guide for visual learners who are interested in understanding subnetting. The book covers the basics of binary, IP addressing, TCP/IP, OSI and subnetting. The target audience are individuals who want to get into the field and prefer learning through infographics. Experienced professionals would also benefit as the ebook could be accessed on your phone and would serve as a refresher for fundamental concepts. The book summarizes several topics and presents them in an interesting and concise manner. Happy reading!

The ebook is in beta and is for free :D

BookContents$ tree

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Index

Binary

What is a Binary Number

It is a number represented using only zeroes (0) and ones (1).

Since only 2 symbols are used (0 or 1), binary notation is considered Base 2.

Examples

Decimal	Binary
2	10
4	100
10	1010
65	1000001
85	1010101

Decimals

Decimals however, are considered Base 10.

This is because the potential symbols are in the range 0-9 leading to a total of 10 symbols.

0, 1, 2, 3, 4, 5, 6, 7, 8, 9

Decimal vs Binary

Decimal	Binary
Base 10	Base 2
0 - 9	0, 1

Binary and Decimal Conversion

Note that a single byte is equivalent to 8 bits

1 byte = 8 bits

Decimal to Binary Table

1 byte representation

(ordering)

8	7	6	5	4	3	2	1
2^7	2^6	2^5	2^4	2^3	2^2	2^1	2^0

(value)

Each Slot has a respective value that is a power of 2. The values double as we go to the left.

← Fill from Right to Left

Conversion Steps

Binary → Decimal

-Slots in the table that have a 1 are activated. Those that have a 0 are not activated.

-We add the respective values of the slots that have a 1 (activated slots).

-The total value is the decimal equivalent.

Example 1

Step 1: Slots with a 1 are activated.

8	7	6	5	4	3	2	1
0	0	0	0	0	0	0	1
2^7	2^6	2^5	2^4	2^3	2^2	2^1	2^0

Step 2: Add the values of activated slots.

0	0	0	0	0	0	0	1
							2^0

Step 3: The total value is the decimal equivalent.

00000001 is equivalent to $2^0 = 1$ in decimal.

Example 2

Step 1: Slots with a 1 are activated.

8	7	6	5	4	3	2	1
0	1	0	0	0	0	1	1
2^7	2^6	2^5	2^4	2^3	2^2	2^1	2^0

Step 2: Add the values of activated slots.

0	1	0	0	0	0	1	1
	2^6					2^1	2^0

Step 3: The total value is the decimal equivalent.

01000011 is equivalent to

$2^6 + 2^1 + 2^0 =$ 67 in decimal.

Example 3

Step 1: Slots with a 1 are activated.

8	7	6	5	4	3	2	1
1	0	0	0	0	0	0	0
2^7	2^6	2^5	2^4	2^3	2^2	2^1	2^0

Step 2: Add the values of activated slots.

1	0	0	0	0	0	0	0
2^7							

Step 3: The total value is the decimal equivalent.

10000000 is equivalent to 2^7 = 128 in decimal.

Example 4

Step 1: Slots with a 1 are activated.

8	7	6	5	4	3	2	1
1	1	1	1	1	1	1	1
2^7	2^6	2^5	2^4	2^3	2^2	2^1	2^0

Step 2: Add the values of activated slots.

1	1	1	1	1	1	1	1
2^7	2^6	2^5	2^4	2^3	2^2	2^1	2^0

Step 3: The total value is the decimal equivalent.

11111111 is equivalent to

$$2^7 + 2^6 + 2^5 + 2^4 + 2^3 + 2^2 + 2^1 + 2^0 = 255$$

in decimal.

In the previous examples we converted from binary to decimal. Now, we want to do the opposite.

We want to convert from decimal to binary.

Example

200 $\longrightarrow$? in binary

Conversion Steps

Decimal ⟶ Binary

-We fill the table by putting a 1 in the slot we want to activate. We put a 0 in other slots that we do not want to activate. We do this based on the decimal value.

-We add the respective values of the slots that have a 1 (activated slots) and make sure they are exactly equal to our desired decimal value (we iterate as needed to reach this point).

200 ⟶ ? in binary

Step 1: Put a 1 in the slots you want to activate.

8	7	6	5	4	3	2	1
0	0	0	0	0	0	0	0
2^7	2^6	2^5	2^4	2^3	2^2	2^1	2^0

1	0	0	0	0	0	0	0

1	0	0	0	0	0	0	0

The value of this binary number (10000000) is $2^7 = 128$

The target value is 200.

200-128 = 72 remains

1	1	0	0	0	0	0	0

1	1	0	0	0	0	0	0

The value of this binary 11000000
is $2^7 + 2^6 = 192$

The target value is 200.
200-192 = 8 remains

1	1	0	0	1	0	0	0

1	1	0	0	1	0	0	0

The value of this binary 11001000
is $2^7 + 2^6 + 2^3 = 200$

Equal to target value!!

The Powers of 2

$2^0 = 1$	$2^7 = 128$
$2^1 = 2$	$2^8 = 256$
$2^2 = 4$	$2^9 = 512$
$2^3 = 8$	$2^{10} = 1024$
$2^4 = 16$	$2^{11} = 2048$
$2^5 = 32$	$2^{12} = 4096$
$2^6 = 64$	$2^{13} = 8192$

Understanding and familiarizing yourself with powers of 2 will be of great importance and will come in handy.

OSI & TCP/IP

Networking Models

Networking models are used to describe the logical flow of data and the steps required for communication to occur.

There are 2 popular networking models

OSI

Was created by the International Organization for Standardization (ISO).

Has 7 Layers.

TCP/IP

Was created by the Department of Defense (DoD).

Has 4 Layers.

More Popular Nowadays.

Why Layers

Using layers in networking models has several benefits:

Layering

1. It facilitates logical representation.

2. It helps in troubleshooting (we can associate a problem to a specific layer).

3. Each layer interacts with the layer directly above it AND OR the layer directly below it.

4. Each layer has a specific and clearly defined function.

OSI

The Open System Interconnection or OSI Model is divided into the 7 layers below.

Seven	Application
Six	Presentation
Five	Session
Four	Transport
Three	Network
Two	Data Link
One	Physical

OSI

It is important to memorize the layers. To do that, mnemonics could be helpful.

Please Do Not Take Same Picture Again.

Pink Dolphins Never Tailgate Silly Pirates Accidentally.

You can create your own mnemonics!

PDU

It is important to know what the Protocol Data Unit (PDU) is. PDU is the name used to describe the data at each layer of a networking model.

OSI

One

Physical

The first layer is the Physical Layer.

This layer deals with the physical structure of the network, such as wires, cables and hubs.

The physical layer also handles transmitting and receiving raw data bits across the network.

The PDU at the Physical Layer is Raw Bits.

OSI

Two

Data Link

The second layer is the Data Link Layer.

This layer encapsulates the data packets coming from the network layer into frames

The PDU at this layer is called a frame.

This layer is divided into two sublayers.

Data Link

Logical Link Control (LLC)	Media Access Control (MAC)
Deals with Error Control & Flow Control	Deals with Physical Addressing

OSI

Three | Network

The third layer is
the Network Layer.

This layer's scope is to route traffic. It deals with logical addressing, switching and route discovery/selection.

The PDU at this layer is called a packet.

Four | Transport

The fourth layer is
the Transport Layer.

The PDU at this layer is called a segment.

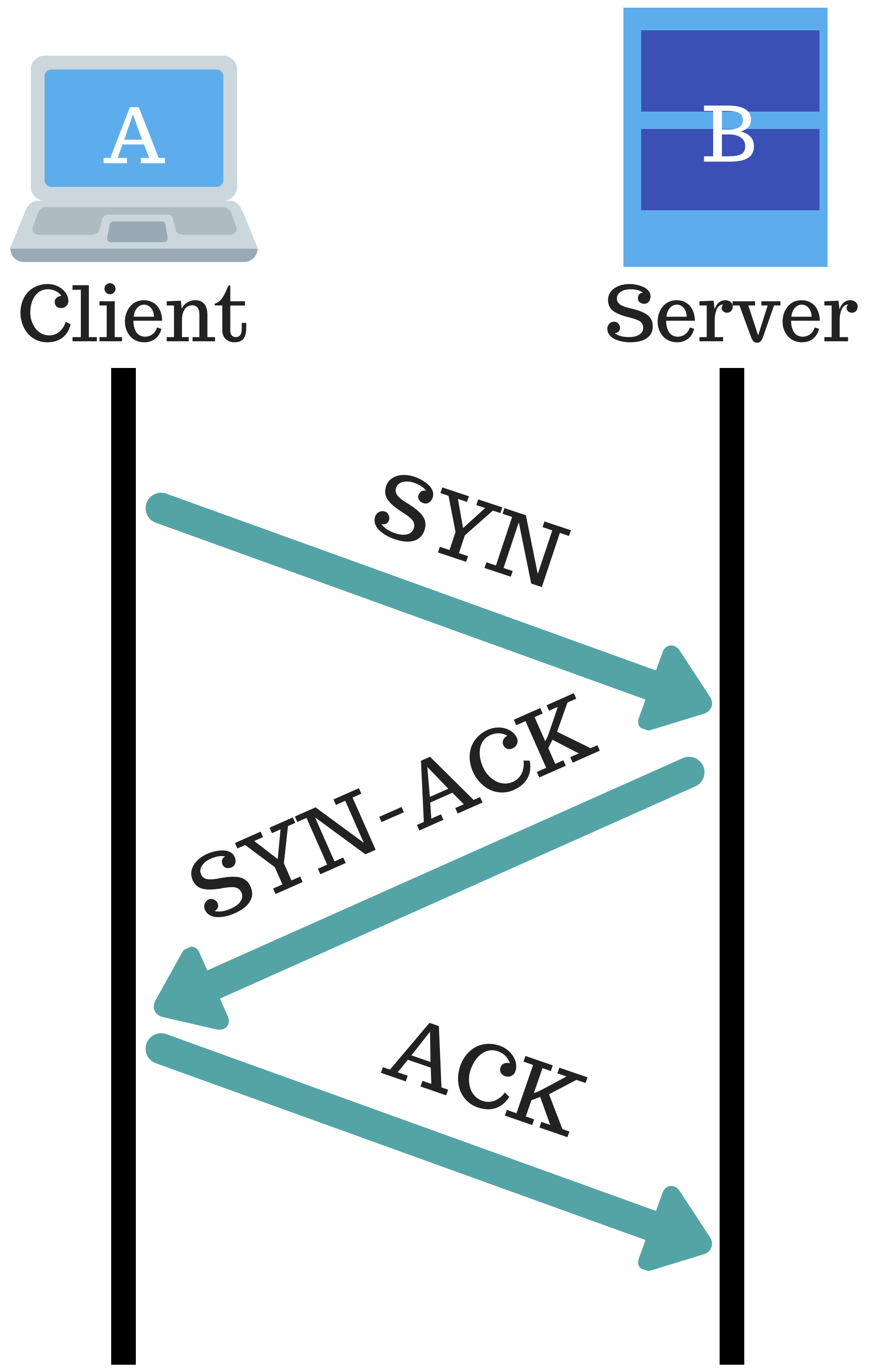
OSI

This layer deals with the reliability of the connection. It is also responsible for the end to end connectivity.

The Transport layer has the 2 protocols below. Both are used to send packet across the network.

TCP	UDP
Transmission Control Protocol	User Datagram Protocol
Slower but Reliable	Fast but Unreliable
Establishes a connection before sending packets	Does not establish a connection. Hence, connectionless

OSI



TCP Handshake

How TCP establishes a connection.

SYN:

Client sends a SYNchronize packet to the Server indicating it wants to communicate with it.

SYN-ACK:

The Server responds with a SYNchronization ACKnowledged packet to highlight that it has indeed received the SYN request.

ACK:

The Client acknowledges the SYN-ACK packet and highlights that it was received by sending an ACKnowledgment packet.

Now, reliable communication can commence

The above process is called 3 way handshake

OSI

Five Session

The fifth layer is the Session Layer.

This layer deals with opening and managing sessions.

The PDU at this layer is called Data.

Six Presentation

The sixth layer is the Presentation Layer.

This layer delivers data to the application layer.

The PDU at this layer is called Data.

OSI

Seven

Application

The seventh layer is
the Application Layer.

This is the layer that users interface with (HTTP, FTP, Telnet, etc..).

The PDU at this layer is called Data.

OSI

Quick recap of the Layers and their respective PDUs.

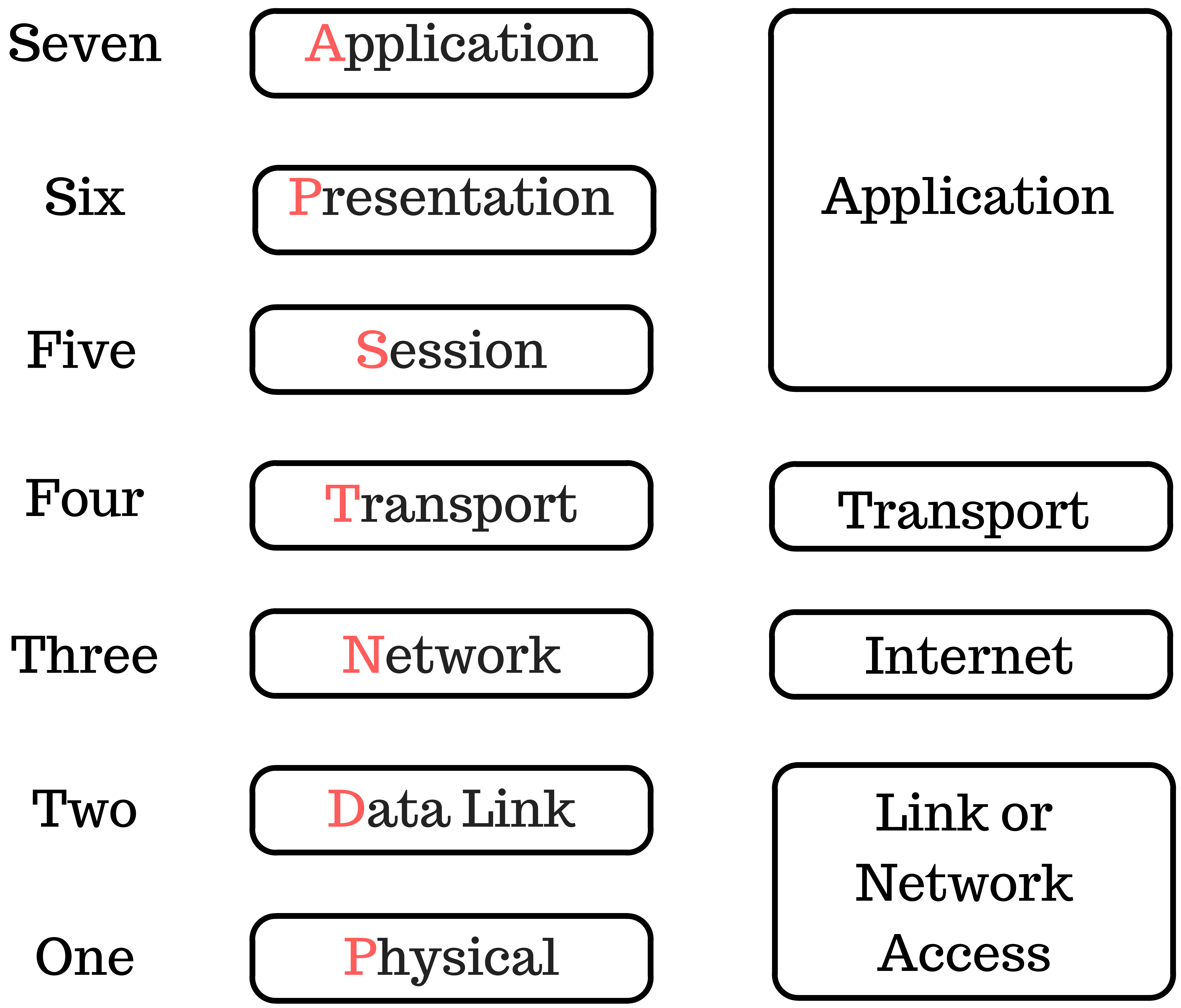
PDU	Layer
Data	Application
Data	Presentation
Data	Session
Segments	Transport
Packets	Network
Frames	Data Link
Bits	Physical

TCP/IP

The TCP/IP Model has only 4 layers. However, these 4 layers are almost equivalent to the 7 layers of the OSI model when it comes to functionality.

Four	Application
Three	Transport
Two	Internet
One	Link or Network Access

TCP/IP & OSI Side By Side



The OSI and TCP/IP model in this diagram have the similar layers next to each other.

TCP/IP

One | Link or Network Access

This layer deals with mapping IP Addresses to MAC Addresses as well as encapsulating IP packets into frames.

The PDUs at this layer are both frames and bits.

TCP/IP

Two | Internet

This layer deals with logical addressing and IP datagrams routing.

The main protocols at the Internet layer are the Internet Protocol (IP), Address Resolution Protocol (ARP) and the Internet Control Message Protocol (ICMP).

The PDU at the Internet Layer is called a packet.

TCP/IP

Three **Transport**

Similar to the OSI, this layer deals with the reliability of the connection.

The main protocols at the Transport layer are the User Datagram Protocol (UDP) and the Transmission Control Protocol (TCP).

The PDU at the Transport Layer is called a segment.

TCP/IP

Four | Application

The scope of this layer is to provide network services to the applications that need them.

The PDU at this layer is called data unit.

The application layer includes the following protocols HTTP, FTP, Telnet, etc..

IP

IP ?

IP is short for Internet Protocol.

What Exactly is that?

The Internet Protocol is the main protocol in the Internet Layer of the TCP/IP model.

This Layer's Main Function is Routing

Internet
Layer Protocols*

IP

Main Protocol

ICMP
ARP

useful protocols to help IP do its function

*These are the most important protocols in this layer. Other protocols are outside the scope of the book.

What is an IP address?

An IP address is a unique identifier for a device on a TCP/IP network. It is short for Internet Protocol address.

Why do we have IP addresses?

So a device can be reachable!

An IP address in networking is analogous to a home address in a mailing system. When you send a package to a friend, you include the street address followed by the home/apartment #. Similarly, an IP address is divided into 2 portions (network portion and host portion) to serve the same purpose.

Street Address

Network Portion

All devices on the same network have the same Network portion

Home/Appt

Host Portion

Each device has a unique number

185.20.40.35 /16

Network Portion

Host Portion

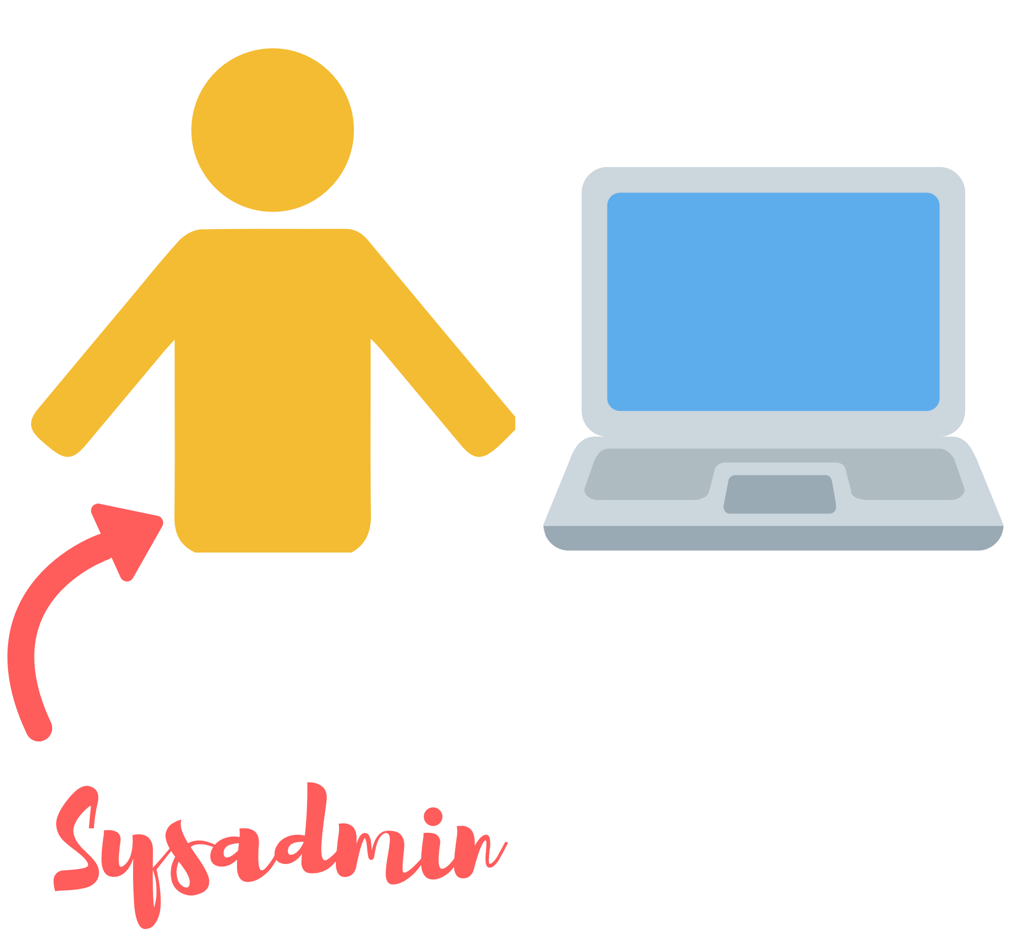
Class B Address with /16 CIDR Value (more on that later)

Methods of Assigning IP Addresses

Static Allocation

A static IP address is assigned manually and does not change.

The System Administrator / Network Administrator manually sets the IP address on each device.



In this approach, each computer should be manually configured which is time consuming.

Dynamic Allocation

A dynamic IP address is assigned dynamically and can change.

The DHCP Server automatically sets the IP address.

In this approach, the Dynamic Host Configuration Protocol (DHCP) Server automatically assigns IPs for all hosts which saves time.

DHCP Continued

The steps of DHCP operation are explained below.

1. DHCP Discovery

In this step, the client sends a broadcast message to discover a DHCP server.

2. DHCP Offer

In this step, the DHCP server responds to the client by sending an IP offer.

3. DHCP Request

In this step, the client indicates acceptance of an offered IP address by sending a request to the DHCP server.

4. DHCP Acknowledgment

In this final step, the DHCP server sends an acknowledgment to the client to confirm the receipt of the request.

More on DHCP

When a client gets assigned an IP address it is not a permanent assignment. It is considered a lease.

Can either..

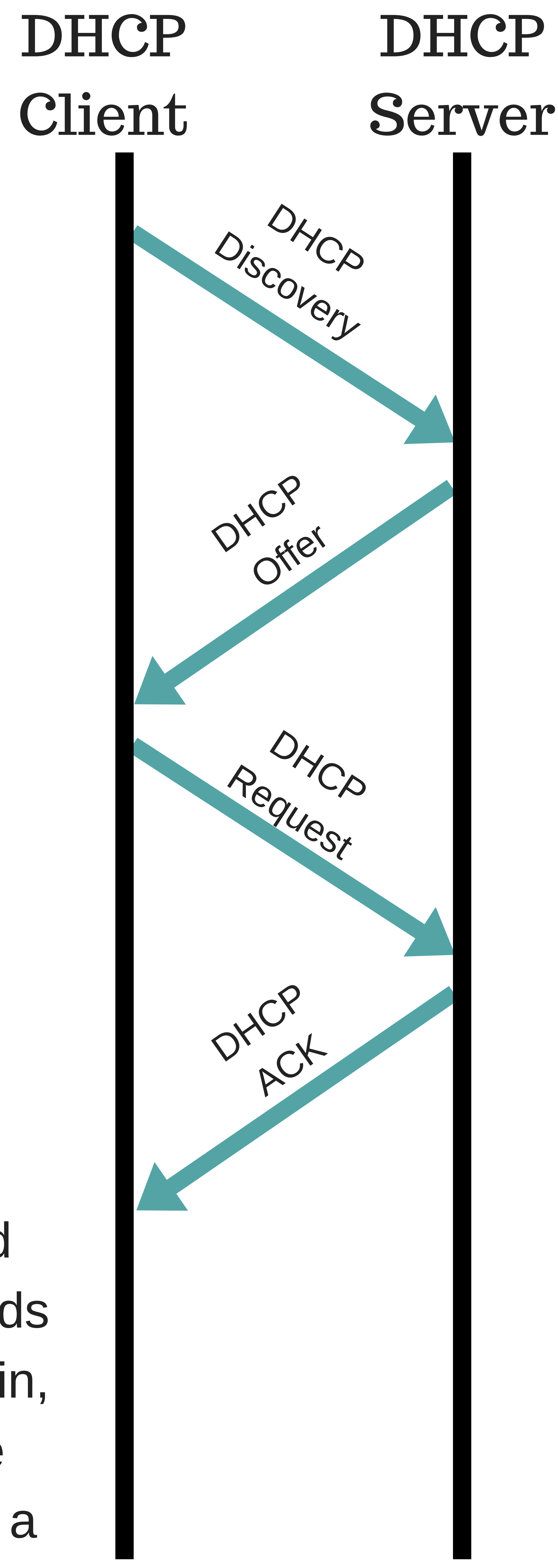
Renew the lease and keep the assigned IP.

Release the IP.

In this case

The server can reassign this IP to another client.

If the old client needs an IP again, it will be assigned a different IP.



Versions of IP addresses

There are 2 versions of IP. These are Internet Protcol Version 4 and Version 6.

IPv4

IPv4 is more common than IPv6.

An IPv4 address is 32 bits long.

$2^{32} = 4,294,967,296$ IP addresses allowed by IPv4.

IPv6

IPv6 is considered the future of IP addressing.

An IPv6 address is 128 bits long.

$2^{128} = 340,282,366,920,938,463,463,374,607,431,768,211,456$ IP addresses allowed by IPv6.

With more and more devices connected to the Internet (mainly thanks to IoT), the 4 billion devices supported by IPv4 will not be enough.

This is one of the main reasons we need IPv6 -> We need to cater for more connected devices

More on Versions of IP addresses

IPv6 → Is represented by hexadecimals separated by colons.

e.g. 7efc:f40a:7b94:a7d1:48fb:a793:c3f9:7ab8

IPv4 → Is represented by 4 decimal numbers separated by dots.

e.g. 164.48.26.17

IP address representation can also be in binary like we will see in a bit.

We will focus on IPv4 primarily since it is currently the most common IP version.

IPv6

Better Security
Better Efficiency
Better Address Space

32 bit IPv4 address

8.8.8.8

octet

A 32 bit IPv4 address consists of 4 octets (8 bits).

4 octets x 8 bits = 32 bits

An Octet can NEVER go beyond 255. This is because 255 is the maximum number represented by an 8 bit number (Check the Binary chapter).

IPv4 Notation

Binary Notation

01101100.01100000.11001110.10111101

Dot Decimal Notation

108.96.206.189

IP Addresses can be represented either in dot decimal notation or binary notation.

N.B.

IPv4 addresses could be mathematically expressed in hexadecimal notation. However, this is not a standard nor is it common in the industry.

The conversion between hexadecimal, decimal and binary is merely mathematical. However, each IP version has its common notation that is followed.

Types of IP addresses

Private

Private IP addresses are assigned by the router.

Each device on your internal network has a private address.

2 different networks could have a repeating private IP address.

Public

Public IP addresses are assigned by the ISP (Internet Service Provider).

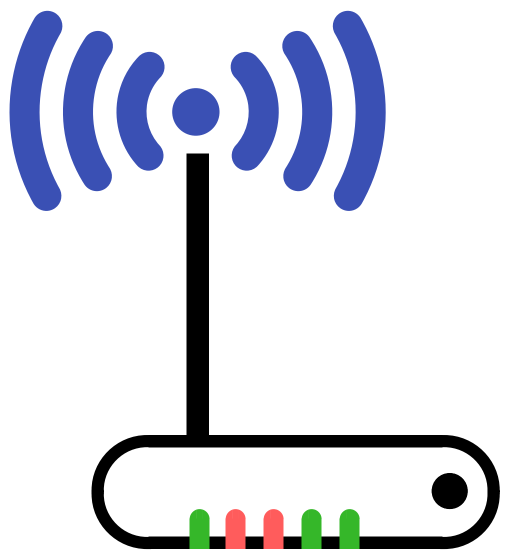
Public IP addresses are unique addresses. They are not repeated.

The purpose of these addresses is to identify your home network to the internet.

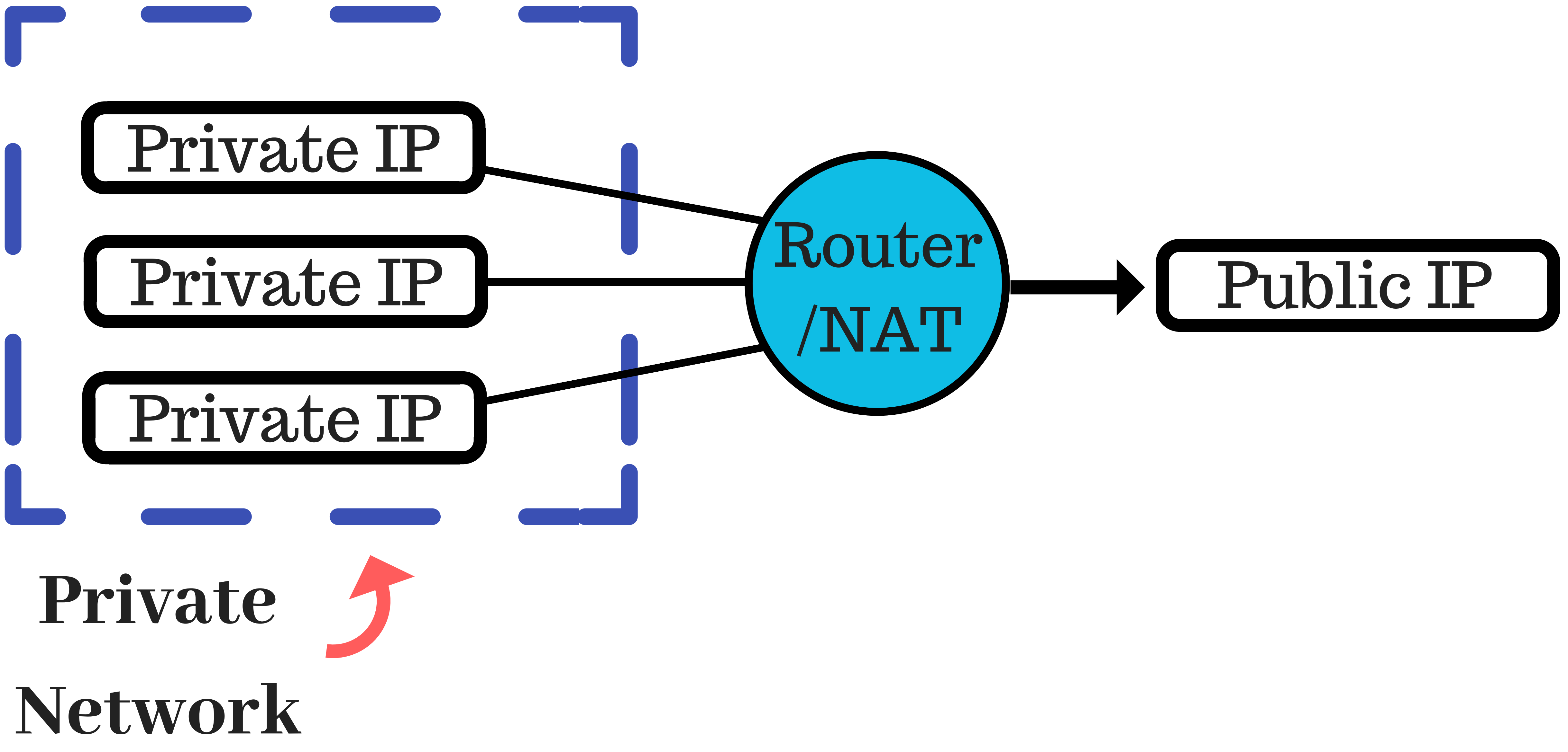
N.B.
Private addresses help fix the issue of the limited number of IP addresses provided by IPv4.

Private IP Ranges

Class	Private IP Ranges
Class A	10.0.0.0 – 10.255.255.255
Class B	172.16.0.0 – 172.31.255.255
Class C	192.168.0.0 – 192.168.255.255

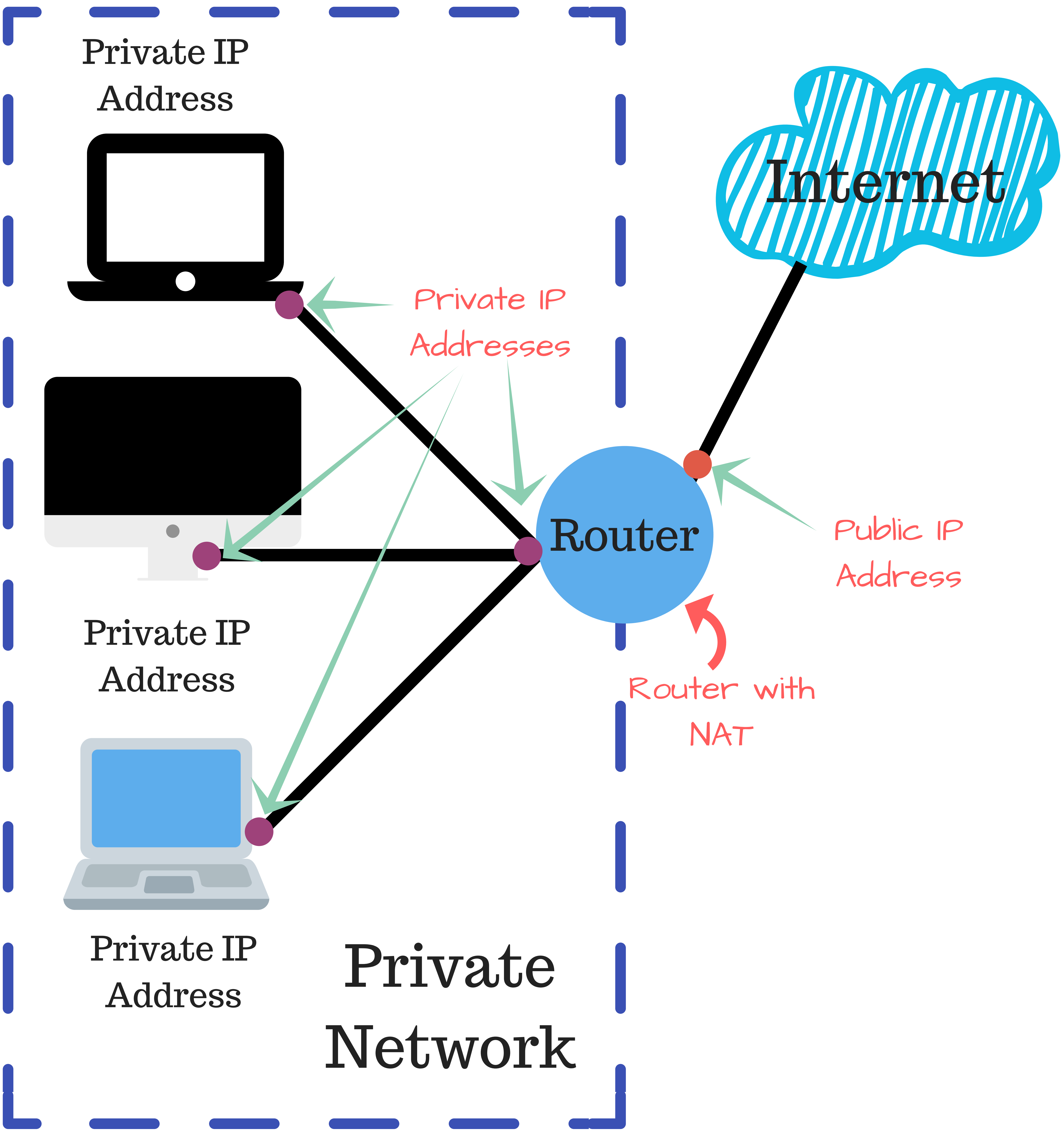


These are the ranges that can be assigned to devices in a private network.



A device cannot directly access the internet with a private IP. Thus, it needs a public IP. Private IPs are converted to Public IPs through NAT (more on that later)

More on Private and Public Addressing



NAT

NAT is short for Network Address Translation.

Why NAT?

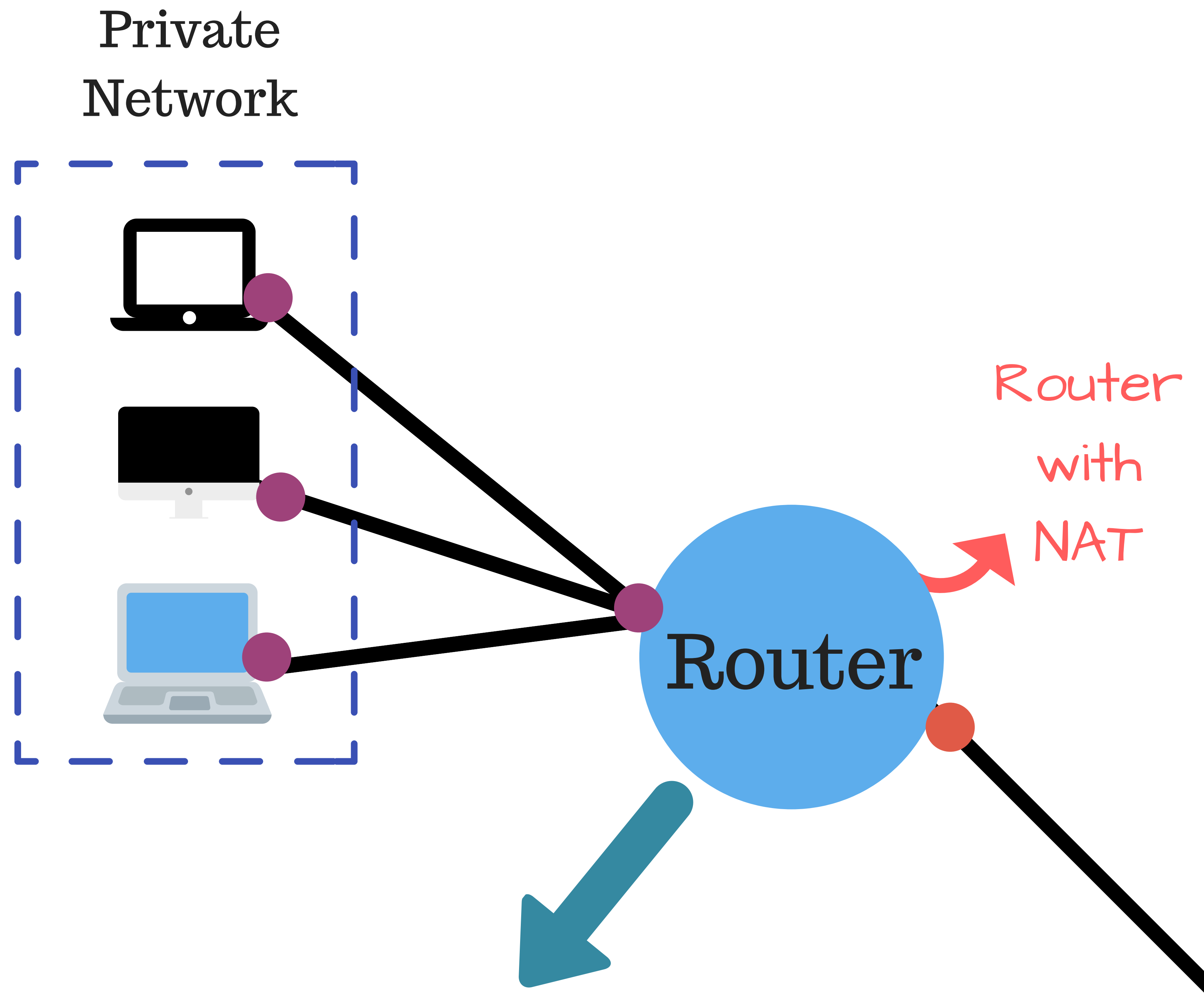
When a device on a private network needs to access the internet, it needs a public IP. This is where NAT comes into play. NAT translates the private IP of a device to a public IP that can access the internet.

Benefits of NAT

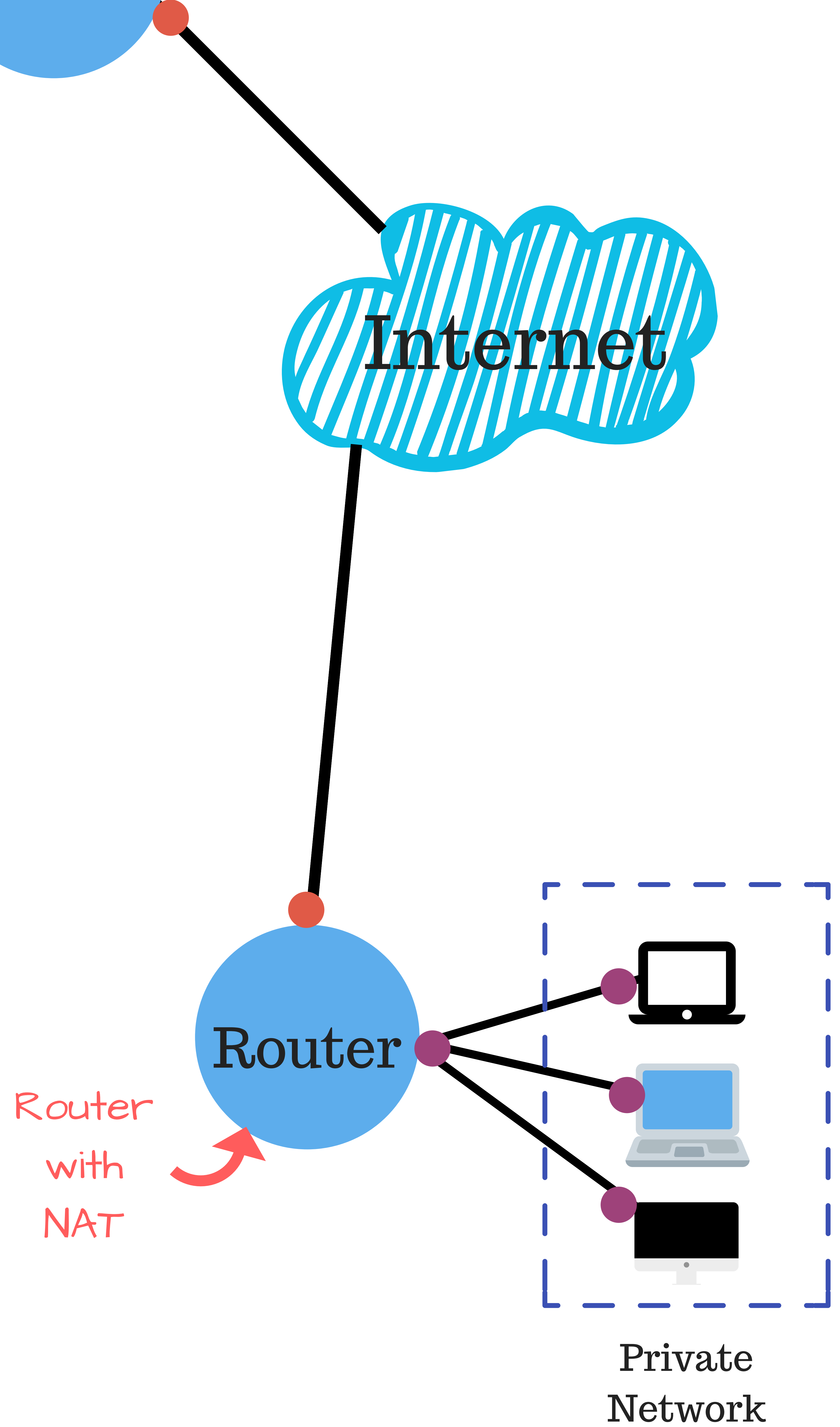
Less number of IPv4 addresses are consumed.

Provides better privacy as the IP addresses of internal devices are hidden from the outside world.

More on NAT



A NAT Table is a table inside a NAT enabled device that has the network translations stored for all the local devices.



NAT Table

	Internal Address	Public Address
	x	x
	x	x
	x	x

Internal Address is Also known as
Inside Local Address
Public Address is Also known as
Inside Global

Hierarchical IP Addressing

There are 2 types of addressing in general.

Flat Addressing

All the digits forming the number have the same level of importance. Hence, **flat**.

The number/address cannot be broken down into smaller meaningful sections.

Hierarchical Addressing

This is the form of addressing used for IP addresses.

Each section/portion of the number/address has a certain meaning.

Makes routing faster and more efficient.

e.g. Phone Numbers, IP Addresses.

+1 (614) 000-0000

Country Code

Area Code

163.146. 65.199

Network Portion

Host Portion

Hierarchical IP Addressing

Flat Addressing

In Flat Addressing, each device connected to the internet needs an entirely different number.

→

This leads to capacity issues. Since every router needs to store all those numbers to route packets to a desired target.

Hierarchical Addressing

In Hierarchical Addressing, a router does not need to store all IPs. Instead, a router identifies the network of an IP address from its network portion and sends the data packets to that network.

→

According to the host portion of the IP address, the data packets are sent to the destination machine within the network.

↓

This solves the issue of capacity as the routers do not need to store all the IP addresses it would have needed to store under flat addressing.

Hierarchical IP Addressing

There are 3 main classes for addressing based on network size.

Hierarchical Addressing Classes

	Class A	Class B	Class C
Value Range of 1st Octet	1 – 126	128 – 191	192 – 223
1st Octet Fixed Bits	**0** **0**0000000 **0**1111111	**10** **10**000000 **10**111111	**110** **110**00000 **110**11111
# of Hosts per Network	Highest $2^{24} - 2$	Medium $2^{16} - 2$	Low $2^{8} - 2$
# of Networks	Low $2^{7} - 2$	Medium $2^{14} - 2$	Highest $2^{21} - 2$

Range of 1st Octet

Hierarchical IP Addressing

Hierarchical Addressing Classes

Class A **Class B** **Class C**

In all the classes, the first octet has a certain number of bits that is always fixed. Then the range of the first octet starts from all zeros to all ones for the remaining bits

	Class A	Class B	Class C
1st Octet Fixed Bits	**0**	**10**	**110**
Range of 1st Octet	**0**0000000	**10**000000	**110**00000
	01111111	**10**111111	**110**11111

Depending on the class, each address is divided between a network portion and a host portion differently.

	Network and Host Portions
Class A	**Network**.Host.Host.Host
Class B	**Network**.**Network**.Host.Host
Class C	**Network**.**Network**.**Network**.Host

There are 2 other classes (Class D and Class E). However, they are out of our scope

Hierarchical IP Addressing

The 32 bits are divided between a Network portion and a Host portion.

Network	Host

	Byte 1	Byte 2	Byte 3	Byte 4
Class A	Network .	Host .	Host .	Host
Class B	Network .	Network .	Host .	Host
Class C	Network .	Network .	Network .	Host
Class D	Multicast			
Class E	Reserved			

Classful vs Classless Addressing

Classful

Honors the rules of network/host portion division

Initial Network-Host Barrier

172.16|.0.1

Class B address with a default network/host divider after 16 bits (2 octets).

Classless

Breaks the rules of classful addressing regarding the network/host portion division.

New Network-Host Barrier

172.16|.0|.1/24

Still a class B address because it is in the range. However, the network/host divider has shifted beyond the 2nd octet.

Classless addressing allows for the use of Variable Length Subnet Masks (VLSM)

IP address vs MAC Address

IP Addresses (which are also called Logical Addresses) can vary based on the network and its setup. However, MAC Addresses (also called Physical Addresses) are permanent and do not change.

IP Address	MAC Address
Logical Address	Physical Address
Could Vary	Permanent

If an attacker has the MAC address of a device, they could easily track this device regardless of the network it is connected to. This is because there is only one device with a specific MAC Address.

ICMP

ICMP is short for Internet Control Message Protocol.

Functions of ICMP

Identifying if a Destination Computer/IP is Reachable

Network Troubleshooting

ICMP is NOT used for data exhange.

ICMP supports two programs

Ping

Short for Packet Internet Groper.

Checks the connection between devices.

Traceroute

Traces the route that a packet follows to reach its destination.

More on ICMP

Ping

- Checks the connectivity of machines.
- It provides important information about the trip to the destination and back. These include the..
  - Time to Live.
  - # of Packets Transmitted, Received and Dropped.
- It indicates if a connection is established with the destination.
- It indicates if a host is unreachable.

Traceroute

- Discovers the path and number of hops that a packet follows to reach a destination.
- Provides the user with the time taken at each hop.

5

ARP

ARP is short for Address Resolution Protocol.

Function of ARP

Finding the MAC address of a host from its IP address

ARP in Action

1 Host A wants to reach Host C.
Host A has the IP of Host C. However, it does not have the MAC address of Host C.

2 Host A sends an ARP Request with the destination IP address but no destination MAC address.

3 Every Host aside from A on the network receives this request. They all drop it except Host C.

4 Host C Responds with its MAC address.

5 Host A updates its ARP table and matches both the IP address and the MAC address of Host C together.

6 Host A sends its message to Host C using the destination MAC address retrieved earlier.

More on ARP

ARP in Action

1 Host A wants to reach Host C.
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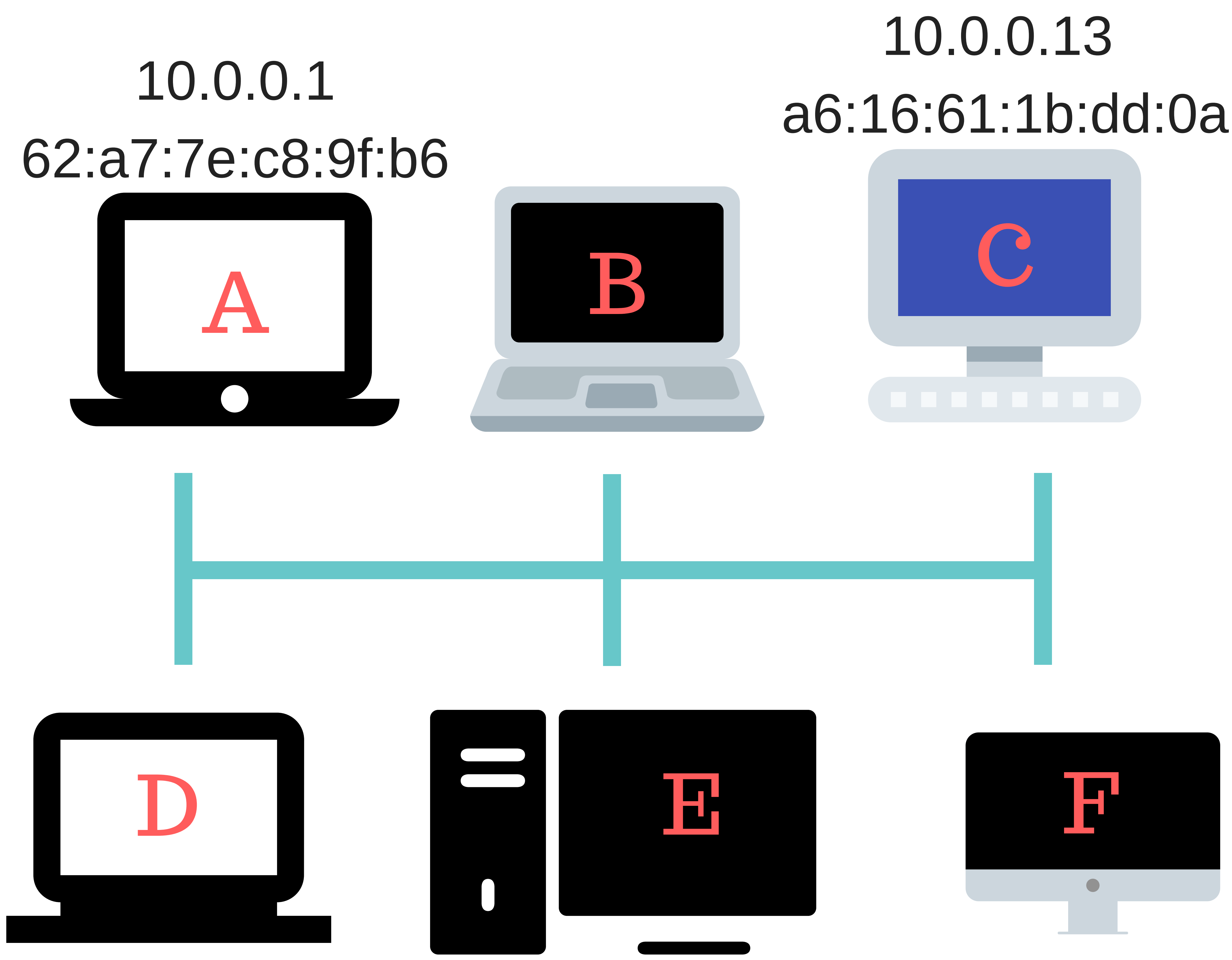
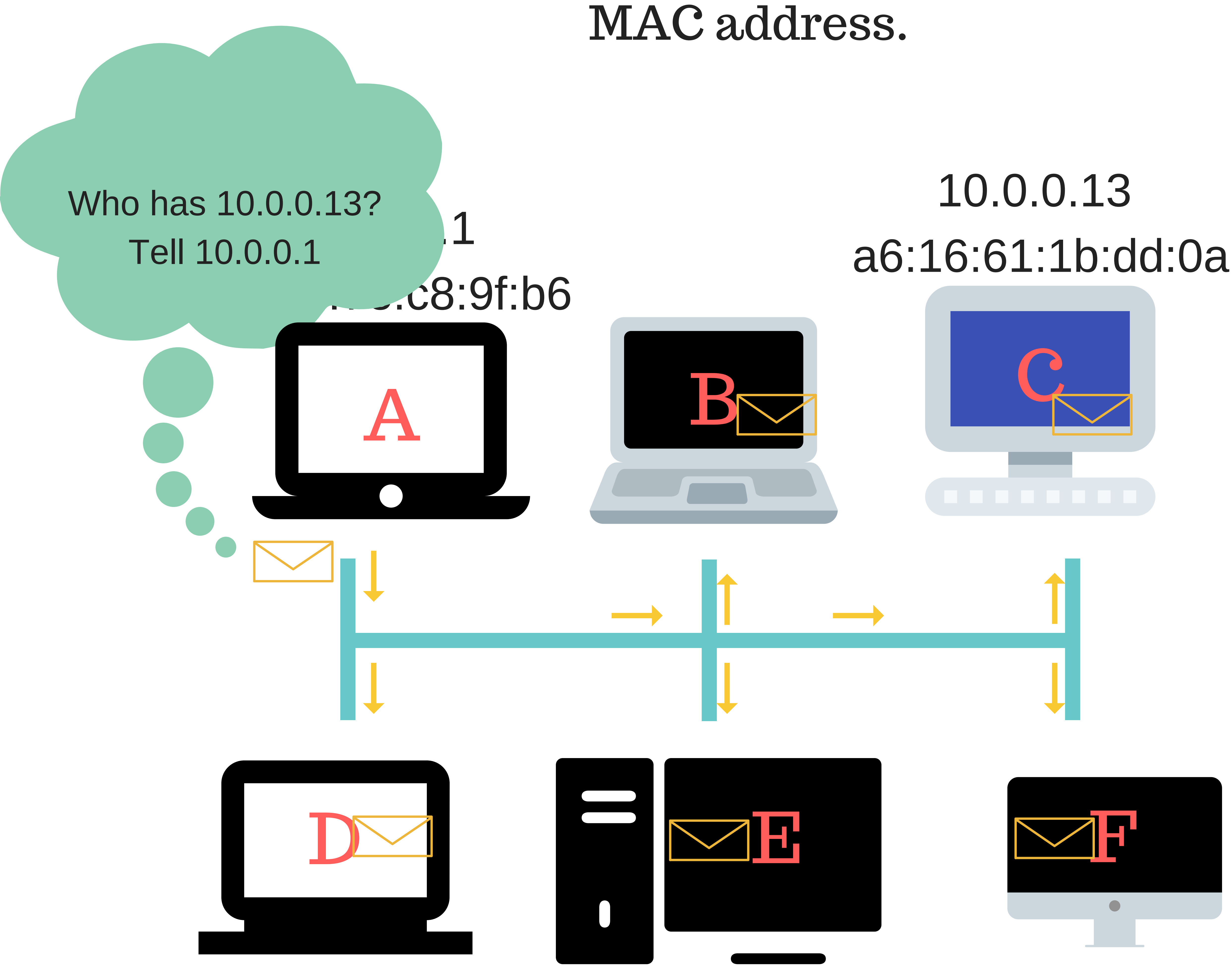


More on ARP

ARP in Action

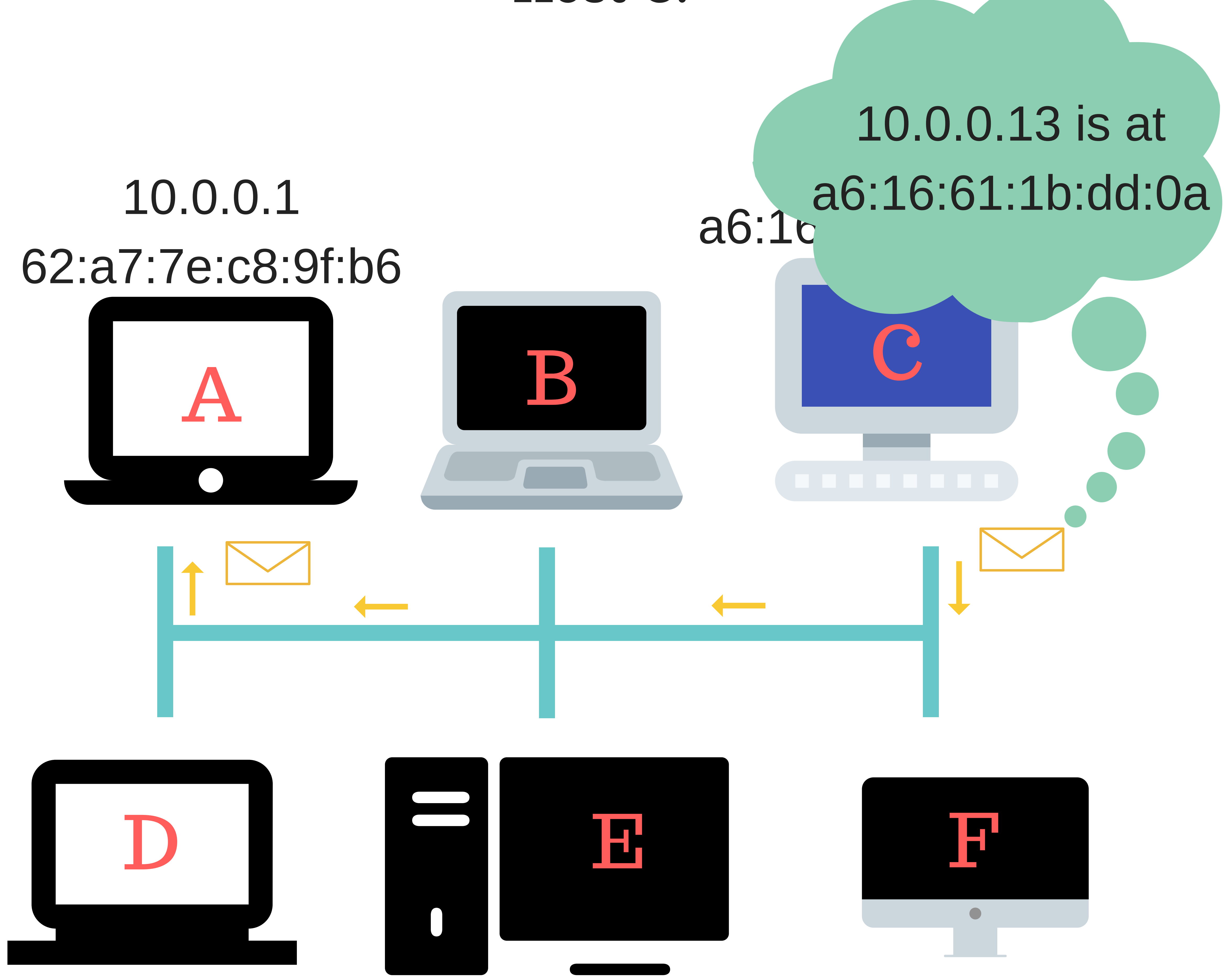
2 Host A sends an ARP Request with the destination IP address but no destination MAC address.



More on ARP

ARP in Action

3 Every Host aside from A on the network receives this request. They all drop it except Host C.

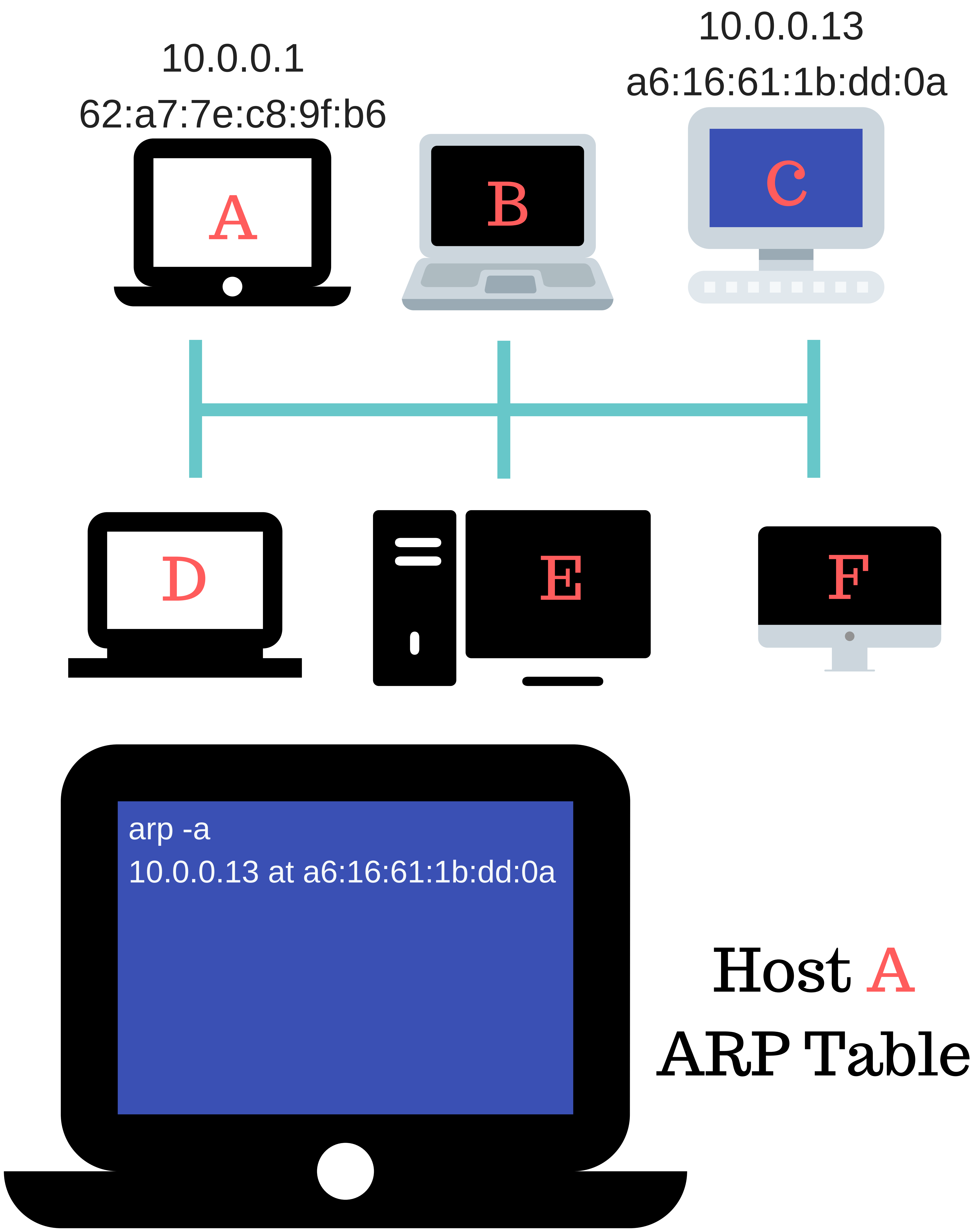


4 Host C Responds with its MAC address.

More on ARP

ARP in Action

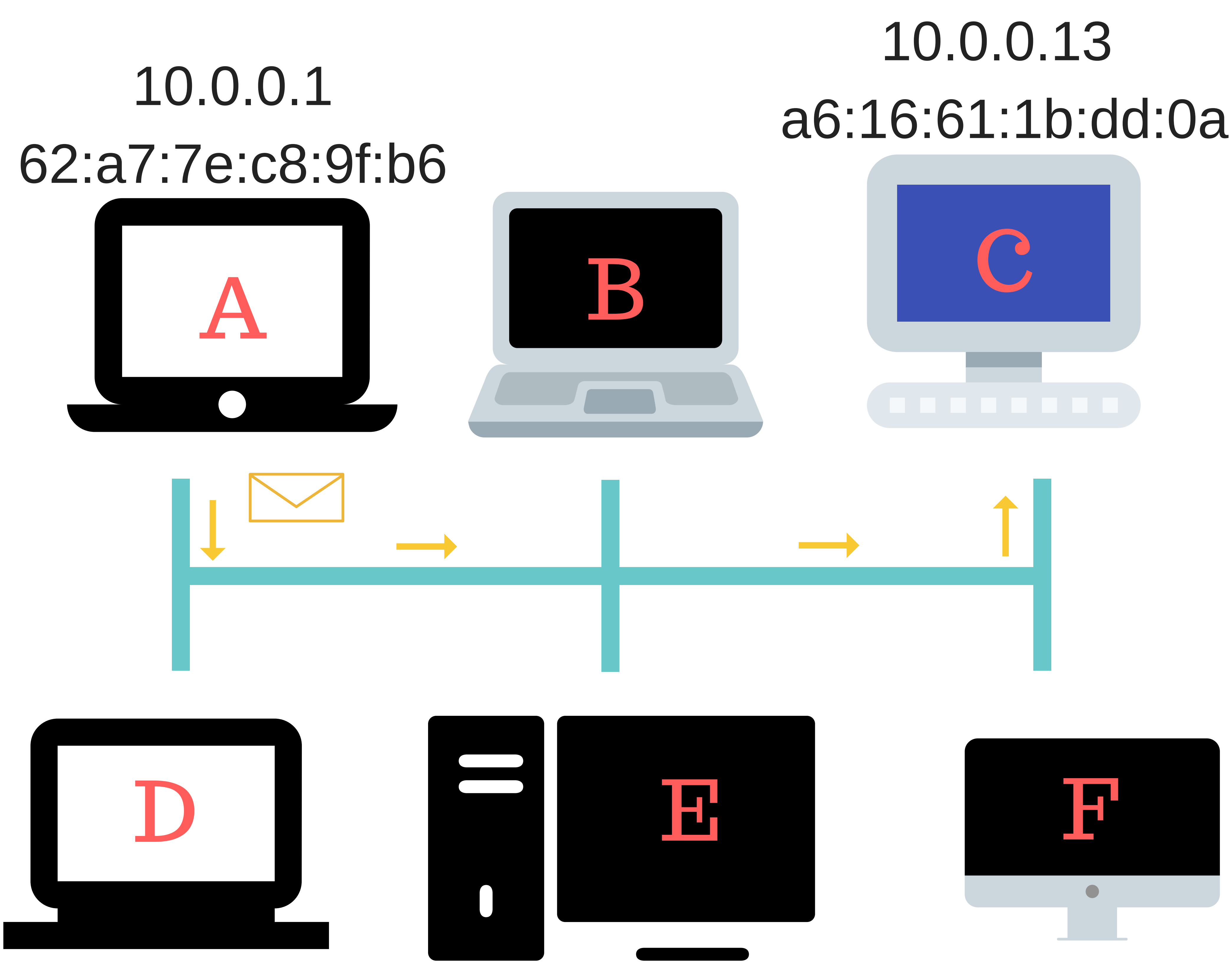
5 Host A updates its ARP table and matches both the IP address and the MAC address of Host C together.



More on ARP

ARP in Action

6 Host A sends its message to Host C using the destination MAC address retrieved earlier.

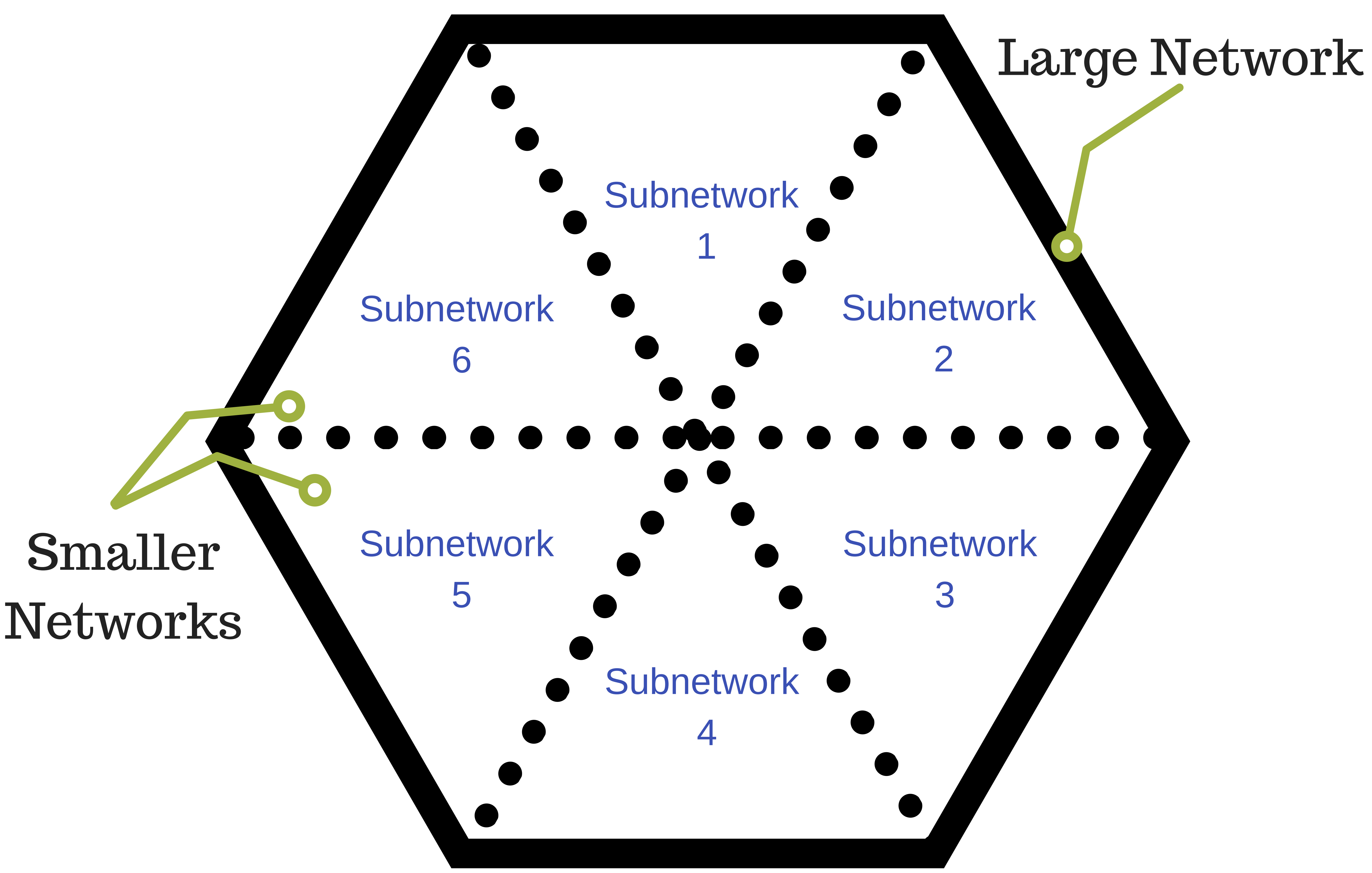


Message from Host A to Host C

SUBNETTING

What is Subnetting??

Subnetting is the act of dividing a large network into smaller portions/smaller networks.



A large network divided into several subnetworks

Why do we subnet?

We subnet for several reasons

Better Network Management

With subnetting, large organizations can better manage their networks. For instance, each department will be on a different subnet. Thus, if an error occurs, troubleshooting will be easier.

Improved Security

Subnetting provides better security. For example, if the HR department is on a subnet different from that of the Finance department, security is improved. This is because breaching the subnet of HR (i.e. through sending a malicious resume) doesn't necessarily mean breaching the Finance department.

Better Network Performance

When a network is divided into smaller pieces, this leads to better traffic.

Classless vs. Classful

You need to know about the 2 types of routing

Classless Routing

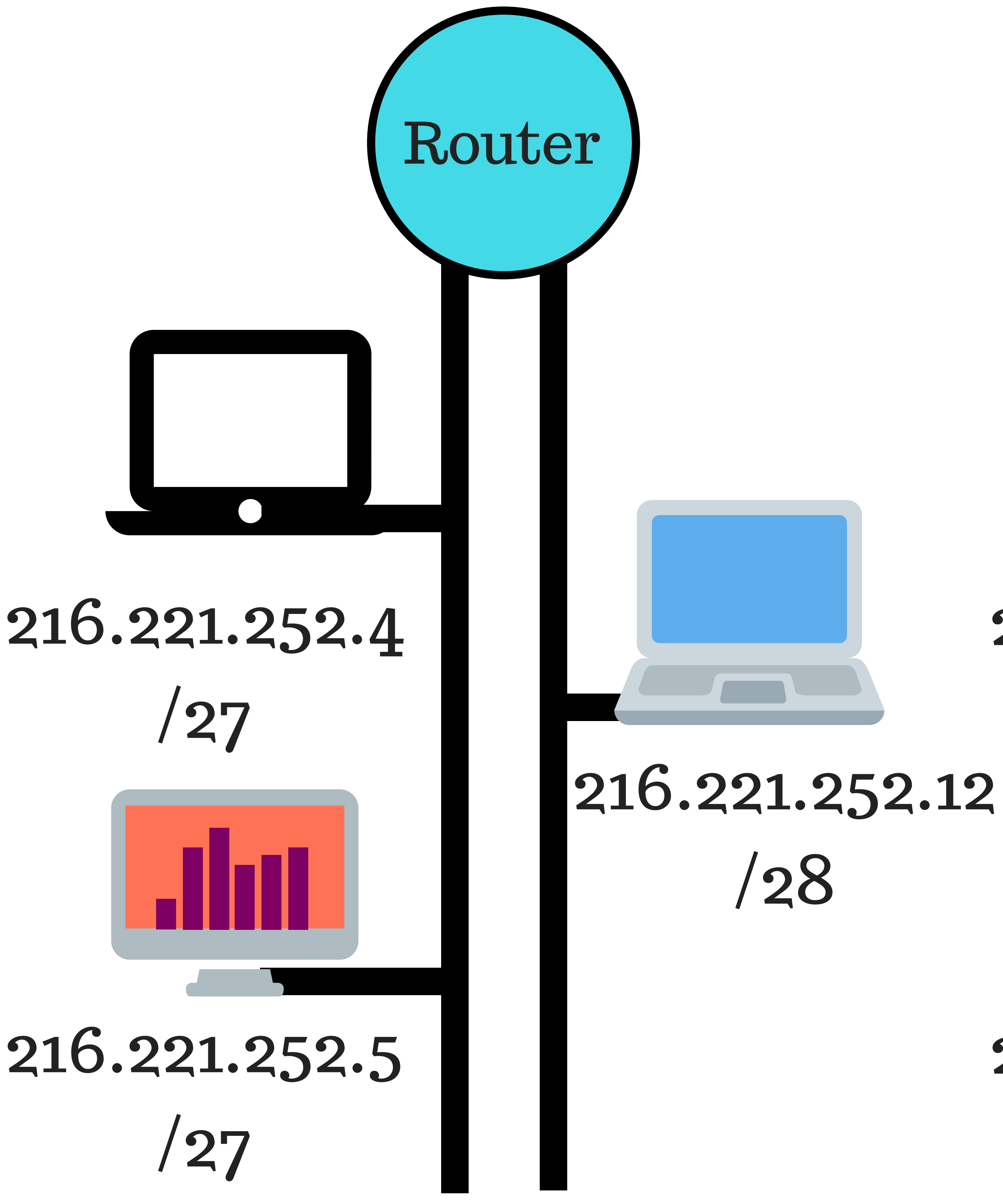
Each network section can have its own unique subnet mask.

Subnet Mask info is sent with routing updates.

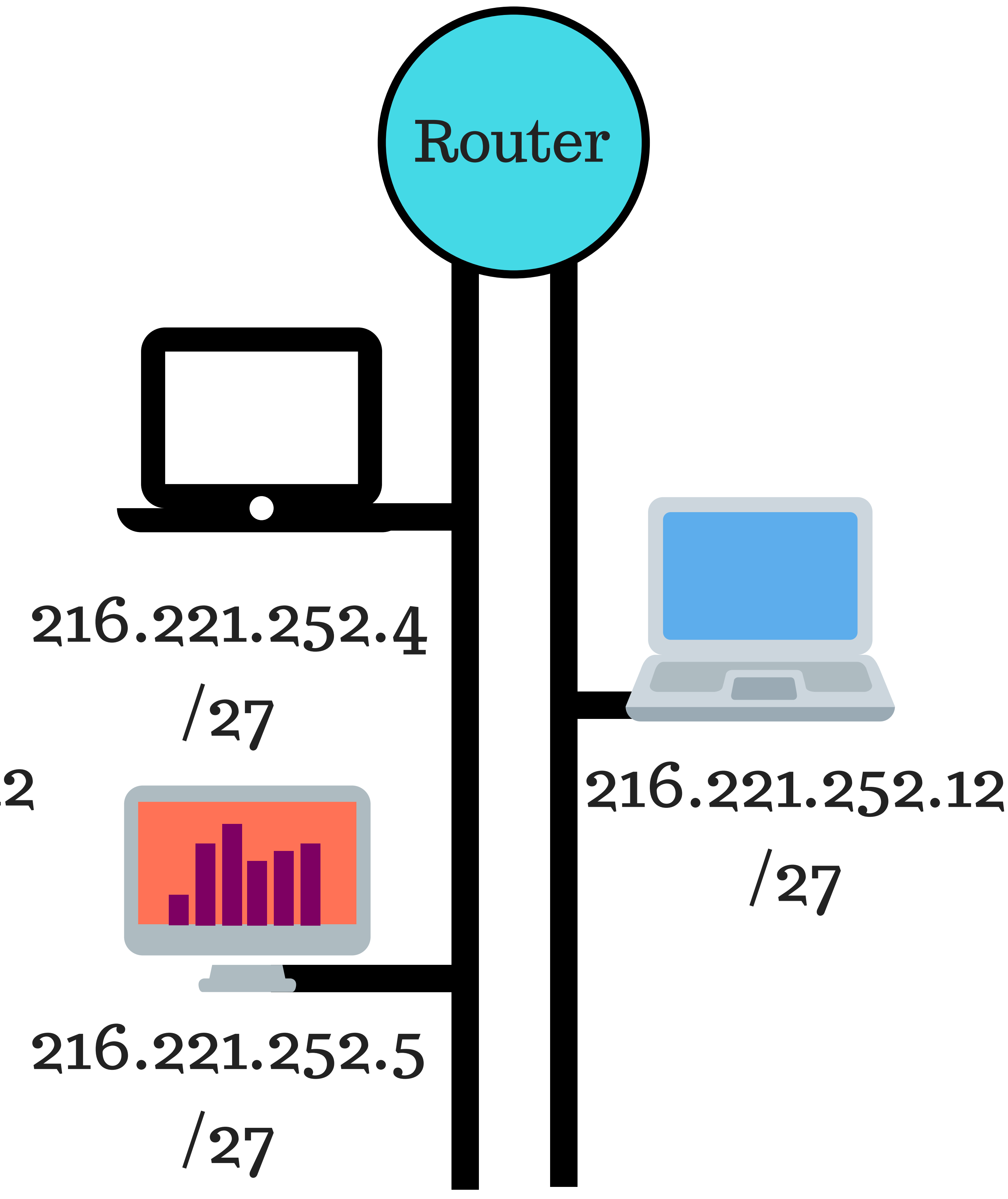
Classful Routing

When all the devices/interfaces in a network have the same subnet mask.

Subnet Mask info is not sent with routing updates.



Different Masks



Same Mask

The Powers of 2 (Again)

$2^0 = 1$

$2^1 = 2$

$2^2 = 4$

$2^3 = 8$

$2^4 = 16$

$2^5 = 32$

$2^6 = 64$

$2^7 = 128$

$2^8 = 256$

$2^9 = 512$

$2^{10} = 1024$

$2^{11} = 2048$

$2^{12} = 4096$

The Powers of 2 will always come in handy when it comes to Networking. Knowing them (and potentially memorizing them) will help you in Binary to Decimal conversions. This will make your life easier in subnetting.

CIDR

CIDR is short for Classless Inter-Domain Routing. It is a method used in allocating addresses to a customer by the ISP.

To represent a CIDR value, a prefix notation (also known as a slash notation) is used.

The purpose of a prefix notation is to indicate the number of bits that are turned on and the number of bits that are turned off.

Prefix
/26 → Indicates that there are 26 bits that are switched on in a subnet mask.

Default Subnet Masks

Class A	255 .	0 .	0 .	0
Class B	255 .	255 .	0 .	0
Class C	255 .	255 .	255 .	0

Each class of IP Addresses has its own default subnet mask.

If represented with prefix notation it will be as below.

	Prefix
Class A	/8
Class B	/16
Class C	/24

CIDR

CIDR allows us to go beyond the default masks.

In order to do that, we borrow ones (1's) from the host portion.

The minimum number of hosts is 2. Thus, we need a minimum of 2 bits for the host portion.

Prefix

/30

→ Indicates that there are 30 bits that are switched on in a subnet mask.

↓

2 bits are left for hosts.

The largest possible subnet mask.

Since the minimum number of hosts is 2.

More on CIDR

255.0.0.0

11111111 .00000000.00000000.00000000

8 bits are on. /8

255.128.0.0

11111111.1 0000000.00000000.00000000

9 bits are on. /9

255.192.0.0

11111111.11 000000.00000000.00000000

10 bits are on. /10

CIDR

255.224.0.0

11111111.111 00000.00000000.00000000

11 bits are on. /11

The number that follows the slash "/" is the count of 1's in the subnet mask. The 1's represent the network portion and the 0's represent the host portion.

Remember that the IP address is 32 bits. Thus, in a /26 subnet mask there is 26 bits for the network portion and 6 bits for the host portion (32-26).

You get the point.

255.0.0.0	→	/8
255.128.0.0	→	/9
255.192.0.0	→	/10
255.224.0.0	→	/11
255.240.0.0	→	/12
255.248.0.0	→	/13
255.252.0.0	→	/14
255.254.0.0	→	/15
255.255.0.0	→	/16
255.255.128.0	→	/17
255.255.192.0	→	/18
255.255.224.0	→	/19
255.255.240.0	→	/20
255.255.248.0	→	/21
255.255.252.0	→	/22
255.255.254.0	→	/23

# of bits that are on.

Borrowing From the Host Portion

In subnetting, we borrow bits from the host portion to go beyond the default subnet mask.

For example, the below is the default subnet mask and prefix notation for a class A address

255.0.0.0

11111111.0.0.0

/8

Thus the barrier between the network portion and the host portion is represented after the first octet.

255 .0.0.0

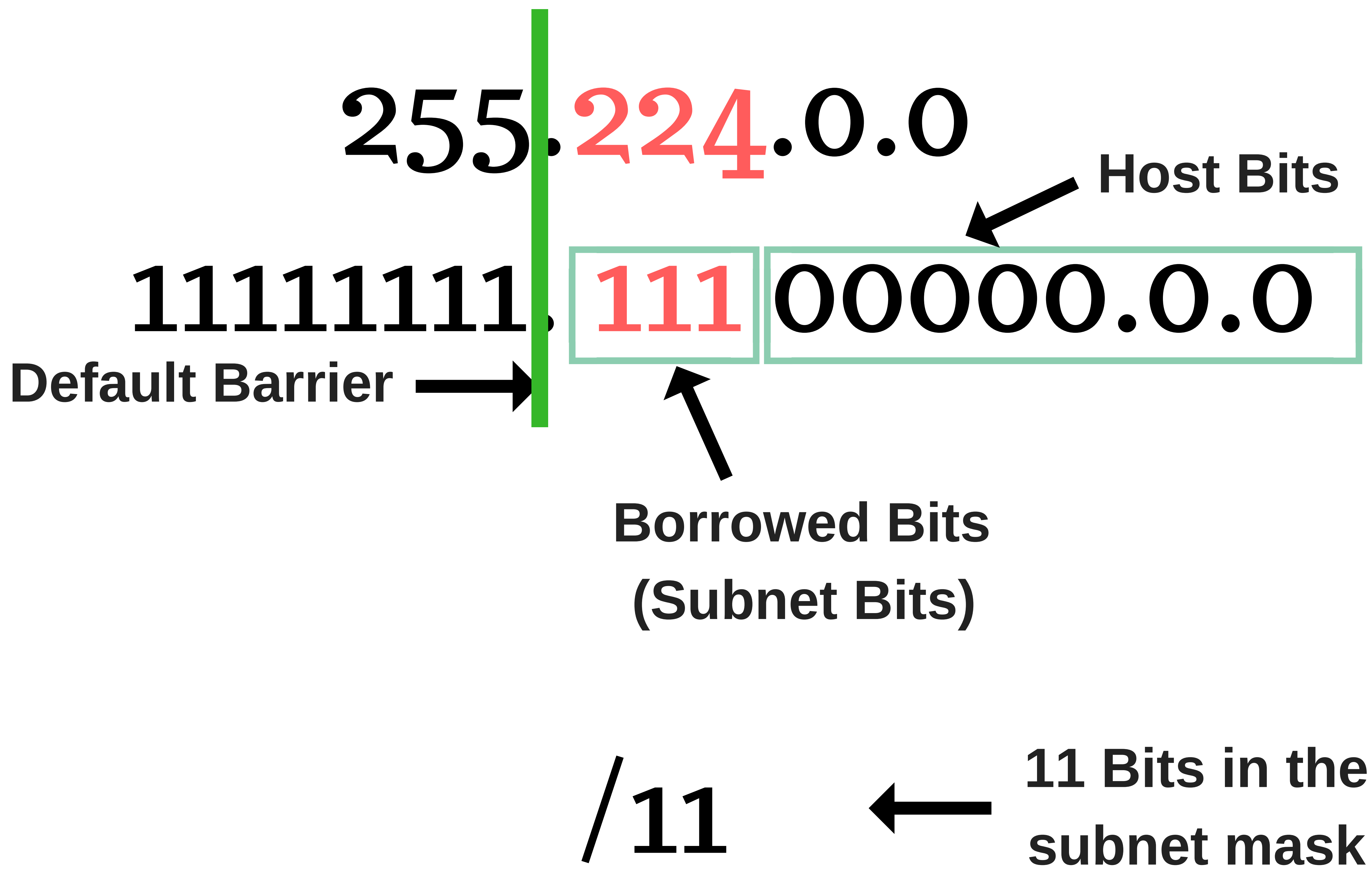
Three bits for hosts

11111111 .0.0.0

Network and Host Barrier

Borrowing From the Host Portion

We can borrow 1's from the host portion and update the prefix notation accordingly.



In this case, the host portion is updated. Also, the borrowed ones (bits) represent the bits available for subnetting.

Borrowing From the Host Portion

More Examples..

Class A

Again, Class A default mask

255.0.0.0

or

/8

Therefore, any 1 that comes after 8 bits is borrowed from the host portion.

11111111. $\boxed{00000000.00000000.000000}$ $\boxed{00}$

22 bits available for subnetting

At least 2 bits for hosts

Borrowing From the Host Portion

Class A

11111111. 00000000.00000000.00000000

/8

24 bits in host portion
8 ones (1) in subnet mask

Default Barrier

New Barrier

11111111.1 0000000.00000000.00000000

borrowed 1 bit

/9

23 bits in host portion
9 ones (1) in subnet mask

11111111.11 000000.00000000.00000000

borrowed 2 bit

/10

22 bits in host portion
10 ones (1) in subnet mask

Borrowing From the Host Portion

Class A

11111111.111 | 00000.00000000.00000000

borrowed
3 bit

/11

21 bits in host portion
11 ones (1) in subnet
mask

11111111.11111111.11111111.111111 | 00

borrowed 22 bit

2 bits in host
portion

/30

30 ones (1) in subnet
mask

Borrowing From the Host Portion

More Examples..

Class B

Again, Class B default mask

255.255.0.0

or

/16

Default Barrier

Therefore, any 1 that comes after 16 bits is borrowed from the host portion.

11111111.11111111. 00000000.000000 00

16 bits available for subnetting

At least 2 bits for hosts

Borrowing From the Host Portion

Class B

11111111.11111111.00000000.00000000

24 bits in host portion

/16

16 ones (1) in subnet mask

Default Barrier

New Barrier

11111111.11111111.11111111.00000000

borrowed 8 bits

8 bits in host portion

/24

24 ones (1) in subnet mask

Borrowing From the Host Portion

Class B

11111111.11111111.11111111.111111 00

borrowed
14 bits

2 bits in host
portion

/30

30 ones (1) in
subnet mask

Borrowing From the Host Portion

More Examples..

Class C

Again, Class C default mask

255.255.255.0

or

/24

Therefore, any 1 that comes after 24 bits is borrowed from the host portion.

11111111.11111111.11111111.000000 00

6 bits available for subnetting

At least 2 bits for hosts

Borrowing From the Host Portion

More Examples..

Class C

Default Barrier

New Barrier

11111111.11111111.11111111.11 000000

/26

borrowed 2 bits

6 bits in host portion

26 ones (1) in subnet mask

11111111.11111111.11111111.11111 000

/29

borrowed 5 bits

3 bits in host portion

29 ones (1) in subnet mask

Borrowing From the Host Portion

More Examples..

Class C

11111111.11111111.11111111.111111 00

borrowed 6 bits

2 bits in host portion

/30

30 ones (1) in subnet mask

Network Address

This is the address that identifies the entire subnet.

Broadcast Address

Information sent to this address is received by every machine in the subnet.

Useful Rules and Definitions

of Hosts

To get the number of hosts provided by using a certain mask, we get the number of zeros in the mask, then we follow the below rule.

$$\text{Number of Hosts} = 2^{\#\text{ of zeros}} - 2$$

Broadcast Address   Network Address

Example

Let's say we have the subnet mask /24 and a class B IP Address.

IP Address 148.175.176.18

Subnet Mask 255.255.255.0

Useful Rules and Definitions

Decimal

255.255.255.0

Binary

11111111.11111111.11111111.$\boxed{00000000}$

Here we have 8 zeros

Number of Hosts = $2^{8} - 2 = 256 - 2$

$= 254$ hosts

Size of each Subnet

To get the size of each subnet, we just do the first part of the previous rule

Size of a Subnet = $2^{\text{\# of zeros}}$

Thus the size of each subnet is

$$2^{8} = 256$$

of Subnets

To get the number of subnets, we get the number of borrowed ones and use it in the below rule.

$$\text{Number of Subnets} = 2^{\#\text{ of borrowed ones}}$$

In our example we use a Class B IP Address which has a /16 default mask. Thus, any 1 after 16 in the mask is borrowed from the host portion.

Useful Rules

Subnet Mask Again

11111111.11111111.11111111.00000000

Default Class B Network-Host Barrier

Here we have 8 borrowed ones

New Network-Host Barrier

Number of Subnets = 2^8 = 256

Network Address

Network Address is the first value in the subnet range. It identifies the network/subnetwork.

A Network Address has all 0's after subnet mask boundary.

For instance, in our example the network mask is obtained below.

148.175.176.0

zeros after network host barrier

Useful Rules Continued

The Network Address could be also obtained by using the bitwise AND operator between the subnet mask and the IP Address.

IP Address

148.175.176.18

10010100.10101111.10110000.00010010

Subnet Mask

/24

255.255.255.0

11111111.11111111.11111111.00000000

AND both the IP and Subnet Mask

10010100.10101111.10110000.00010010

11111111. 11111111.11111111.00000000

10010100.10101111.10110000.00000000

Network Address

All zeros after network-host barrier

Bitwise AND:
1 AND 1 = 1

Broadcast Address

Broadcast Address is the last value in the subnet range.
It is the address used to send messages to every host on the subnet.

A Broadcast Address has all 1's after subnet mask boundary

148.175.176.255

ones after network host barrier

10010100.10101111.10110000.11111111

First Host

The first host is the value that comes right after the network address.

148.175.176.1

Last Host

The last host is the value that comes right before the broadcast address.

148.175.176.254

Summary

Network Address	148.175.176.0	
	148.175.176.1	1st Host
	148.175.176.254	Last Host
Broadcast Address	148.175.176.255	

Class A Address Subnetting Example 1

IP Address

Decimal Format 35.0.0.0

Binary Format
00100011.00000000.00000000.00000000

Subnet Mask

Decimal Format 255.255.0.0 (/16)

Binary Format

11111111. | 11111111. | 00000000.00000000

Default Network-Host Barrier for Class A is after 8 bits since the default mask is /8

A /16 mask pushes the barrier 8 additional bits

A default class A mask is /8. However, since we are using a /16 mask the network-host barrier is moved an additional 8 bits.

Network Address

We use the bitwise operation AND between the Subnet Mask and IP Address to get the network address

AND the Subnet Mask with the IP Address

00100011.00000000.00000000.00000000

11111111.11111111. 00000000.00000000

00100011.00000000.00000000.00000000

Network Address

Bitwise AND Operation

The bitwise AND operation is really simple. When you have 1 AND 1 you get a 1. Otherwise, you get a zero

0 AND 0 = 0

1 AND 0 = 0

1 AND 1 =1

Network address in both decimal and binary

00100011.00000000.00000000.00000000

35.0.0.0 Network Address

First usable host is 1 after the network address

35.0.0.1 First Usable Address

We can have hosts until we run of the last 2 octets (the last 2 octets are dedicated for hosts with the /16 subnet mask). Thus the last usable IP address is

35.0.255.254 Last Usable Address

Note that the last octet is 254 not 255. This is because we need to account for the Broadcast Address.

35.0.255.255 Broadcast Address

Network Address	Broadcast Address
All zeros after Network-Host Barrier	All ones after Network-Host Barrier
35.0.0.0	35.0.255.255

So far we have the below

35.0.0.0 ← Network Address

35.0.0.1 ← First Usable IP

35.0.255.254 ← Last Usable IP

35.0.255.255 ← Broadcast Address

To gain more details we can follow the rules mentioned before.

11111111.11111111.00000000.00000000

We have 16 zeros

Size of a Subnet = 2^{16} = 65,536

Number of Hosts = $2^{16} - 2$ = 65,534

11111111.11111111.00000000.00000000

We borrowed 8 ones

Number of Subnets = 2^8 = 256

The size of each subnet is 65,536.
We can see that from

256*256 = 65,536

35.0.255.255

[0-255] are
256 numbers

We subtract 2 from the subnet size to get the total number of hosts. These 2 addresses removed are the Network Address and the Broadcast Address.

65,536-2 = 65,534 hosts

Class A Address Subnetting Example 2

IP Address 95.45.204.0

01011111.00101101.11001100.00000000

Subnet Mask 255.255.248.0 (/21)

11111111.11111111.11111000.00000000

Network Address

We use the bitwise operation AND between the Subnet Mask and IP Address to get the network address

AND the Subnet Mask with the IP Address

01011111.00101101.11001100.00000000
11111111.11111111 .11111000 .00000000

01011111.00101101.11001000.00000000

Network Address

Network address in both decimal and binary

01011111.00101101.11001000.00000000

95.45.200.0 Network Address

01011111.00101101.11001 | 000.00000000

Bits for Hosts

First usable host is 1 after the network address

95.45.200.1 ← First Usable Address

01011111.00101101.11001 | 000.00000001

The bits designated for hosts keep on filling up till we reach the network-host barrier

01011111.00101101.11001 | 000.00000001

01011111.00101101.11001 | 000.00000010

⋮

Hosts

01011111.00101101.11001 | 111.11111110

95.45.207.254 ← Last Usable Address

Broadcast address is all ones in the available bits

95.45.207.255

So far we have the below

95.45.200.0 ← Network Address

95.45.200.1 ← First Host

95.45.207.254 ← Last Host

95.45.207.255 ← Broadcast Address

Using the rules

Bits for Hosts

11111111.11111111.11111 000.00000000

We have 11 zeros

Size of a Subnet = 2^{11} = 2048

Number of Hosts = $2^{11} - 2$ = 2046

The size of each subnet is 2048.
We can see that from

Octet 1.Octet 2.11001 | 000.00000000
Octet 1.Octet 2.11001 | 111.11111111
| 0-7.0-255

8*256 = 2048

[0-7] are 8 values [0-255] are 256 values

Borrowed Ones

11111111.$\boxed{11111111.11111}$000.00000000

We have 13 ones

Number of Subnets = $2^{13} = 8192$

Class A Address Subnetting Example 3

IP Address 95.45.204.149

01011111.00101101.11001100.10010101

Subnet Mask 255.255.255.192 (/26)

11111111.11111111.11111111.11000000

11111111.11111111.11111111.11 | 000000

Bits for Hosts

11111111 | 11111111.11111111.11 | 000000

Borrowed Bits

Network Address

We use the bitwise operation AND between the Subnet Mask and IP Address to get the network address

AND the Subnet Mask with the IP Address

01011111.00101101.11001100.10010101
11111111. 11111111. 11111111.11000000

01011111.00101101.11001100.10000000

Network Address

Network address in both decimal and binary

01011111.00101101.11001100.10000000
95.45.204.128

01011111.00101101.11001100.10|000000

Bits for Hosts

First usable host is 1 after the network address

95.45.204.129 ← First Host

01011111.00101101.11001100.10 | 000001

Last usable host is 1 less than the broadcast address

95.45.204.190 ← Last Host

01011111.00101101.11001100.10 | 111110

The broadcast address has all ones after the network-host barrier

95.45.204.191 ← Broadcast Address

01011111.00101101.11001100.10 | 111111

So far we have the below

95.45.204.128 ← Network Address

95.45.204.129 ← First Host

95.45.204.190 ← Last Host

95.45.204.191 ← Broadcast Address

Using the rules

Bits for Hosts

11111111.11111111.11111111.11 $\boxed{000000}$

We have 6 zeros

Size of a Subnet = $2^6 = 64$

Number of Hosts = $2^6 - 2 = 62$

The size of a subnet is 64.
We can see that below.

Octet 1.Octet 2.Octet 3.11 | 000000
Octet 1.Octet 2.Octet 3.11 | 111111

With the /26 mask, we get the below range for the available 6 bits designated for the host portion.

00 | 000000 - 00 | 111111

0 63

[0-63]
are 64 values.

Therefore, the size of a subnet is 64.

Borrowed Ones

11111111.11111111.11111111.11 000000

We have 18 ones

Number of Subnets = 2^{18} = 262,144

Class A Address Subnetting Example 4

IP Address 62.235.196.98

00111110.11101011.11000100.01100010

Subnet Mask 255.255.255.0 (/24)

11111111.11111111.11111111.00000000

11111111.11111111.11111111.00000000

Bits for Hosts

11111111.11111111.11111111.00000000

Borrowed Bits

Network Address

We use the bitwise operation AND between the Subnet Mask and IP Address to get the network address

AND the Subnet Mask with the IP Address

00111110.11101011.11000100.01100010
11111111 .11111111 .11111111 .00000000

00111110.11101011.11000100.00000000

Network Address

Network address in both decimal and binary

00111110.11101011.11000100.00000000
62.235.196.0

00111110.11101011.11000100 | 00000000

Bits for Hosts

First usable host is 1 after the network address

62.235.196.1 ← First Host

00111110.11101011.11000100.|00000001

Last usable host is 1 less than the broadcast address

62.235.196.254 ← Last Host

00111110.11101011.11000100.|11111110

Last usable host is 1 less than the broadcast address

62.235.196.255 ← Broadcast Address

01011111.00101101.11001100.10|111111

So far we have the below

62.235.196.0 ← Network Address

62.235.196.1 ← First Host

62.235.196.254 ← Last Host

62.235.196.255 ← Broadcast Address

Using Rules

Bits for Hosts

11111111.11111111.11111111.|$\boxed{00000000}$

We have 8 zeros

Size of a Subnet = 2^{8} = 256

Number of Hosts = 2^{8} - 2 = 254

Borrowed Ones

11111111.|$\boxed{11111111.11111111.}$|00000000

We have 16 ones

Number of Subnets = 2^{16} = 65,536

Now, we move to Class B Subnetting.

Remember

The default Class B subnet mask is /16.
This means that 16 bits are designated for the network portion and 16 bits are left for the host portion.

Any "1" in the subnet mask that comes after the first 16 bits is borrowed from the host portion.

/17 -> We borrow a one (1) from host portion
/18 -> We borrow 2 ones (11) from host portion
/19 -> We borrow 3 ones (111) from host portion

Class B Address Subnetting Example 1

IP Address 156.11.205.0

10011100.00001011.11001101.00000000

Subnet Mask 255.255.0.0 (/16)

Binary Format

11111111. 11111111. 00000000.00000000

Default Network-Host Barrier for Class B is after 16 bits.

A default class B mask is /16.

Network Address

AND the Subnet Mask with the IP Address

10011100.00001011.11001101.00000000
11111111.11111111.00000000.00000000

10011100.00001011.00000000.00000000

Network Address

Network address in both decimal and binary

10011100.00001011.00000000.00000000

156.11.0.0 ← Network Address

First usable host is 1 after the network address

156.11.0.1 ← First Usable Address

Last usable host is 1 less than the broadcast address

156.11.255.254 ← Last Usable Address

The broadcast address has all 1 in the host portion

156.11.255.255 ← Broadcast Address

10011100.00001011.11111111.11111111

156.11.0.0 ← Network Address

156.11.0.1 ← First Host

156.11.255.254 ← Last Host

156.11.255.255 ← Broadcast Address

Using Rules

Bits for Hosts

11111111.11111111.$\boxed{00000000.00000000}$

We have 16 zeros

Size of a Subnet = $2^{16} = 65{,}536$

Number of Hosts = $2^{16} - 2 = 65{,}534$

Borrowed Ones

11111111.11111111.00000000.00000000

We have 0 borrowed ones

Number of Subnets = $2^{0} = 1$

Class B Address Subnetting Example 2

IP Address 156.11.205.164

10011100.00001011.11001101.10100100

Subnet Mask 255.255.192.0 (/18)

Binary Format

11111111. 11111111. | 11 | 000000.00000000

Default Network-Host Barrier for Class B is after 16 bits.

A /18 mask pushes the barrier 2 more bits

11111111.11111111.11 | 000000.00000000

Bits for Hosts

11111111.11111111. | 11 | 000000.00000000

Borrowed Bits

Network Address

AND the Subnet Mask with the IP Address

10011100.00001011.11001101.10100100
11111111. 11111111.11000000.00000000

10011100.00001011.11000000.00000000

Network Address

Network address in both decimal and binary

10011100.00001011.11 | 000000.00000000

156.11.192.0 ← Network Address

First usable host is 1 after the network address

156.11.192.1 ← First Usable Address

10011100.00001011.11 | 000000.00000001

Last usable host is 1 less than the broadcast address

156.11.255.254 ← Last Host

10011100.00001011.11 | 111111.11111110

The broadcast address has all ones after the network-host barrier

156.11.255.255 ← Broadcast Address

10011100.00001011.11 | 111111.11111111

156.11.192.0 ← Network Address

156.11.192.1 ← First Host

156.11.255.254 ← Last Host

156.11.255.255 ← Broadcast Address

Using Rules

Bits for Hosts

10011100.00001011.11 000000.00000000

We have 14 zeros

Size of a Subnet = $2^{14} = 16,384$

Number of Hosts = $2^{14} - 2 = 16,382$

Borrowed Ones

10011100.00001011. 11 000000.00000000

We have 2 ones

Number of Subnets = $2^{2} = 4$

Class B Address Subnetting Example 3

IP Address 176.11.197.0

10110000.00001011.11000101.00000000

Subnet Mask 255.255.254.0 (/23)

Binary Format

11111111. 11111111. 1111111 0.00000000

Default Network-Host Barrier for Class B is after 16 bits.

A /18 mask pushes the barrier 2 more bits

11111111. 11111111. 1111111 0.00000000

Bits for Hosts

11111111. 11111111. 1111111 0.00000000

Borrowed Bits

Network Address

AND the Subnet Mask with the IP Address

10110000.00001011.11000101.00000000
11111111. 11111111. 11111110.00000000

10110000.00001011.11000100.00000000

Network Address

Network address in both decimal and binary

10110000.00001011.1100010 | 0.00000000

176.11.196.0 ← Network Address

First usable host is 1 after the network address

176.11.196.1 ← First Usable Address

10110000.00001011.1100010 | 0.00000001

Last usable host is 1 less than the broadcast address

176.11.197.254 ← Last Usable Address

10110000.00001011.1100010|1.11111110

The broadcast address has all ones after the network-host barrier

176.11.197.255 ← Broadcast Address

10110000.00001011.1100010|1.11111111

So far we have the below

176.11.196.0 ← Network Address

176.11.196.1 ← First Host

176.11.197.254 ← Last Host

176.11.197.255 ← Broadcast Address

Using Rules

Bits for Hosts

11111111. 11111111. 1111111 | 0.00000000

We have 9 zeros

Size of a Subnet = 2^9 = 512

Number of Hosts = $2^9 - 2$ = 510

Borrowed Ones

11111111. 11111111 | 1111111 | 0.00000000

We have 7 ones

Number of Subnets = 2^7 = 128

Class B Address Subnetting Example 4

IP Address 171.224.216.86

10101011.11100000.11011000.01010110

Subnet Mask 255.255.254.0 (/26)

Binary Format

11111111. 11111111. | 11111111.11 | 000000

Default Network-Host Barrier for Class B is after 16 bits.

A /26 mask pushes the barrier 10 more bits

11111111. 11111111. 11111111.11 | 000000

Bits for Hosts

11111111. 11111111. | 11111111.11 | 000000

Borrowed Bits

Network Address

AND the Subnet Mask with the IP Address

10101011.11100000.11011000.01010110
11111111. 11111111. 11111111.11000000

10101011.11100000.11011000.01000000

Network Address

Network address in both decimal and binary

10101011.111000001.11011000.01 | 000000

171.224.216.64 ← Network Address

First usable host is 1 after the network address

171.224.216.65 ← First Usable Address

10101011.11100000.11011000.01 | 000001

Last usable host is 1 less than the broadcast address

171.224.216.126 ← Last Usable Address

10101011.11100000.11011000.01 | 111110

The broadcast address has all ones after the network-host barrier

171.224.216.127 ← Broadcast Address

10101011.11100000.11011000.01 | 111111

So far we have the below

171.224.216.64 ← Network Address

171.224.216.65 ← First Host

171.224.216.126 ← Last Host

171.224.216.127 ← Broadcast Address

Using Rules

Bits for Hosts

11111111. 11111111. 11111111.11 | 000000

We have 6 zeros

Size of a Subnet = $2^{6} = 64$

Number of Hosts = $2^{6} - 2 = 62$

Borrowed Ones

11111111. 11111111. | 11111111.11 | 000000

We have 10 ones

Number of Subnets = $2^{10} = 1024$

Now, we move to Class C Subnetting.

Remember

The default Class C subnet mask is /24.
This means that 24 bits are designated for the network portion and 8 bits are left for the host portion.

Any "1" in the subnet mask that comes after the first 24 bits is borrowed from the host portion.

/25 -> We borrow a one (1) from host portion
/26 -> We borrow 2 ones (11) from host portion
/27 -> We borrow 3 ones (111) from host portion

Class C Address Subnetting Example 1

IP Address 194.220.19.0

Subnet Mask 255.255.255.128 (/25)

11111111.11111111.11111111.10000000

Size of each Subnet

To get the size of a subnet, we use this formula.

$2^{\#\text{ of 0's}}$

11111111.11111111.11111111.1 $\boxed{0000000}$

Host bits = 7

# of 0's = 7

$2^7 = 128$

of Hosts

In order to get the number of assignable hosts, we subtract 2 from the above value of 128.

$2^7 - 2 = 128 - 2 = 126$

Broadcast Address

Network Address

of Networks

To get the number of subnets, we follow this formula.

$$2^{\#\text{ of borrowed 1's}}$$

Since the IP address is Class C, any 1 after this line is borrowed

11111111.11111111.11111111. $\boxed{1}$ 0000000

Subnet bits = 1

$$2^{1} = 2$$

So far, we know the following

We have 2 subnets.
Each with a size of 128.
The number of hosts in each subnet is 126.

Let's create the subnets together.

First, we calculate the range of the 1st subnet (subnet 0).

We start with 0

0 - ...

Then, we get the final value of this subnet. We recall that the size of each subnet is 128. If we start counting at the value 0 and include it, then the final value will be 127 (the 128th value is 127).

The range of the subnet → 0 - 127

We call the above subnet, subnet 0.

$\boxed{0}$ - 127

The 1st value of the range is the subnetwork address (commonly known as the network address).

We do the same to calculate the range of the 2nd subnet.

To get the 1st value of the range of the 2nd subnet, we add 1 to the last value in the range of the 1st subnet.

0 - 127

127 + 1 ← 128 - ...

The last value in the last subnet range is always 255 (the max. value).

126 hosts

0 - 127

128 - 255

2 subnets

1st host in range

194.220.19. 1

Last host in range

194.220.19. 126

0 - [1 - 126] - 127

128 - [129 - 254] - 255

Host Range

Network Address

The address that identifies the entire subnet.

AND the Subnet Mask with the IP Address

11000010.11011100.00010011.00000000
11111111.11111111.11111111.10000000

11000010.11011100.00010011.00000000

Network Address

Network address in both decimal and binary.

11000010.11011100.00010011.0 | 0000000

194.220.19.0 ← Network Address

First usable host is 1 after the network address.

194.220.19.1 ← First Usable Address

11000010.11011100.00010011.0 | 0000001

Last usable host is 1 less than the broadcast address.

194.220.19.126 ← Last Usable Address

11000010.11011100.00010011.0 | 1111110

So far we have the below:

Network Address ← 0 - 127

128 - 255

194.220.19. 0 → Network Address

1st Host ← 194.220.19. 1

Last Host ← 194.220.19. 126

Broadcast Address

Information sent to this address is received by every machine in the subnet.

The broadcast address has all ones after the network-host barrier.

194.220.19.127 ← Broadcast Address

11000010.11011100.00010011.0 | 1111111

0 - 127

128 - 255

Broadcast Address

To summarize, we have the below:

194.220.19. 0 → Network Address

1st Host ← 194.220.19. 1

Last Host ← 194.220.19. 126

194.220.19. 127 → Broadcast Address

Class C Address Subnetting Example 2

Let's take another example.

IP Address 215.248.121.0 (/27)

Subnet Mask 255.255.255.224

11111111.11111111.11111111.11100000

Size of each Subnet

11111111.11111111.11111111.111 $\boxed{00000}$

\# of 0's = 5

Host bits = 5

$2^5 = 32$

Size of each subnet is 32

\# of Hosts

$2^5 - 2 = 32 - 2 = 30$

There are 30 hosts

of Networks

11111111.11111111.11111111.$\boxed{111}$00000

Subnet bits = 3

$2^3 = 8$

So far, we know the following

We have 8 subnets.
Each with a size of 32.
The number of hosts in each subnet is 30.

We have a total of 8 subnets

0 - 31
32 - 63
64 - 95
96 - 127
128 - 159
160 - 191
192 - 223
224 - 255

1st host in range

215.248.121.1

Last host in range

215.248.121.30

0 - [1 - 30] - 31

Host Range

Network Addresses

The address that identifies the entire subnet.

AND the Subnet Mask with the IP Address

11010111.11111000.01111001.00000000
11111111.11111111.11111111.11100000

11010111.11111000.01111001.00000000

Network Address

Network address in both decimal and binary

11010111.11111000.01111001.000 | 00000

215.248.121.0 ← Network Address

First usable host is 1 after the network address

215.248.121.1 ← First Usable Address

11010111.11111000.01111001.000 | 00001

Last usable host is 1 less than the broadcast address

215.248.121.30 ← Last Host

11010111.11111000.01111001.000 | 11110

Network Address

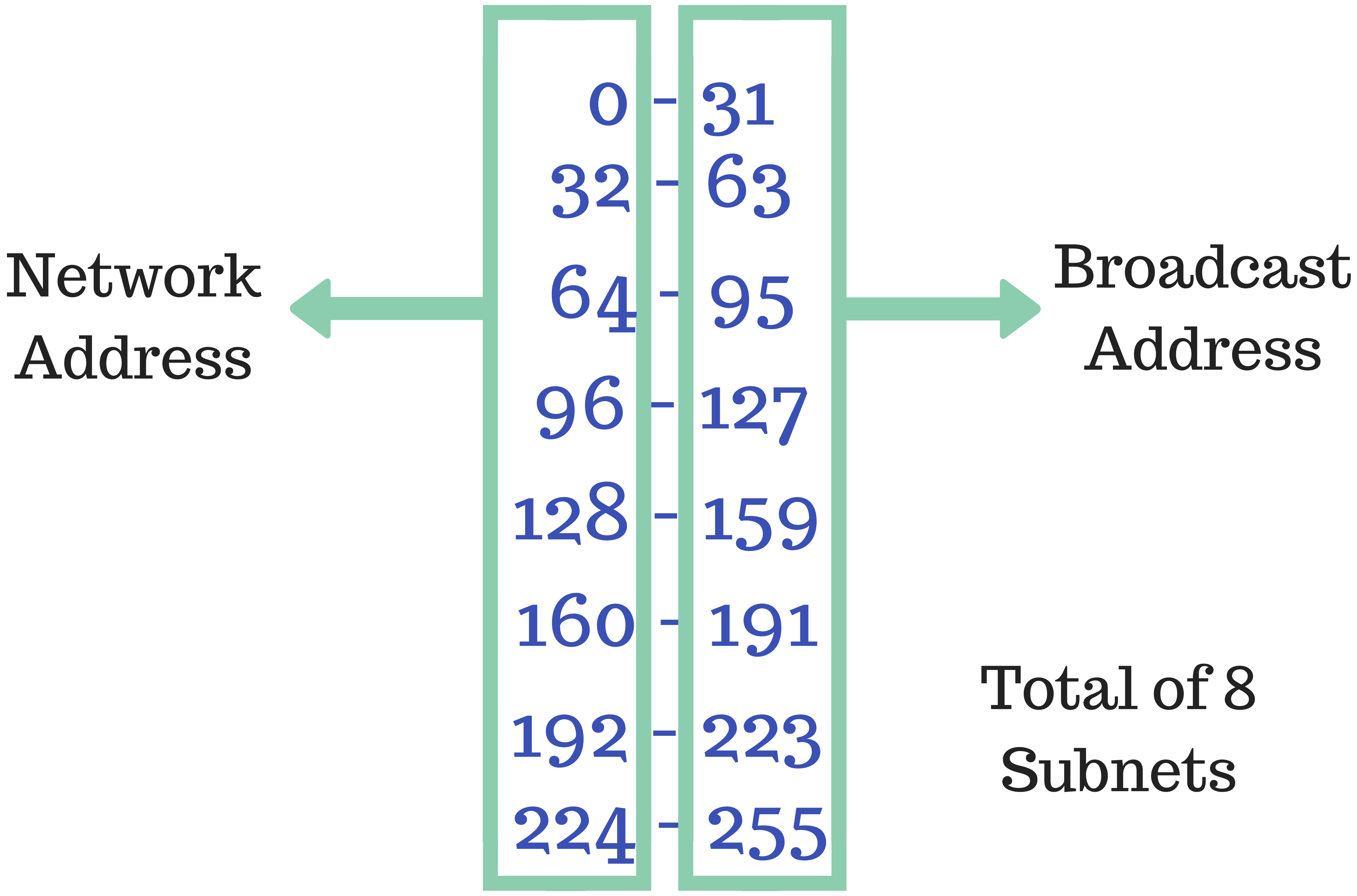
0 - 31
32 - 63
64 - 95
96 - 127
128 - 159
160 - 191
192 - 223
224 - 255

Broadcast Address

The broadcast address has all ones after the network-host barrier

215.248.121.31 ← Last Host

11010111.11111000.01111001.000 | 11111



To summarize, we have the below:

215.248.121.0 ← Network Address

215.248.121.1 ← First Host

215.248.121.30 ← Last Host

215.248.121.31 ← Broadcast Address

Class C Address Subnetting Example 3

Let's take another example.

IP Address 215.248.121.162 (/27)

Subnet Mask 255.255.255.224

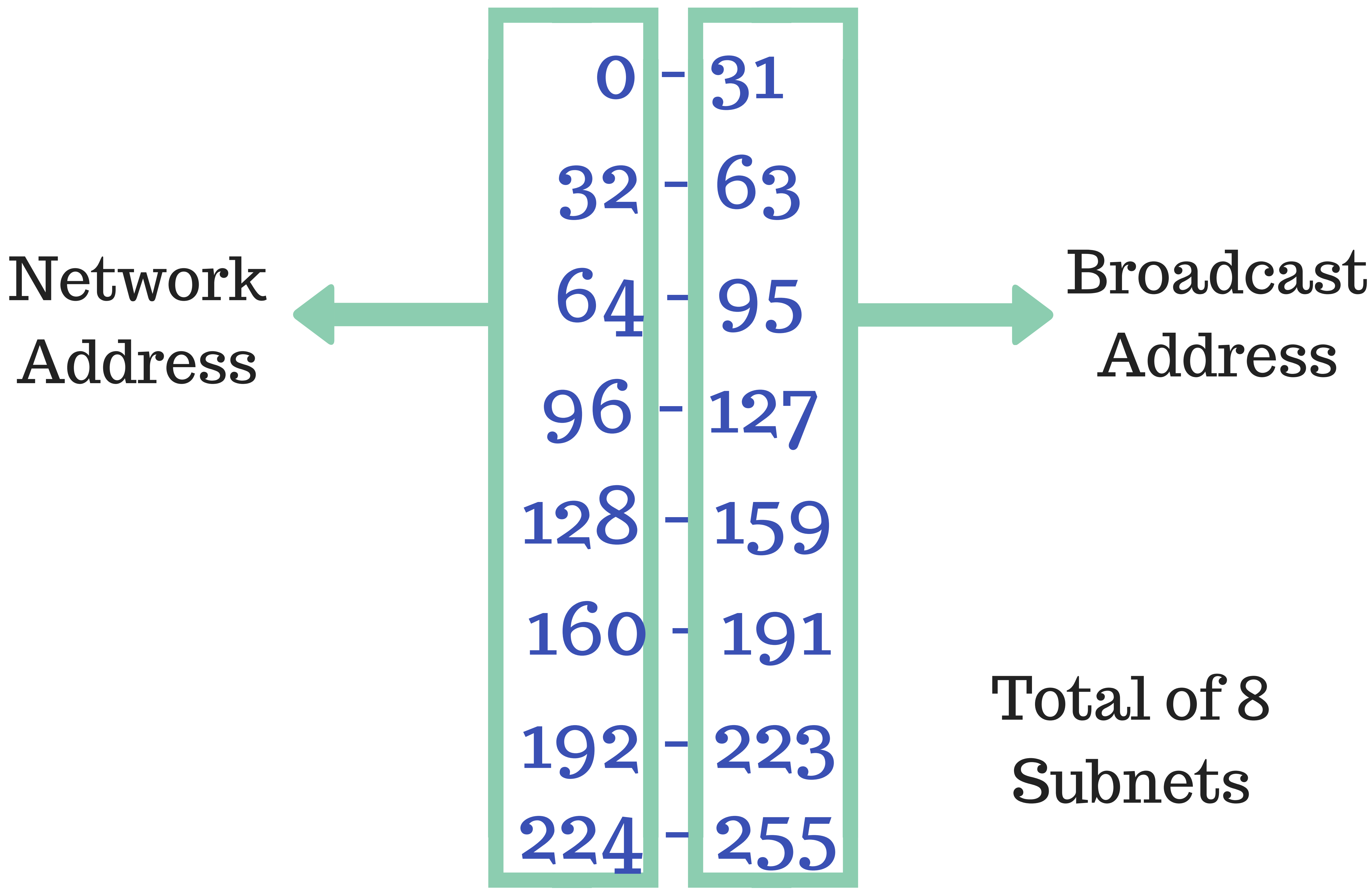
Here only the 4th octet is different. Thus, all the calculations for the previous examples are still valid. The only difference is the subnet within which this IP lies and the host ranges.

1st host in range 215.248.121.161

Last host in range 215.248.121.190

160 - [161 - 190] - 191

Host Range


Network Address
0 - 31
32 - 63
64 - 95
96 - 127
128 - 159
160 - 191
192 - 223
224 - 255
Broadcast Address
Total of 8 Subnets

Class C Address Subnetting Example 4

Let's take another example.

IP Address 215.248.121.162 (/29)

Subnet Mask 255.255.255.248

11111111.11111111.11111111.11111000

Size of each Subnet

11111111.11111111.11111111.11111 $\boxed{000}$

# of 0's = 3

Host bits = 3

$2^3 = 8$

Size of each subnet is 8

# of Hosts

$2^3 - 2 = 8 - 2 = 6$

There are 6 hosts

of Networks

11111111.11111111.11111111. $\boxed{11111}$ 000

Subnet bits = 5

$2^5 = 32$

So far, we know the following

We have 32 subnets.
Each with a size of 8.
The number of hosts in each subnet is 6.

We have a total of 32 subnets

0 - 7
8 - 15
16- 23
24 - 31
⋮
240 - 247
248 - 255

Network Address

AND the Subnet Mask with the IP Address

11010111.11111000.01111001.10100010
11111111.11111111.11111111.11111000

11010111.11111000.01111001.10100000

Network Address

Network address in both decimal and binary

11010111.11111000.01111001.10100|000

215.248.121.160 ← Network Address

First usable host is 1 after the network address

215.248.121.161 ← First Usable Address

11010111.11111000.01111001.10100|001

Last usable host is 1 less than the broadcast address

215.248.121.166 ← Last Host

11010111.11111000.01111001.10100 | 110

The broadcast address has all ones after the network-host barrier

215.248.121.167 ← Broadcast Address

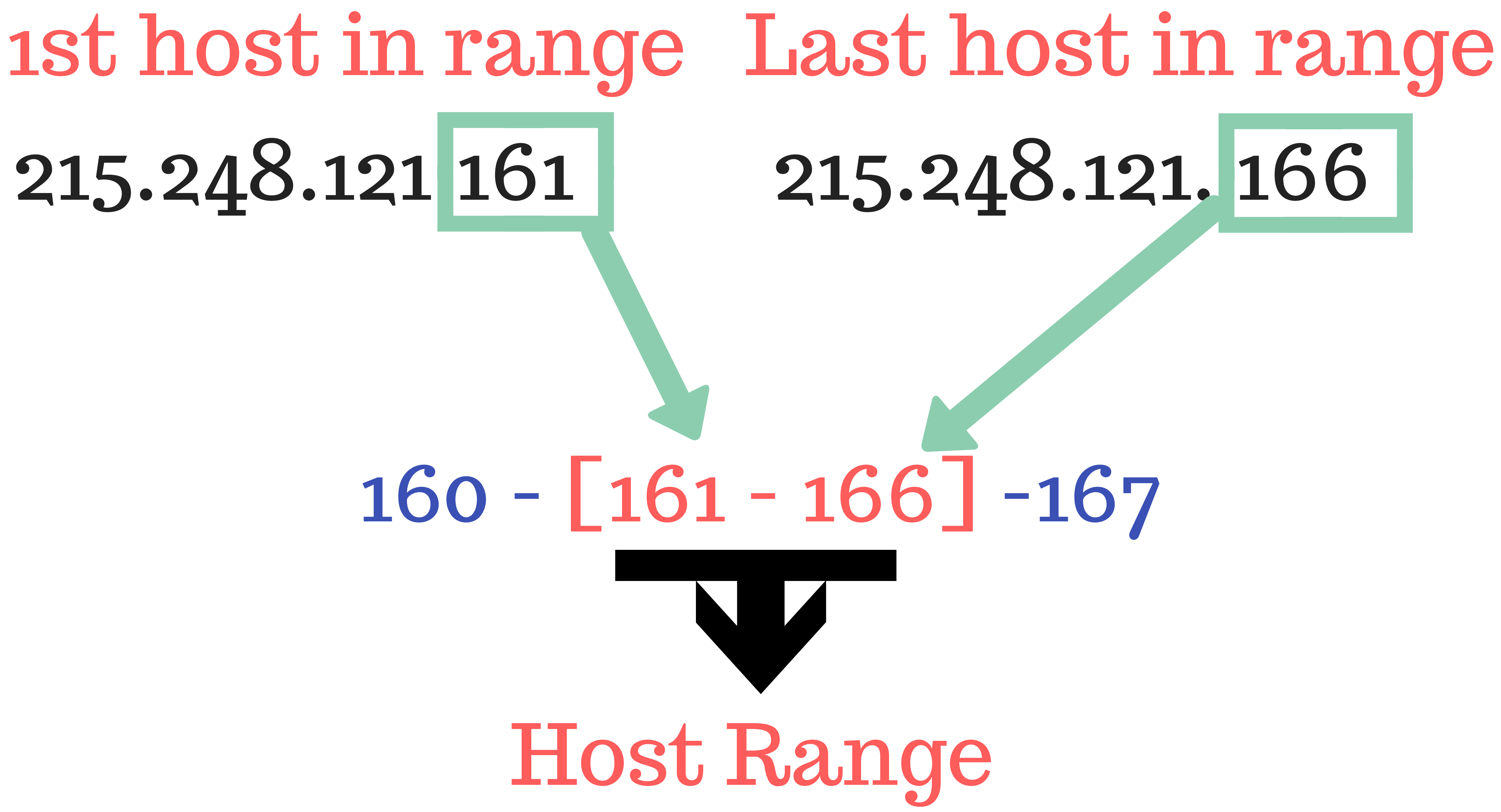
11010111.11111000.01111001.10100 | 111

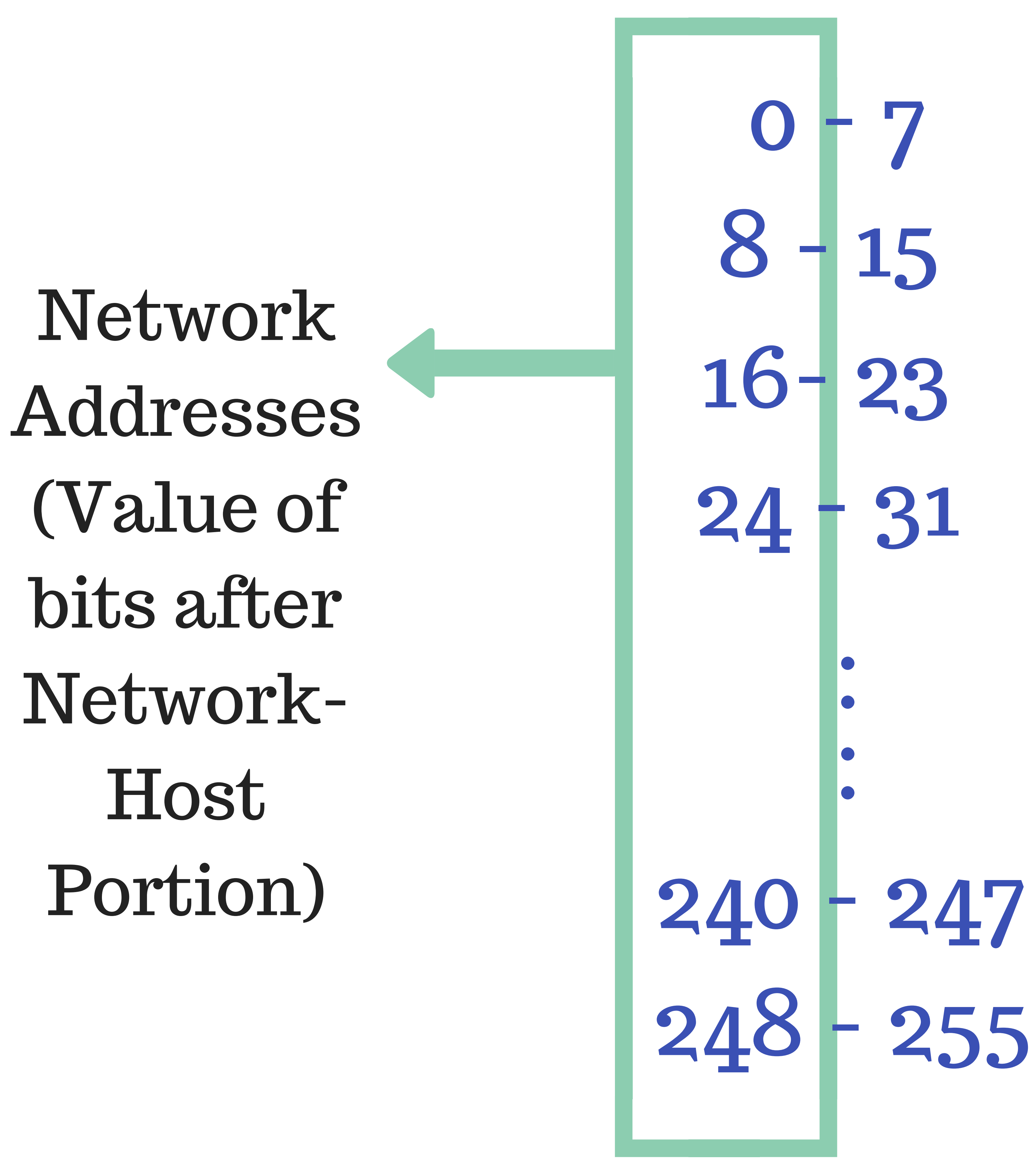
215.248.121.160 ← Network Address

215.248.121.161 ← First Host

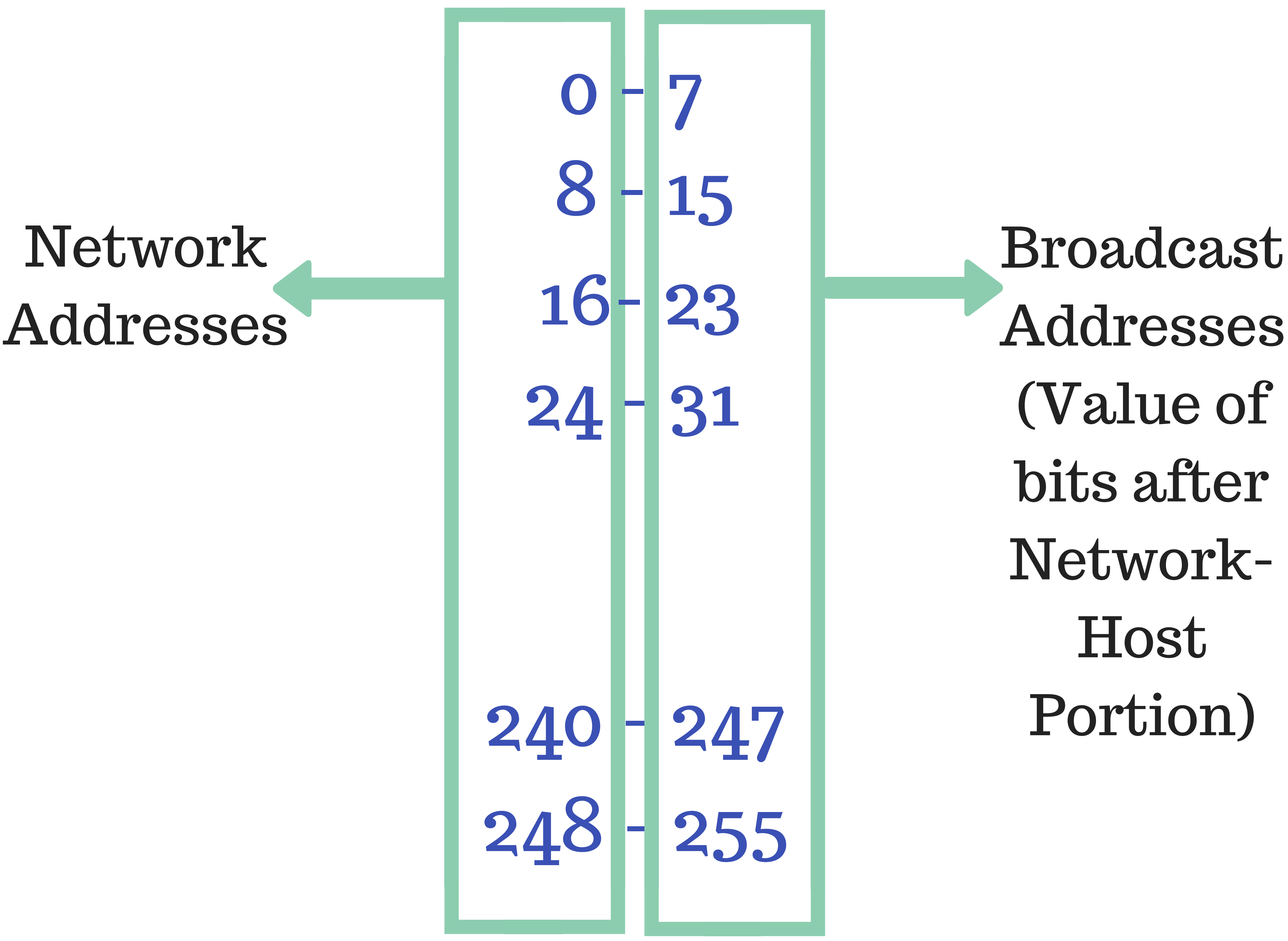
215.248.121.166 ← Last Host

215.248.121.167 ← Broadcast Address


1st host in range
Last host in range
215.248.121 161
215.248.121. 166
160 - [161 - 166] -167
Host Range


Network Addresses (Value of bits after Network-Host Portion)
0 - 7
8 - 15
16 - 23
24 - 31
240 - 247
248 - 255

Broadcast Address



215.248.121.167 ← Broadcast Address

11010111.11111000.01111001.10100 | 111