

IP Addresses and Host-to-host Communication

Lecture 2

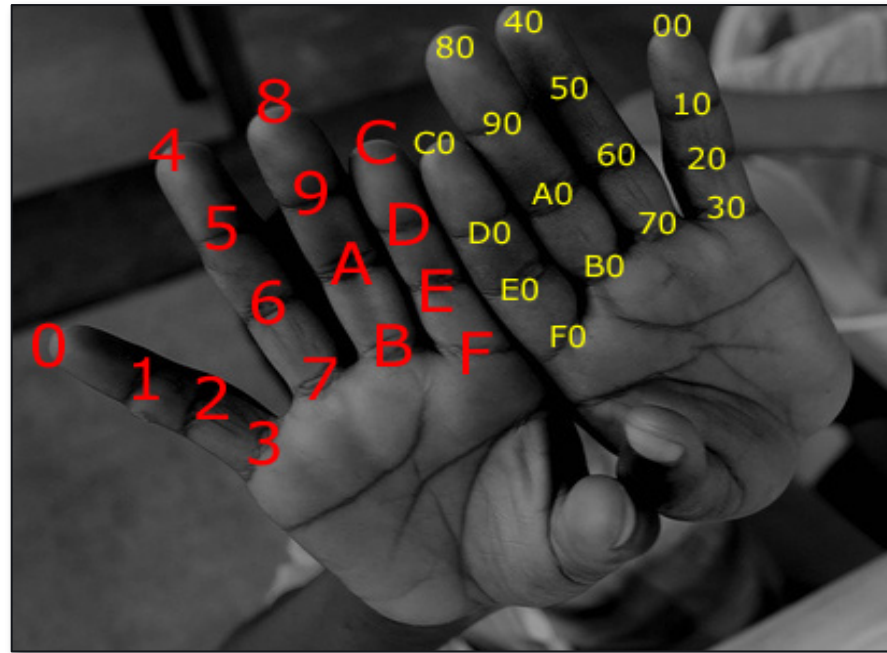


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Binary, decimal and hexadecimal numbers

Different numeral systems

Hexadecimal	Binary	Decimal
0	0000	0
1	0001	1
2	0010	2
3	0011	3
4	0100	4
5	0101	5
6	0110	6
7	0111	7
8	1000	8
9	1001	9
A	1010	10
B	1011	11
C	1100	12
D	1101	13
E	1110	14
F	1111	15

Common Numeral Systems in Computer Networking:

- Decimal
- Binary
- Hexadecimal

Decimal Numeral System

Decimal Numbering System (base 10)

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

4	8	7	2	= $4 \times 1000 + 8 \times 100 + 7 \times 10 + 2 \times 1$
Thousand's Place	Hundred's Place	Ten's Place	One's Place	

written 4872_d or 4872_{10}

- Base of 10
- Called decimal or denary
- A single digit can be:

0 1 2 3 4 5 6 7 8 9

In this example:

$$2 \times 10^0 + 7 \times 10^1 + 8 \times 10^2 + 4 \times 10^3 =$$

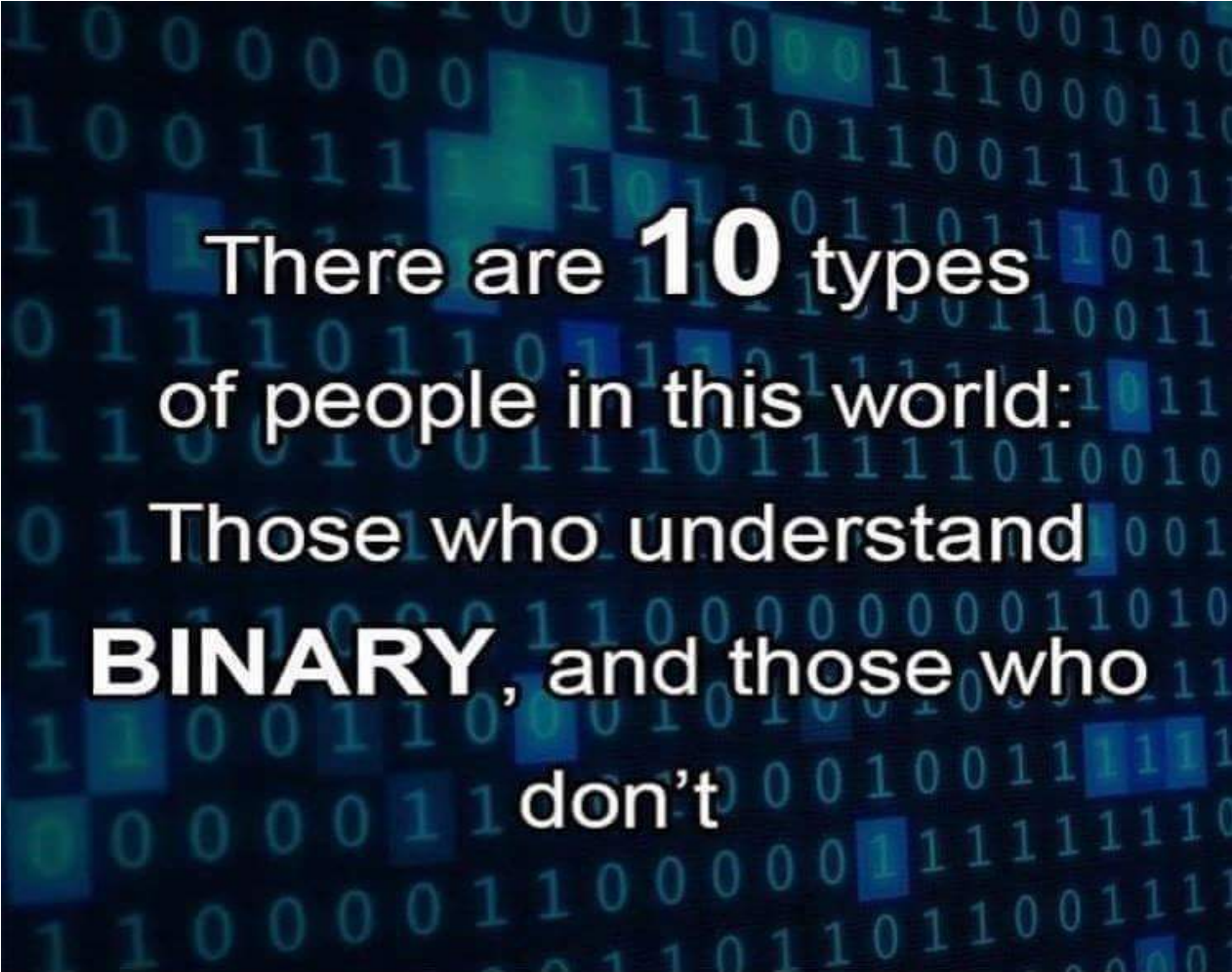
$$2 + 70 + 800 + 4000 = 4872$$

Binary Numeral System

Decimal number	Binary number
0	0
1	1
2	1 0
3	1 1
4	1 0 0
5	1 0 1
6	1 1 0
7	1 1 1
8	1 0 0 0
9	1 0 0 1
10	1 0 1 0

- Base of 2
- Used in computers and all computer-based devices
- Each digit is referred to as a bit
- A single digit (bit) can be either
0 or 1

Binary joke

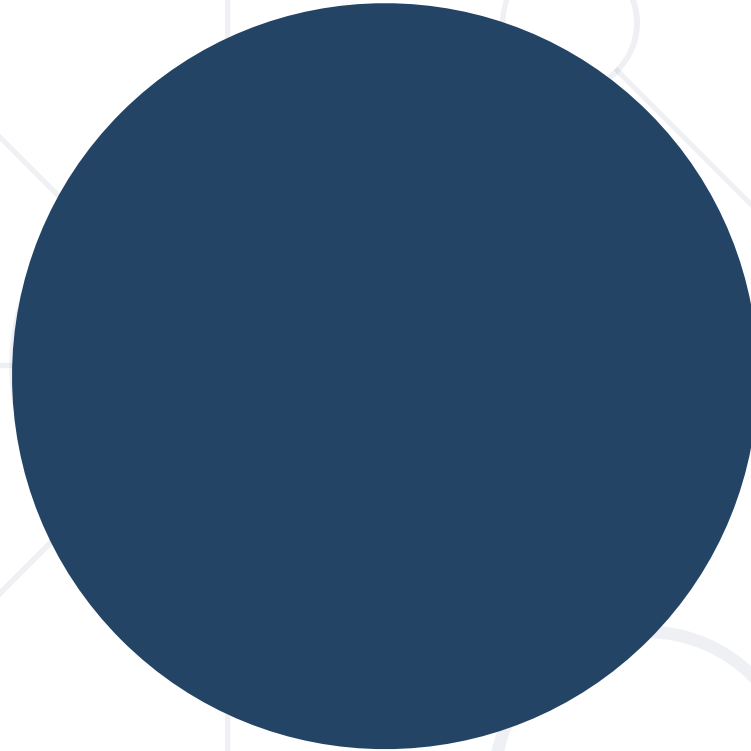


There are **10** types
of people in this world:
Those who understand
BINARY, and those who
don't

Hexadecimal numeral system

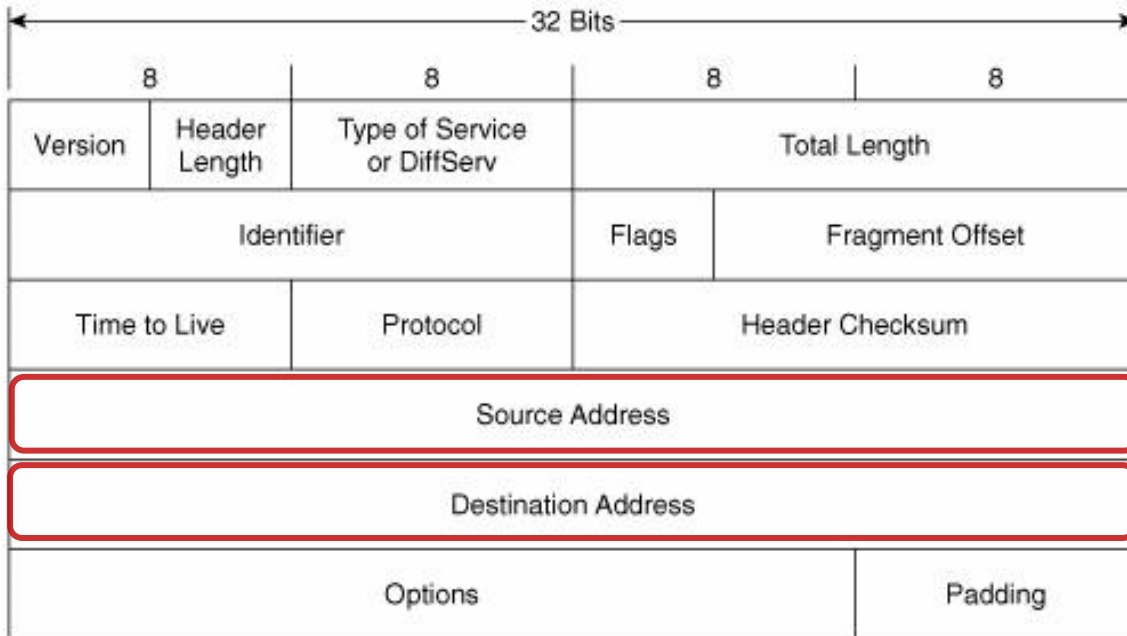


- Base of 16 (made of 16 symbols)
- Widely used by programmers and computer designers
- Used in MAC and IPv6 addresses
- A single digit can be:
0 1 2 3 4 5 6 7 8 9 A B C D E F



IPv4

IPv4 address



- Plays important role for device connectivity
- It is a 32-bit address
- There are 4 294 967 296 IP addresses (2^{32})

Private IP addresses

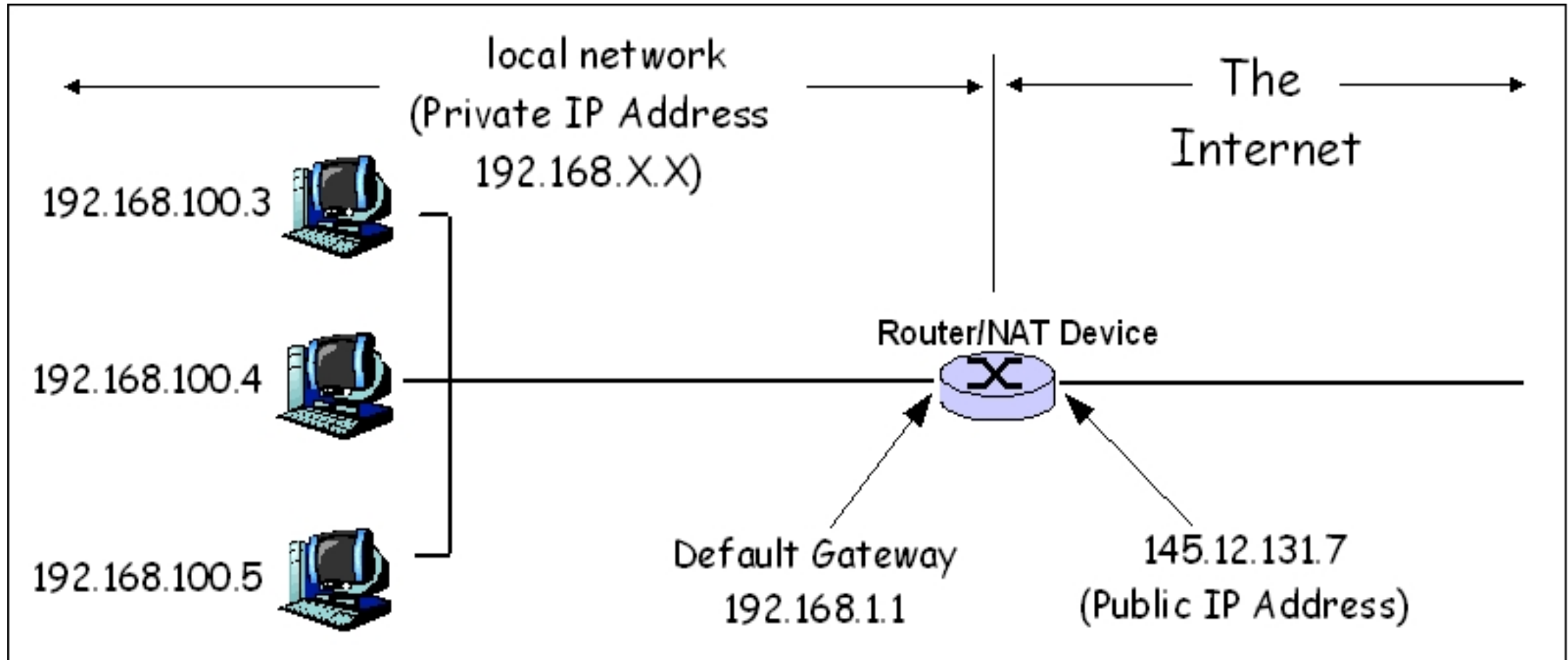
Class	Start of range	End of range
A	10.0.0.0	10.255.255.255
B	172.16.0.0	172.31.255.255
C	192.168.0.0	192.168.255.255

- Used for addressing internal networks (offices, HQs etc.)
- **Not routable** on the Internet
- Can be reused in many networks
- Range of private addresses for each class
(classes are discussed later)

Public IP addresses

- Are not reserved for use in private networks
- Globally routed between ISP routers
- They are unique
- Example: 87.20.114.156

Network Address Translation – NAT



Network Address Translation – NAT (2)

- It is a method of translating one IP address into another

Example : 192.168.17.45 ---> 227.206.89.76



Private



Public

Network masks

IP address: 50.211.197.5
Subnet Mask: 255.0.0.0

	IP network	Host Addresses		
IP address	50.	211.	197.	5
Subnet Mask	255.	0.	0.	0

- Define the border between the network and the hosts part
- Segment the network

Network masks (24-bit mask)

Subnet Mask 255.255.255.0				
	24 bits for Network ID			8 bits for Host ID
Decimal	255	255	255	0
Binary	11111111	11111111	11111111	00000000
The "subnet" part				The "host" part

Network masks (26-bit mask)

Subnet Mask 255.255.255.192				
	26 bits for Network ID			6 bits for Host ID
Decimal	255	255	255	192
Binary	11111111	11111111	11111111	11000000

The "subnet" part

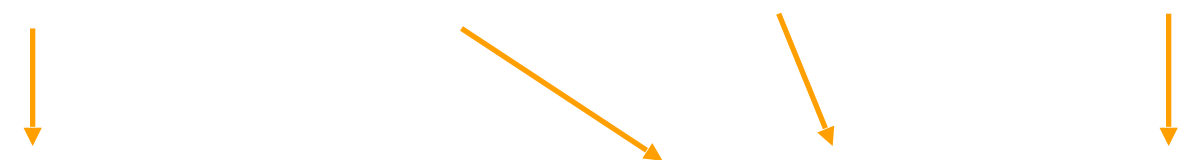
The "host" part

Network masks – example 1

(Class A example)

- In decimal: 255.0.0.0
- Same mask written with prefix: /8
- Same mask written in binary:

11111111.00000000.00000000.00000000



One byte full of 1's.
No address space


Three more bytes full of 0's. This is $2^{24} - 2$ or 16 million computers

Network masks – example 2

(Class B example)

- In decimal: 255.255.0.0
- Same mask written with prefix: /16
- Same mask written in binary:

11111111.11111111.00000000.00000000



Two bytes with 0's. This is $2^{16} - 2$ or 65534 computers

Network masks – example 3

(Class C example)

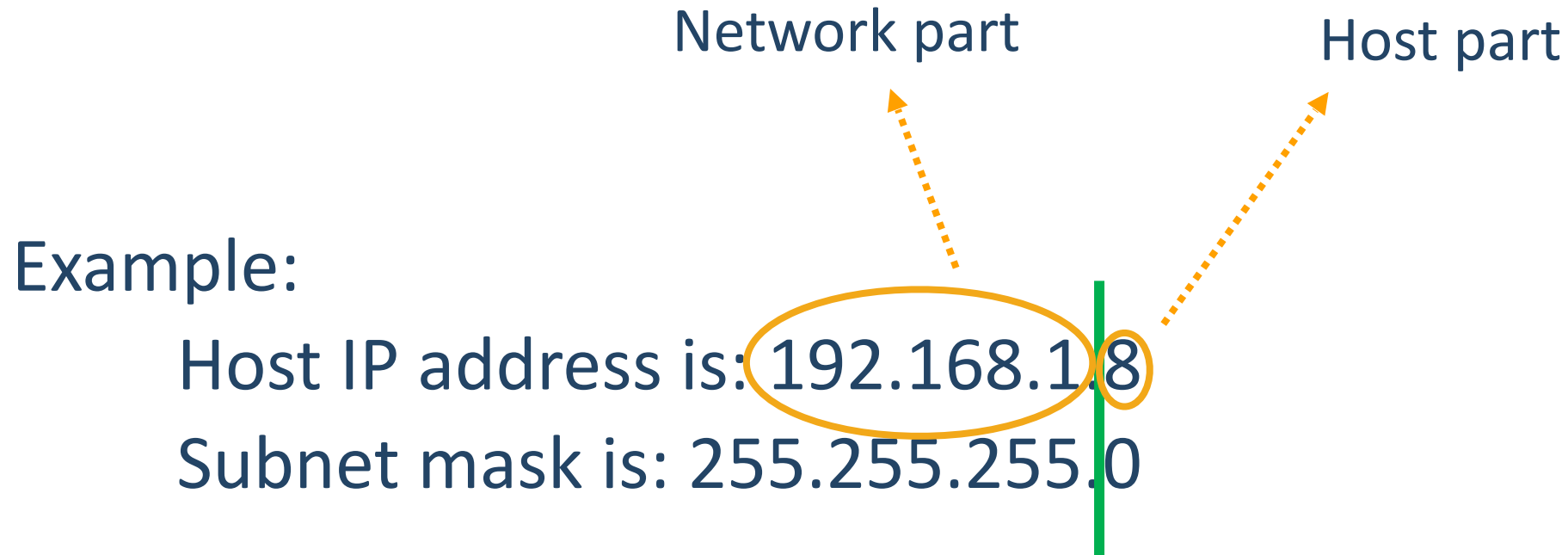
- In decimal: 255.255.255.0
- Same mask written with prefix: /24
- Same mask written in binary:

11111111.11111111.11111111.00000000



One byte with 0's. This is $2^8 - 2$ or 254 computers

Network masks – IP/Mask example



How many IP addresses for the hosts?

To calculate the number of hosts, use the formula $2^n - 2$ where **n** is the number of bits in the host part

- Example: 192.168.1.0 /24 – how many host addresses?

Answer: We have 8 bits in the host part (n), so:

$$2^8 - 2 = 254$$

The Network and the Broadcast address

- Two important and special addresses:
 - The **network** address – first possible address
 - The **broadcast** address – last possible address
- These can NOT be assigned to hosts



The Network and the Broadcast address (2)

Example:

192.168.1.5 /24



192.168.1.5
255.255.255.0

→ 192.168.1.0 is the **network** address

→ 192.168.1.255 is the **broadcast** address

A quick challenge

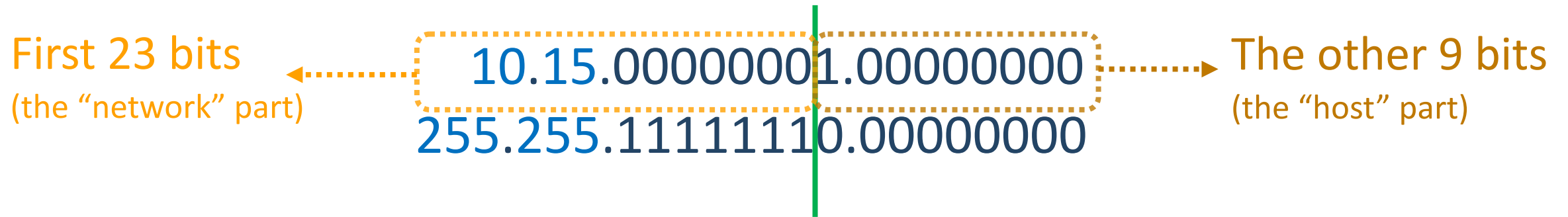
10.15.1.0

Is this a valid HOST IP Address?

A quick challenge (2)

It depends!

Let's see it with /23 mask. 10.15.1.0 /23 can be presented as:



So, is it a valid host IP Address in this case?

A quick challenge (3)

In the example from the previous slide, which is the first and which is the last possible host address for the subnet to which this IP address belongs?

10.15.1.0 /23



10.15.000000001.00000000

255.255.11111110.00000000

- ✓ 10.15.0.0 is the **network** address
- ✓ 10.15.0.1 is the **first host** address
- ✓ 10.15.1.254 is the **last host** address
- ✓ 10.15.1.255 is the **broadcast** address

IP address classes

- IP Address class is determined by the first octet (byte)
- Three of them are used for addressing networks

Class A	0 - 127	For internetwork communication
Class B	128 - 191	For internetwork communication
Class C	192 - 223	For internetwork communication
Class D	224 - 239	Reserved for multicasting
Class E	240 - 254	Reserved for research and experiments

IP address classes (2)

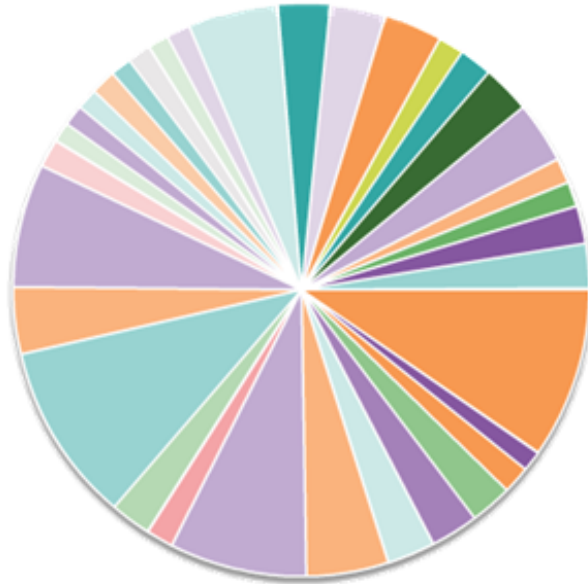
- Examples of class **A** addresses
 - 10.0.0.1
 - 127.0.0.1
 - 0.0.0.1
- Examples of Class **B** addresses
 - 172.16.67.8
 - 169.254.x.x
- Examples of Class **C** addresses
 - 192.168.1.5
 - 198.51.100.0

Introduction to CIDR

Class A (1 - 126)
of possible networks: 126
of Hosts/Net: 16,777,214
Max. # Hosts: 16,777,214

Class B (128 - 191)
of possible networks: 16,384
of Hosts/Net: 65,534
Max. # Hosts: 1,073,709,056

Class C (192 - 223)
of possible networks: 2,097,152
of Hosts/Net: 254
Max. # Hosts: 532,676,608



- Ignores the concept Network Address Classes
- Reduces the amount of route advertisements

Without VLSM and CIDR:

10.1.1.0 /24 will be “seen” as 10.0.0.0 /8
(because /8 is default for Class A)

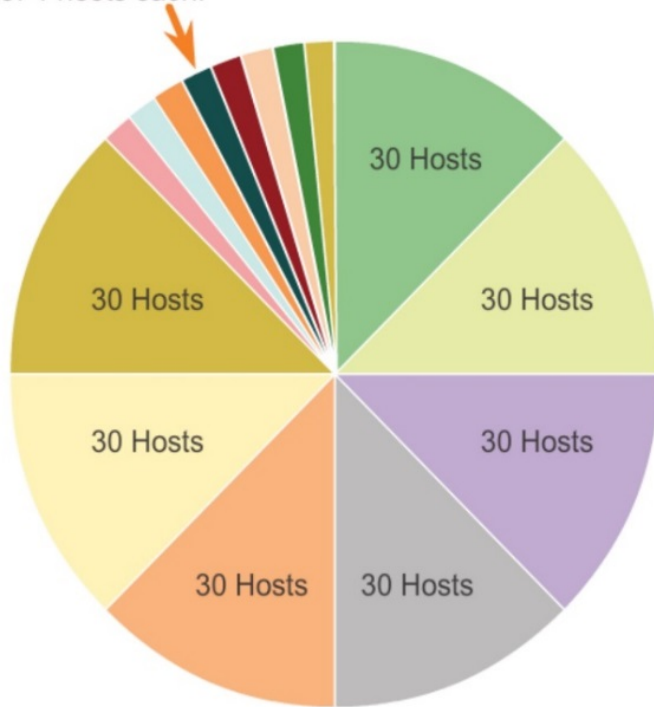
With VLSM and CIDR:

10.1.1.0 /24 is “seen” as it is
(although the mask is NOT the default)

Introduction to VLSM

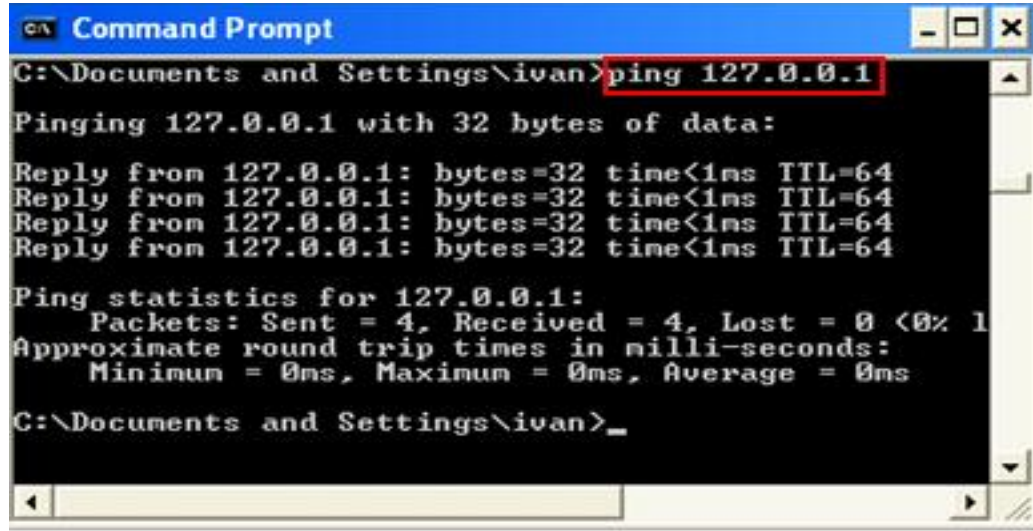
Subnets of Varying Sizes

One subnet was further divided to create 8 smaller subnets of 4 hosts each.



- VLSM: Variable-Length Subnet Masking
- Breaks the IP address classes idea
- “Subnetting of subnets”

Reserved/Special IP addresses



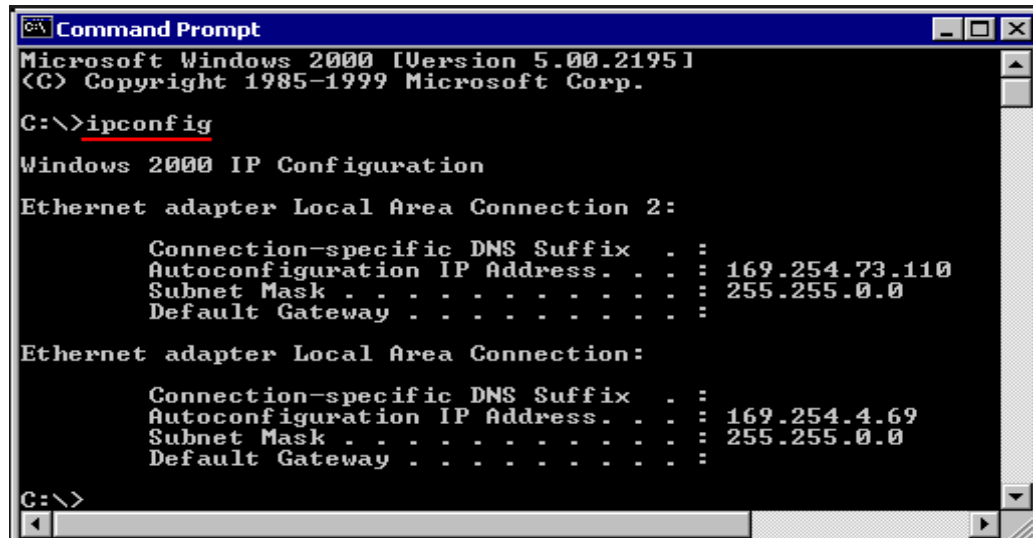
```
Command Prompt
C:\Documents and Settings\ivan>ping 127.0.0.1

Pinging 127.0.0.1 with 32 bytes of data:

Reply from 127.0.0.1: bytes=32 time<1ms TTL=64
Reply from 127.0.0.1: bytes=32 time<1ms TTL=64
Reply from 127.0.0.1: bytes=32 time<1ms TTL=64
Reply from 127.0.0.1: bytes=32 time<1ms TTL=64

Ping statistics for 127.0.0.1:
    Packets: Sent = 4, Received = 4, Lost = 0 (0% loss),
    Approximate round trip times in milli-seconds:
        Minimum = 0ms, Maximum = 0ms, Average = 0ms

C:\Documents and Settings\ivan>
```



```
Command Prompt
Microsoft Windows 2000 [Version 5.00.2195]
(C) Copyright 1985-1999 Microsoft Corp.

C:\>ipconfig

Windows 2000 IP Configuration

Ethernet adapter Local Area Connection 2:

    Connection-specific DNS Suffix  . : 
    Autoconfiguration IP Address. . . : 169.254.73.110
    Subnet Mask . . . . . : 255.255.0.0
    Default Gateway . . . . . : 

Ethernet adapter Local Area Connection:

    Connection-specific DNS Suffix  . : 
    Autoconfiguration IP Address. . . : 169.254.4.69
    Subnet Mask . . . . . : 255.255.0.0
    Default Gateway . . . . . : 

C:\>
```

- There are some special IP addresses. For example:
 - 127.0.0.1 /8
 - Known as loopback address
 - On most computer systems, “localhost” resolves to the IP address 127.0.0.1
 - 169.254.X.X /16
 - When DHCP is not reachable
 - Known as APIPA (Microsoft)

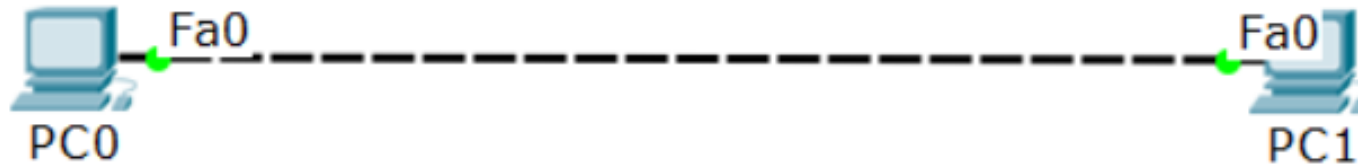


Host-to-host communication

Four addresses required

- There are 4 addresses needed for Ethernet communication:

■ Source IP	■ Destination IP
■ Source MAC	■ Destination MAC



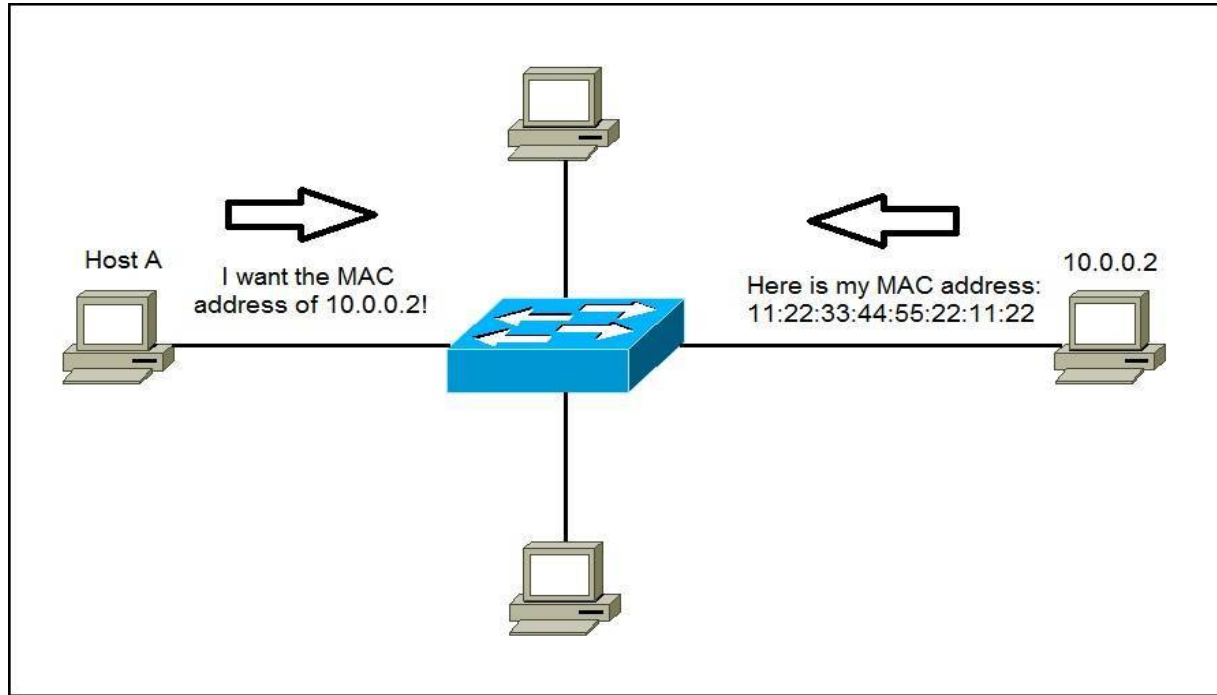
MAC Address: 00E0.F792.0D43

IP Address: 10.0.0.1/24

MAC Address: 000C.CF77.1713

IP Address: 10.0.0.2/24

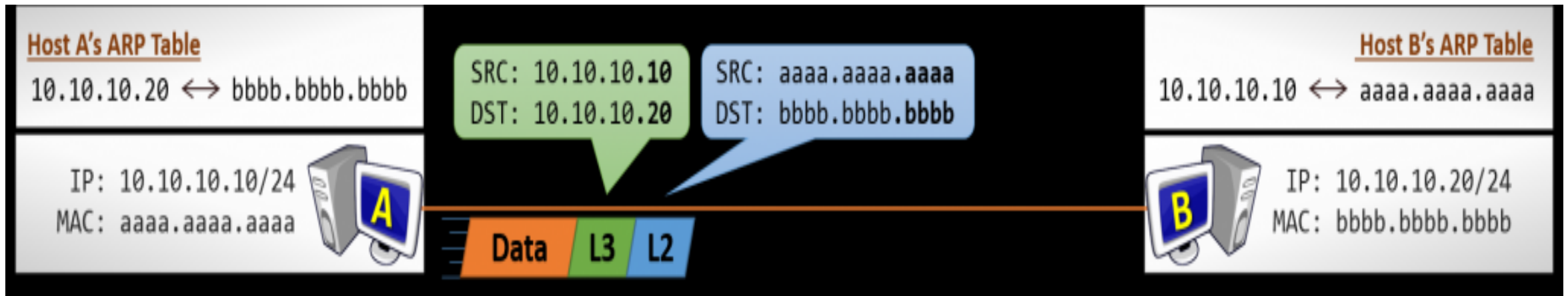
ARP: Address Resolution Protocol



- Used to find the MAC address of the destination
- Uses **Broadcast**

Direct communication (without router)

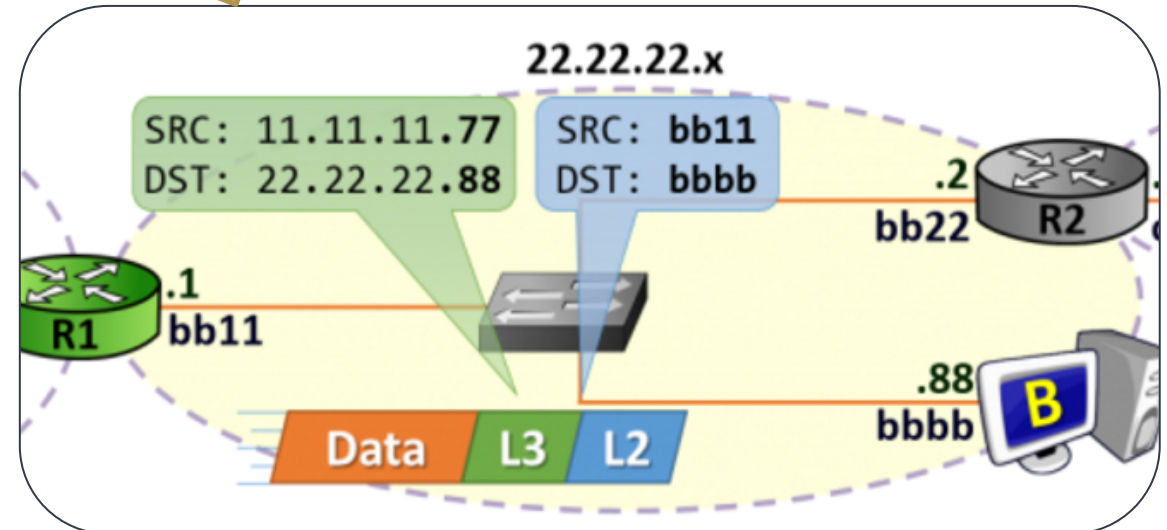
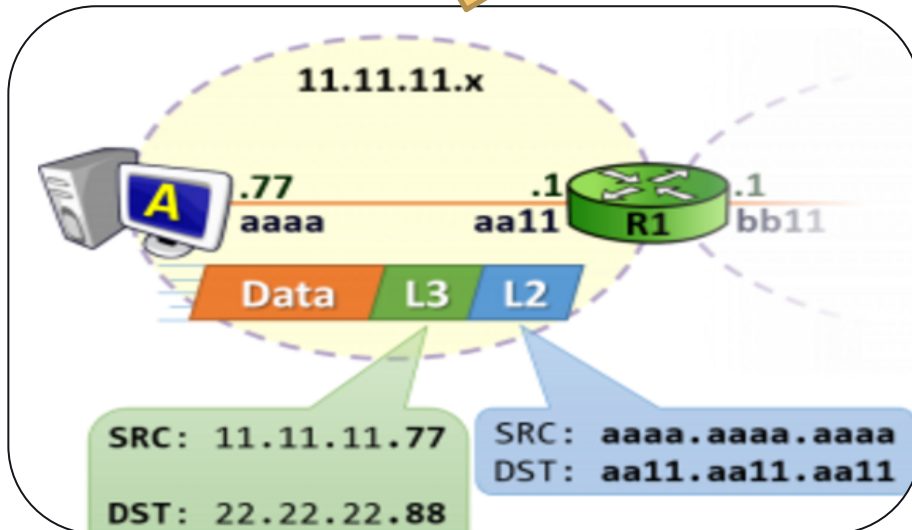
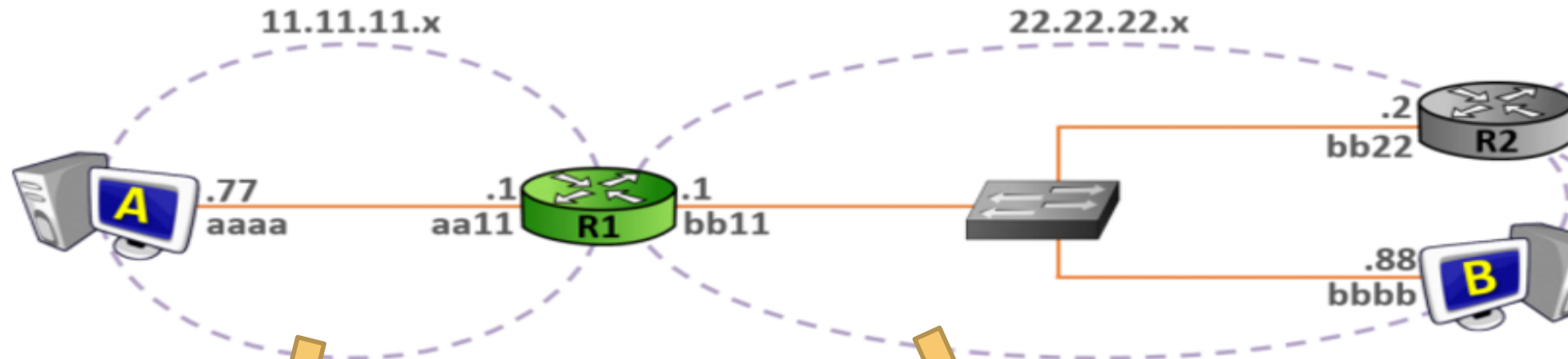
- Source and destination MAC addresses are constant
- Source and destination IP addresses are constant



Host-to-host communication with routers

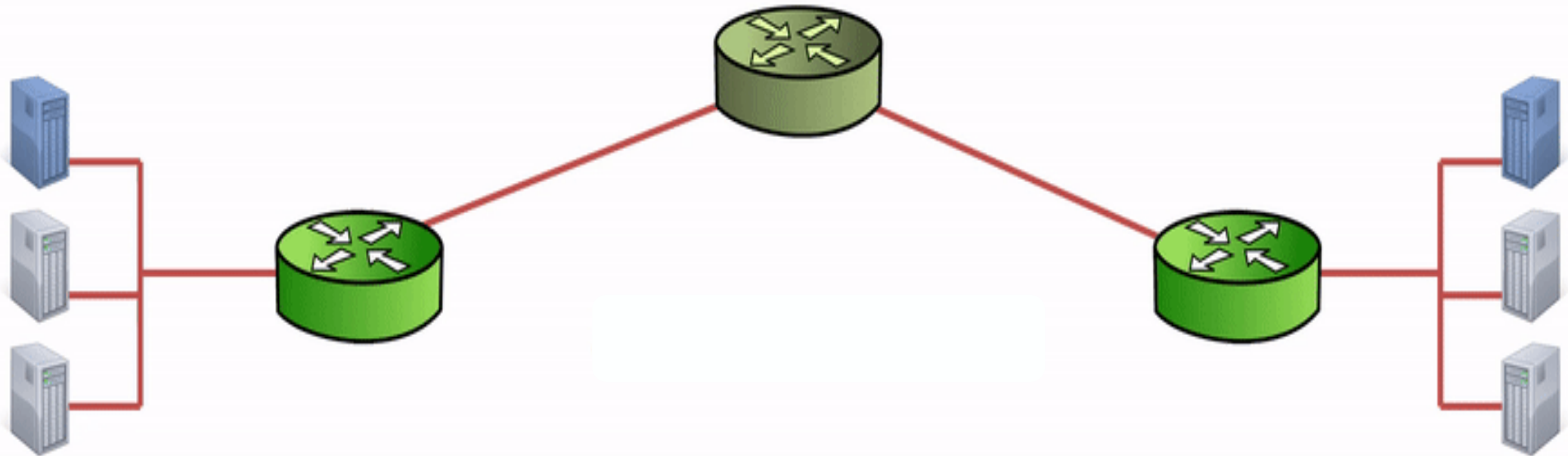
- Source and destination MAC addresses are **changed at every hop** (router)
- Source and destination IP addresses are constant (if we do not use NAT)

Host-to-host communication with routers (2)



Host-to-host communication with routers (3)

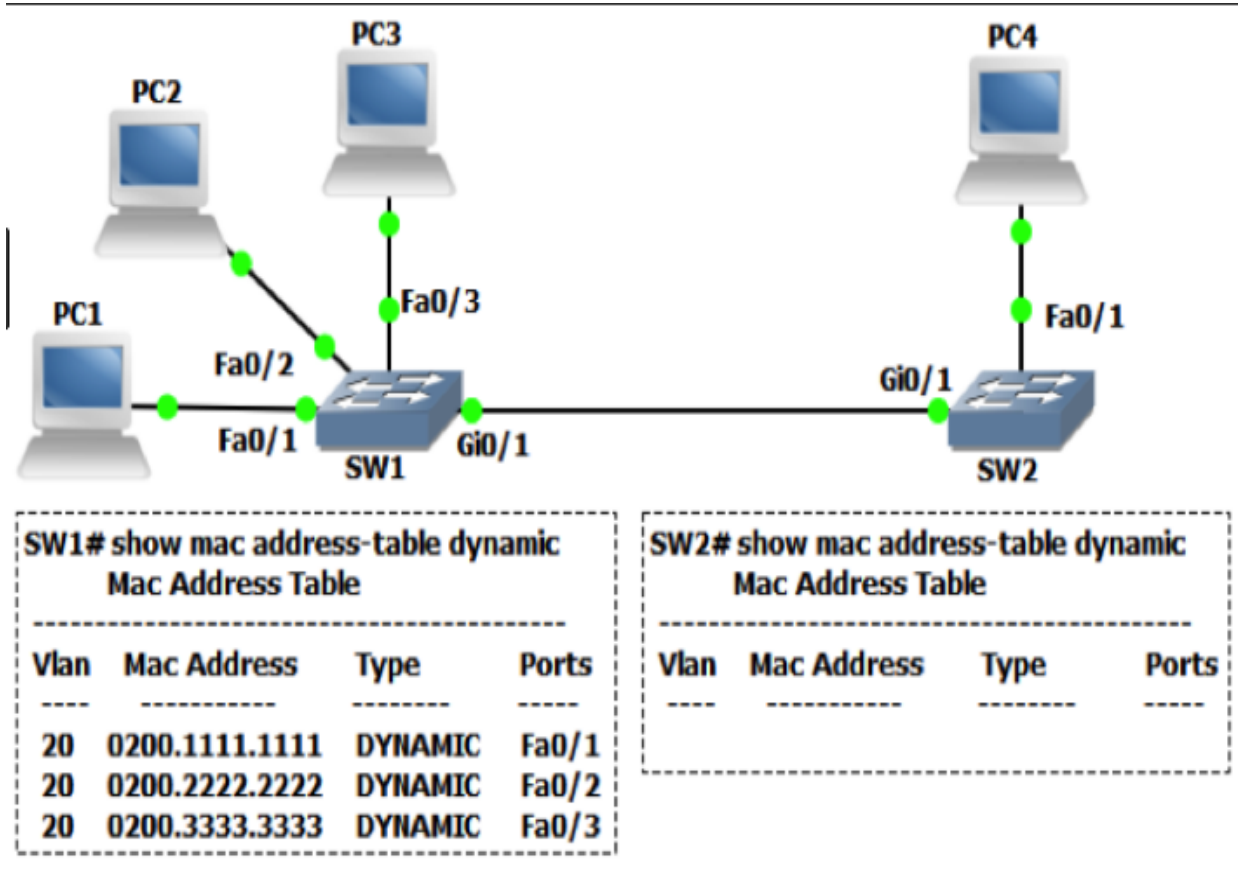
- Source and destination MAC addresses are changed at every hop/router



A network diagram with a central dark blue circle and several smaller white circles connected by lines, forming a mesh-like structure.

Switch MAC address table

The MAC address table



- It is a (dynamic) table that maps MAC addresses to ports
- Used to find the proper interface when the switch forwards a packet

The MAC address table (2)

- You can assign MAC Address statically as well
 - Pros: It is more secure
 - Cons: It is bit slower and harder for sysadmin to assign it manually

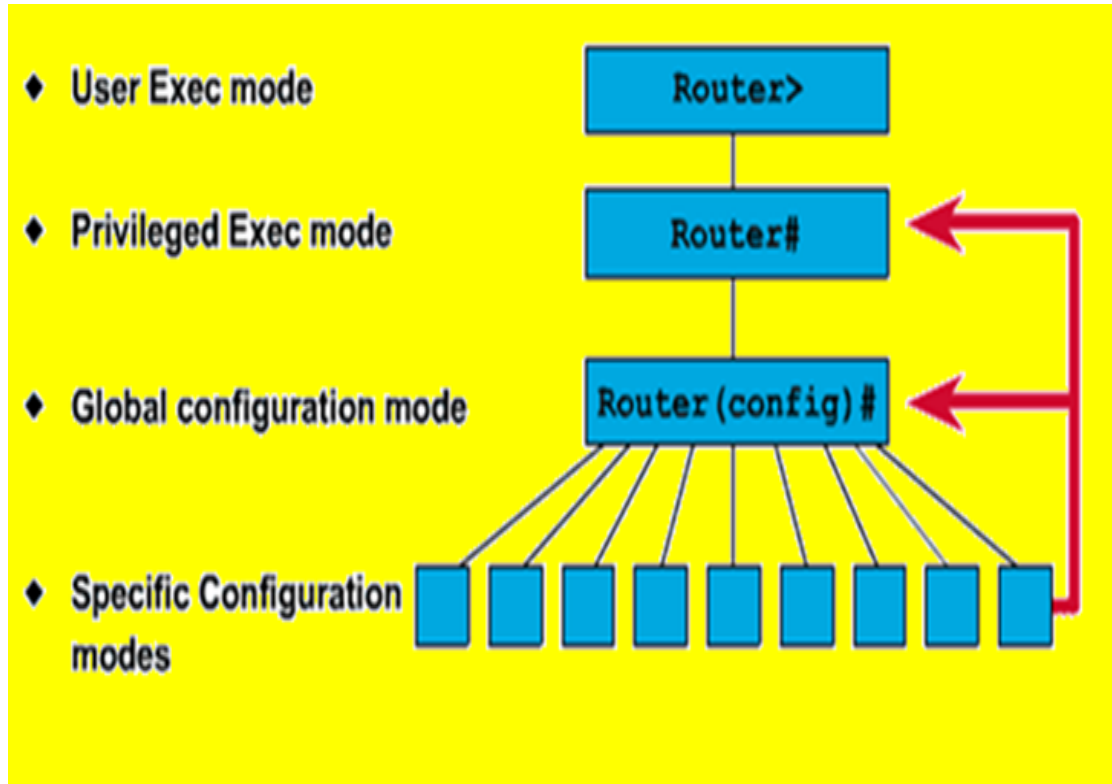
```
SW1#show mac-address-table
      Mac Address Table
-----
```

Vlan	Mac Address	Type	Ports
----	-----	-----	-----
1	1111.1111.1111	STATIC	Fa0/2



The command line

Command line introduction



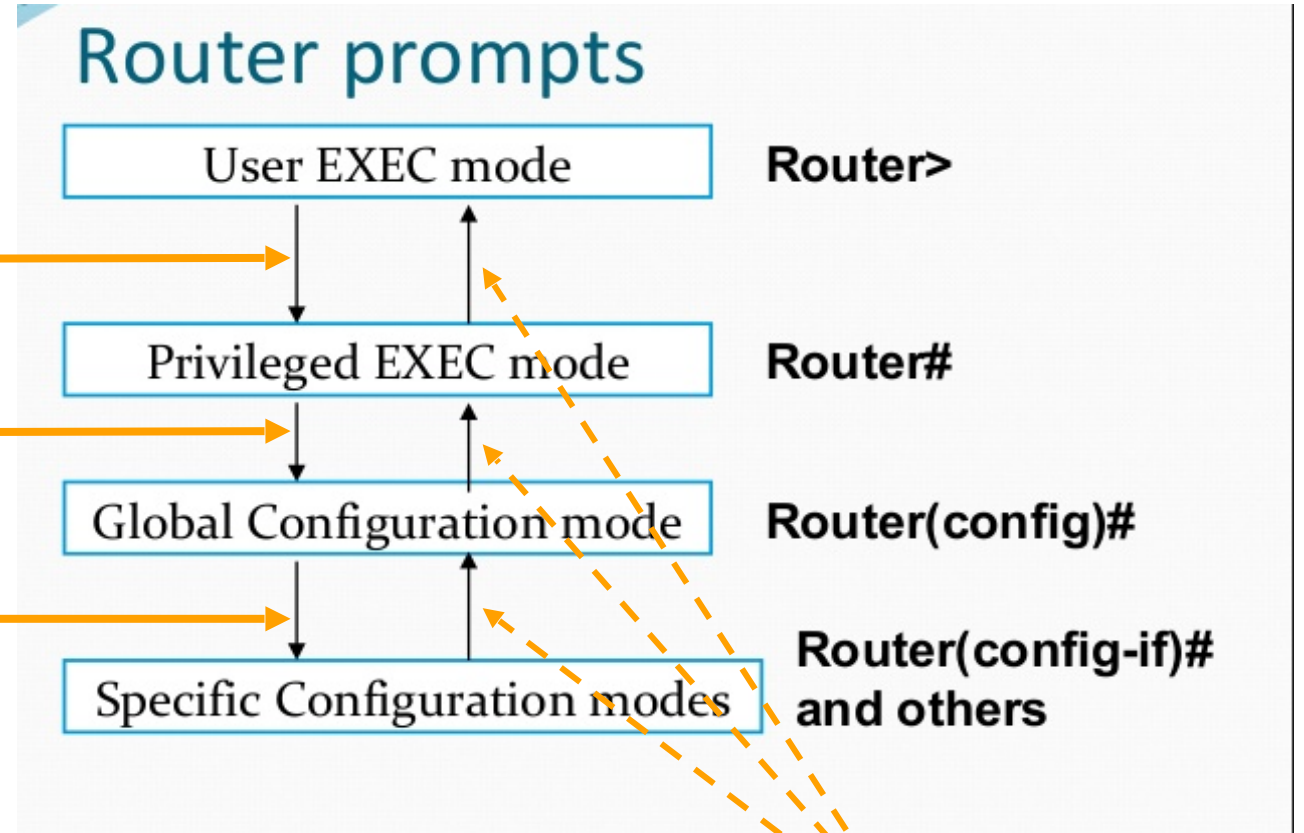
- Different vendors use different names but the logic is similar
- Typical CLI modes:
 - Read-only (User)
 - Read-write (Privilege)
 - Configuration (Global config)
 - Sub-configuration

Command line

type "enable"

type "configure terminal"

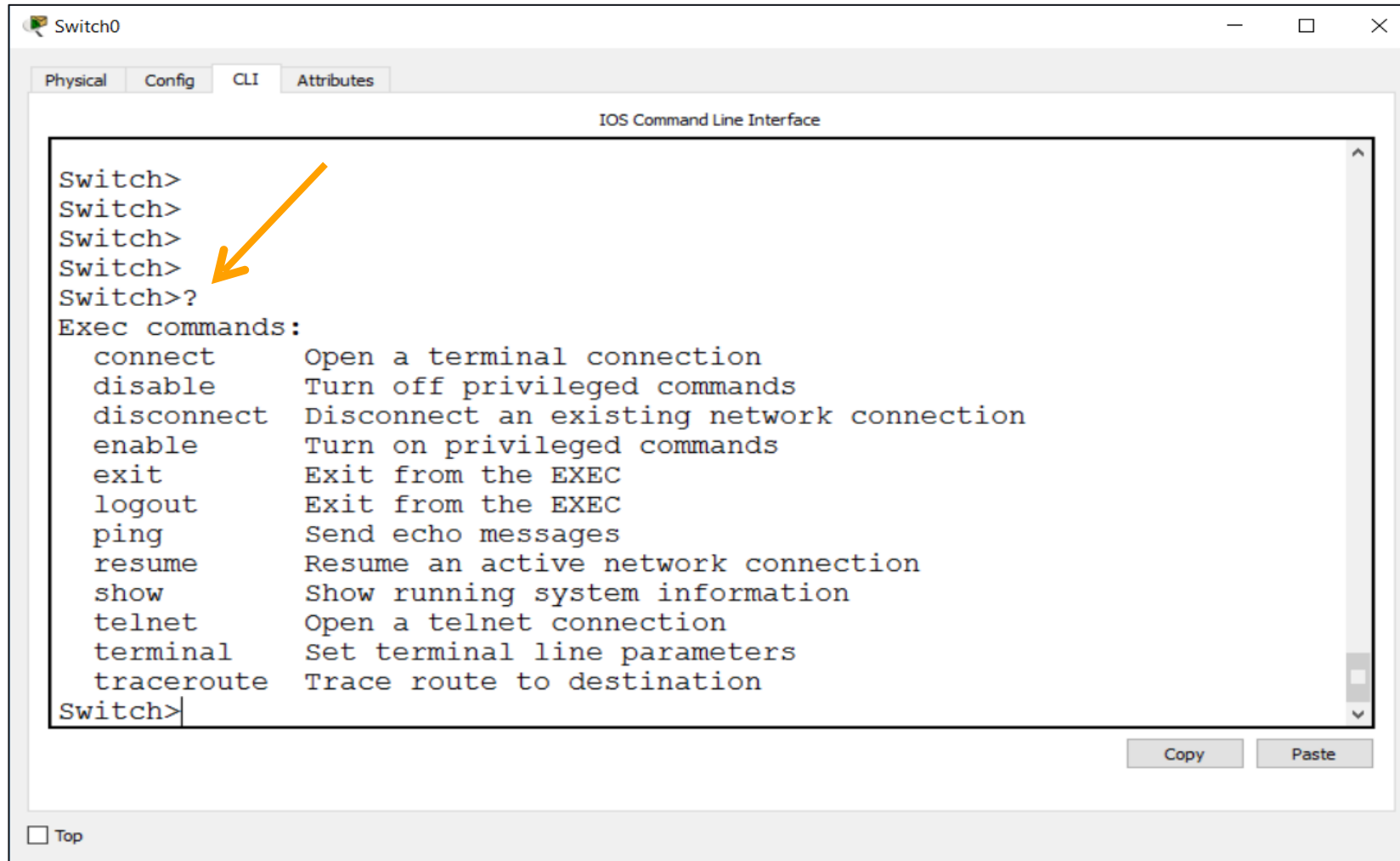
Interface, VLAN,
routing, etc.



to go back, type "exit"

Using the help – “?”

- Use the “?” at each level to see the available commands

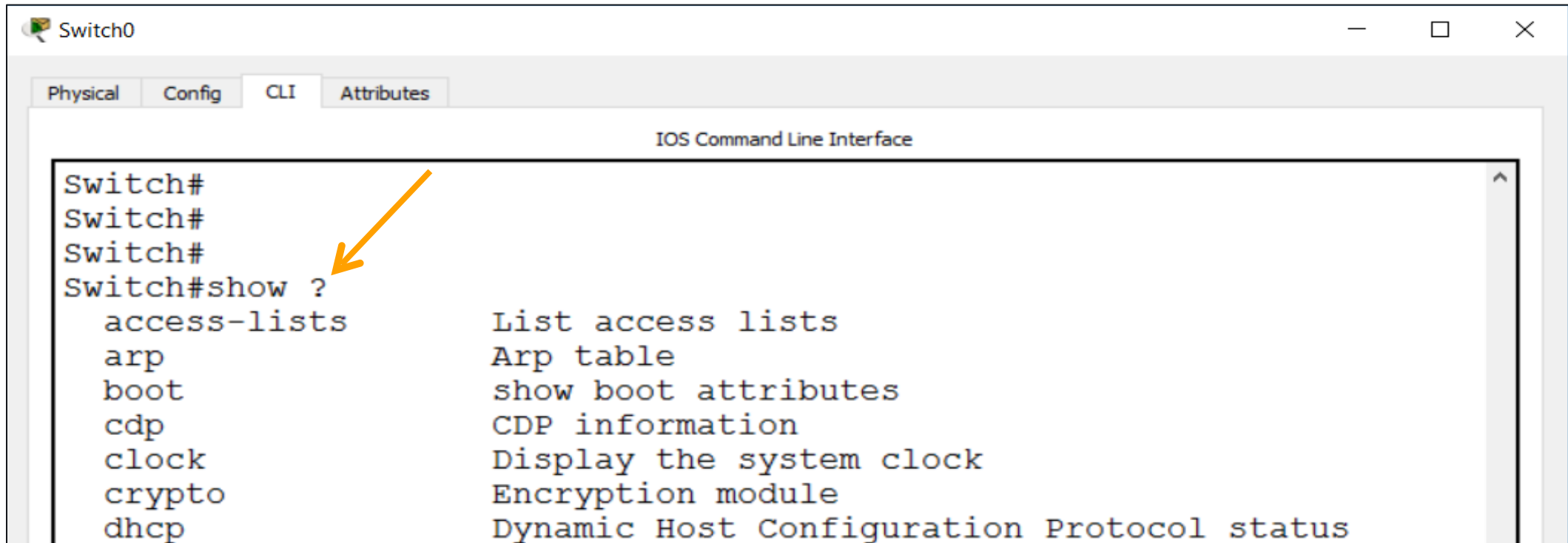


The screenshot shows a window titled "Switch0" with tabs for "Physical", "Config", "CLI", and "Attributes". The "CLI" tab is active, displaying the "IOS Command Line Interface". The command history shows "Switch>" repeated four times, followed by "Switch>?". An orange arrow points to the question mark. Below the prompt, the "Exec commands:" list is displayed, showing various commands and their descriptions. At the bottom, there are "Copy" and "Paste" buttons, and a "Top" button in the bottom left corner.

```
Switch>
Switch>
Switch>
Switch>
Switch>?
Exec commands:
  connect      Open a terminal connection
  disable      Turn off privileged commands
  disconnect    Disconnect an existing network connection
  enable        Turn on privileged commands
  exit          Exit from the EXEC
  logout        Exit from the EXEC
  ping          Send echo messages
  resume        Resume an active network connection
  show          Show running system information
  telnet        Open a telnet connection
  terminal      Set terminal line parameters
  traceroute    Trace route to destination
Switch>
```

Using the help – “?” (2)

- Use the “?” as you type to see:
 - how to finish a command
 - what is/are the next word in the command



The screenshot shows a window titled "Switch0" with four tabs: "Physical", "Config", "CLI", and "Attributes". The "CLI" tab is active, displaying the "IOS Command Line Interface". The terminal shows the following sequence of commands and output:


```
Switch#  
Switch#  
Switch#  
Switch#show ?  
  access-lists      List access lists  
  arp               Arp table  
  boot              show boot attributes  
  cdp               CDP information  
  clock             Display the system clock  
  crypto            Encryption module  
  dhcp              Dynamic Host Configuration Protocol status
```

An orange arrow points to the question mark in the "Switch#show ?" line.

Using the help – TAB

```
reload      Halt and perform a cold restart
resume      Resume an active network connection
setup       Run the SETUP command facility
show        Show running system information

Switch#
Switch#conf
```



Copy

Paste

Hit the TAB key here to autocomplete “configure”

A network diagram with a central dark blue circle and several smaller white circles connected by light gray lines. The text "Basic connectivity checks" is overlaid on the diagram.

Basic connectivity checks

Basic Connectivity Checks

- Ping (Layer 3)
- Traceroute (Layer 3)
- LLDP (Layer 2)
- CDP (Layer 2)

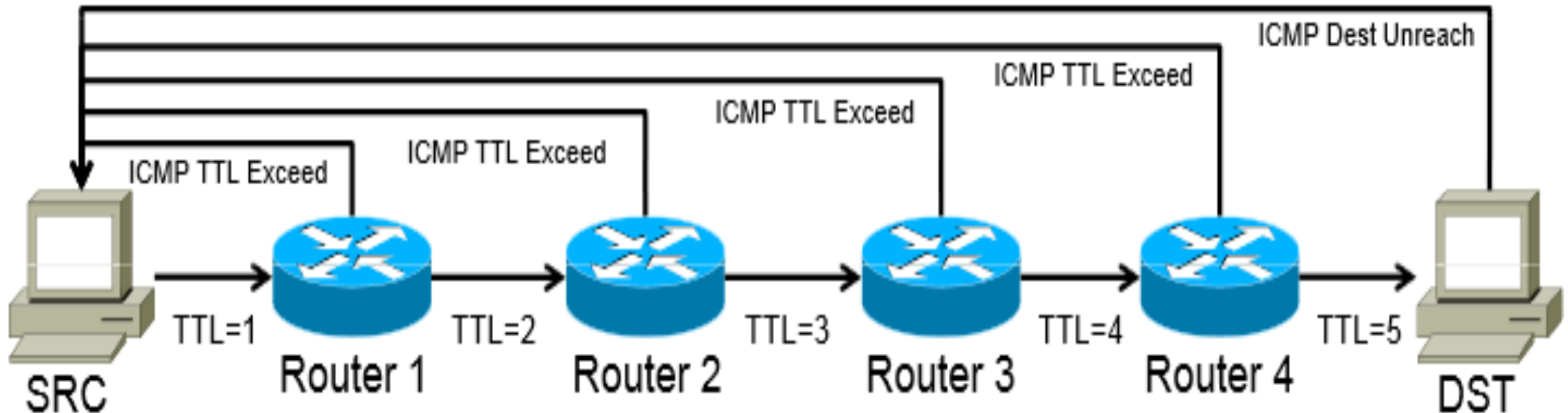
Ping

- Important Layer 3 connectivity check
- Must have IP addresses
- ICMP echo request and ICMP echo reply



Traceroute

- Another **L3** connectivity check
- Uses the TTL (Time to Live) value in the packet
- Can determine the number of hops (routers) in the path



LLDP: Link Layer Discovery Protocol

- Who is connected to me?
- Works at Layer 2
- Must be enabled on both sides
- Vendor-neutral



CDP: Cisco Discovery Protocol

- Cisco proprietary
- Gathers info about other Cisco (CDP) neighbor devices
- Operates at L2
- Turned on default by all Cisco switches and routers



Demonstration

Summary

1. Binary, decimal and hexadecimal numbers
2. IPv4
3. Host-to-Host communication
4. Switch MAC Address table
5. The command line
6. Basic connectivity checks

