COMPUTER NETWORKS

APPLICATION LAYER PROTOCOLS (CH.4 AND 23)

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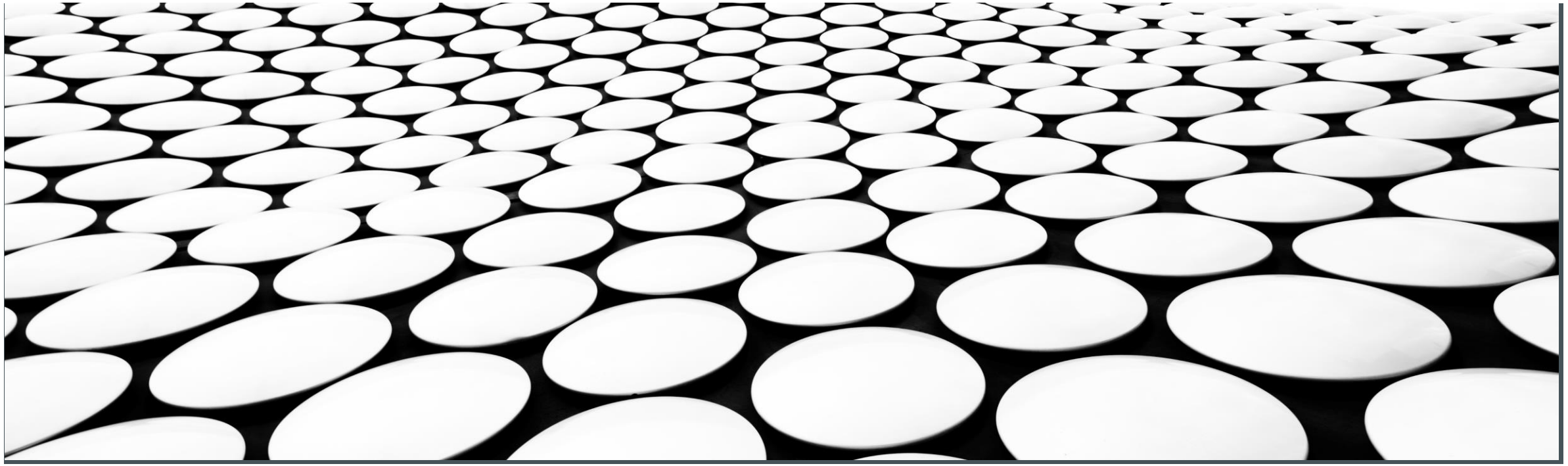
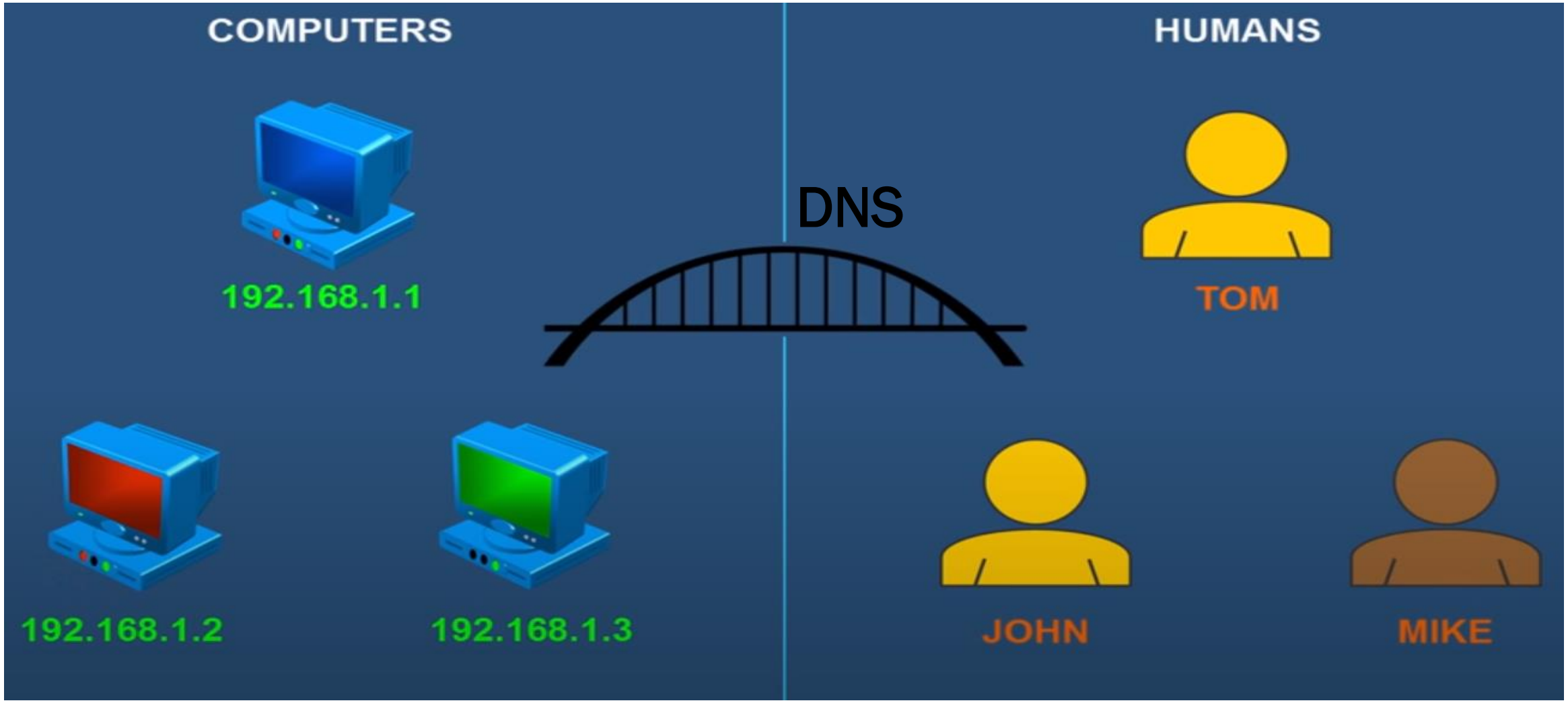


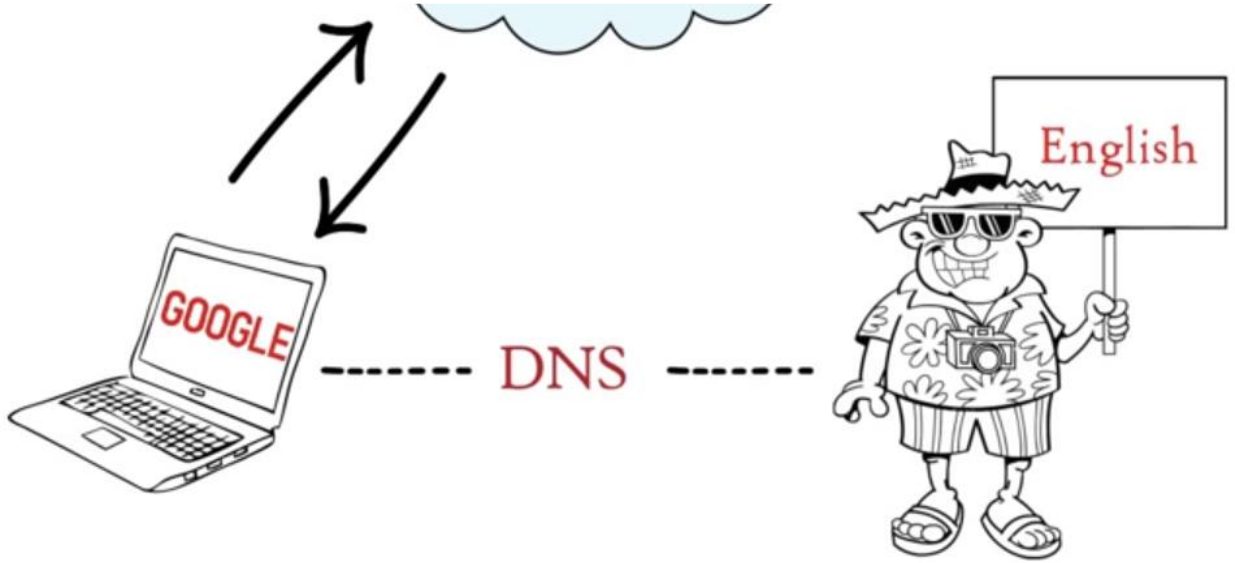
TODAY

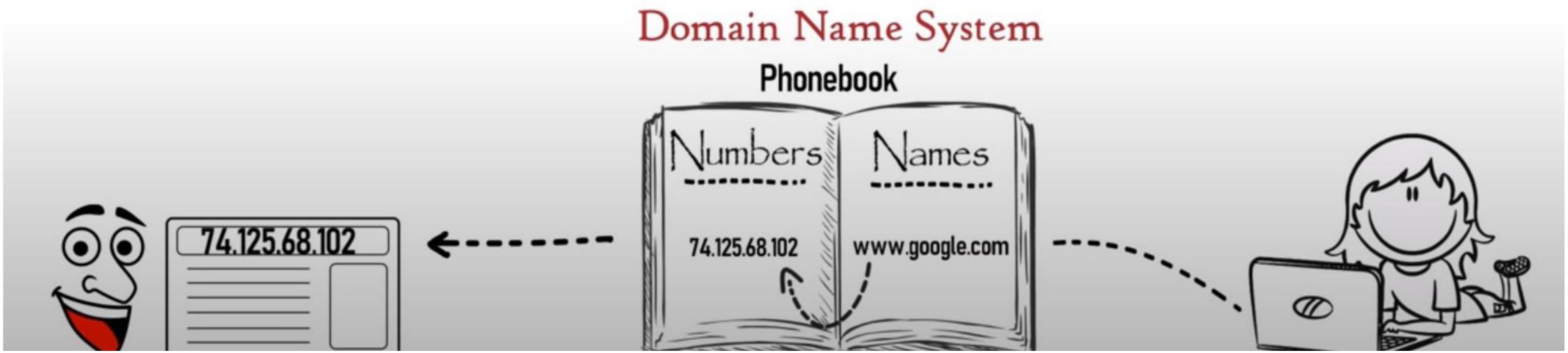
- » IP and naming.
- » (IP) Support protocols and technologies:
  - » ARP, ICMP, DHCP, and NAT
- » Protocols
  - » Web and HTTP

NEED BRIDGING BETWEEN COMPUTER AND HUMAN UNDERSTANDABLE FORMATS



DNS PHONEBOOK ANALOGY





HOSTNAMES VS. IP ADDRESSES

- Suppose you want to access the LNU Moodle site. No problem, you just navigate to mymoodle.lnu.se… mymoodle.lnu.se is a hostname, not an IP address, so we need some mechanism to map it to 194.47.110.145

WHY HOSTNAMES?

» NAMES ARE EASIER TO REMEMBER.

» ADDRESSES CAN CHANGE UNDERNEATH.

» NAME COULD MAP TO MULTIPLE IP ADDRESSES.

» MAP TO DIFFERENT ADDRESSES IN DIFFERENT PLACES.


DOMAIN NAME I.P. ADDRESS
YOUTUBE.COM 20.51.154.170
BOXING.COM 74.67.110.78
NFL.COM 221.10.134.108
Resolves names to numbers.
Resolves domain names to I.P. addresses.
DNS
NSI
DNS SERVER
yahoo.com

DNS RESOLVER

DNS resolver is provided by ISP to connect with the name servers

DNS Resolver

ISP

Telia, Telenor, Vodafone ,etc

Root name server

TLD name server

Authoritative name server

TYPES OF DNS SEVERS

DNS recursive resolver/DNS resolver

Root name server

Top Level Domain/TLD name server

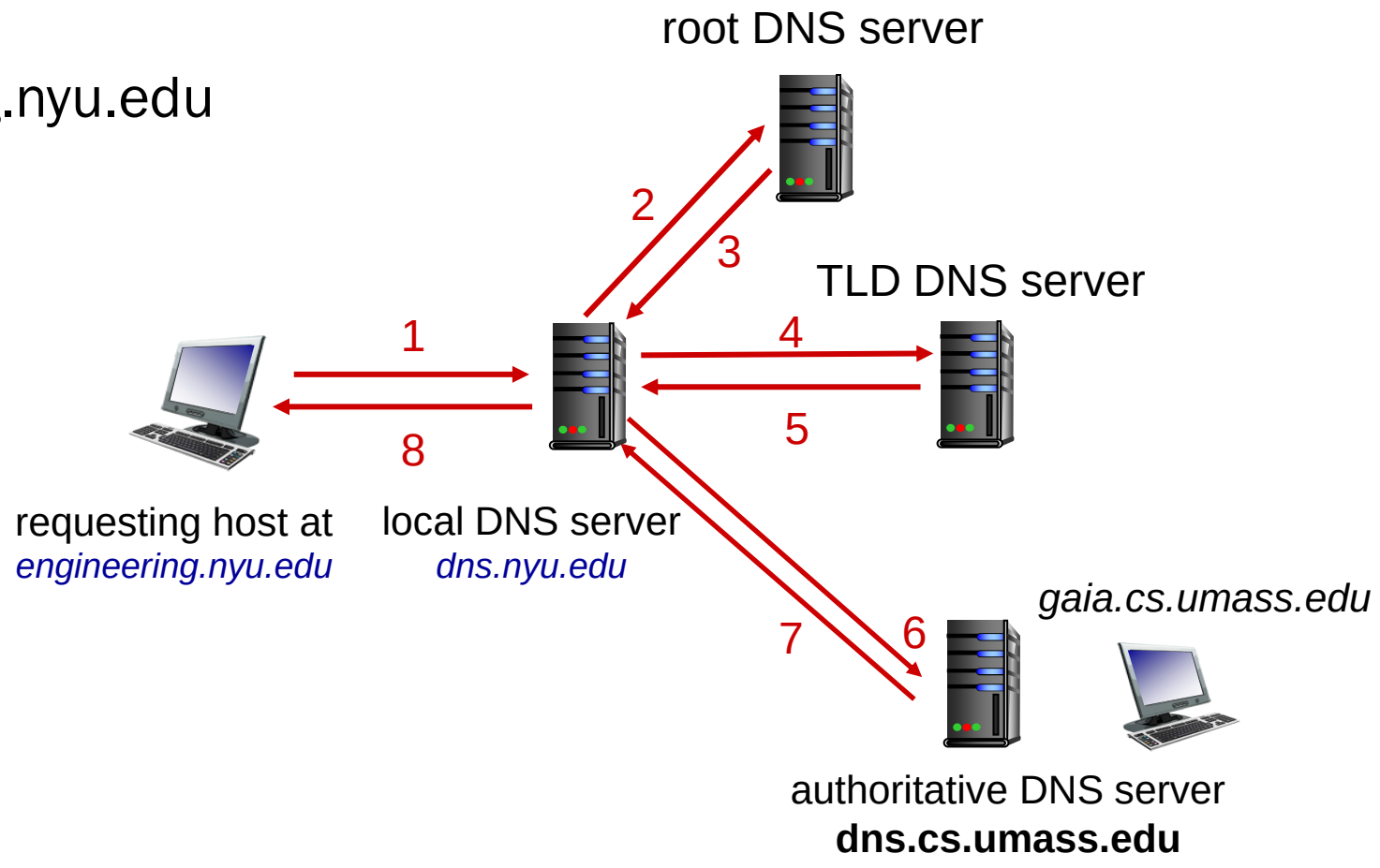
Authoritative name server

DNS NAME RESOLUTION: ITERATED QUERY

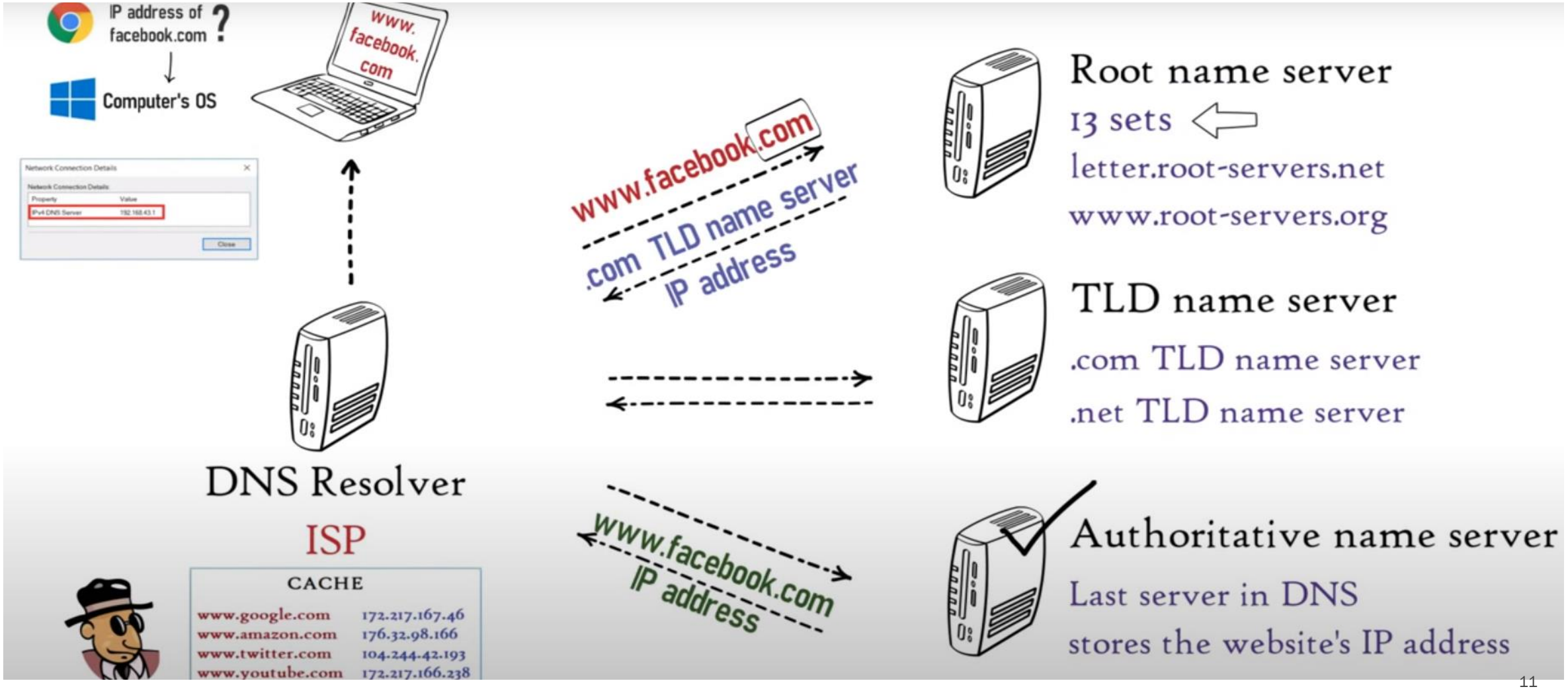
Example: host at engineering.nyu.edu wants IP address for gaia.cs.umass.edu

Iterated query:

- contacted server replies with name of server to contact
- "I don't know this name, but ask this server"



BROWSER-RESOLVER-ROOT RETURN'S TLD SERVER IP TO RESOLVER-TLD RETURN'S AUTHORITATIVE SERVER IP TO RESOLVER- AUTHORITATIVE RETURN'S IP OF THE HOST NAME TO RESOLVER

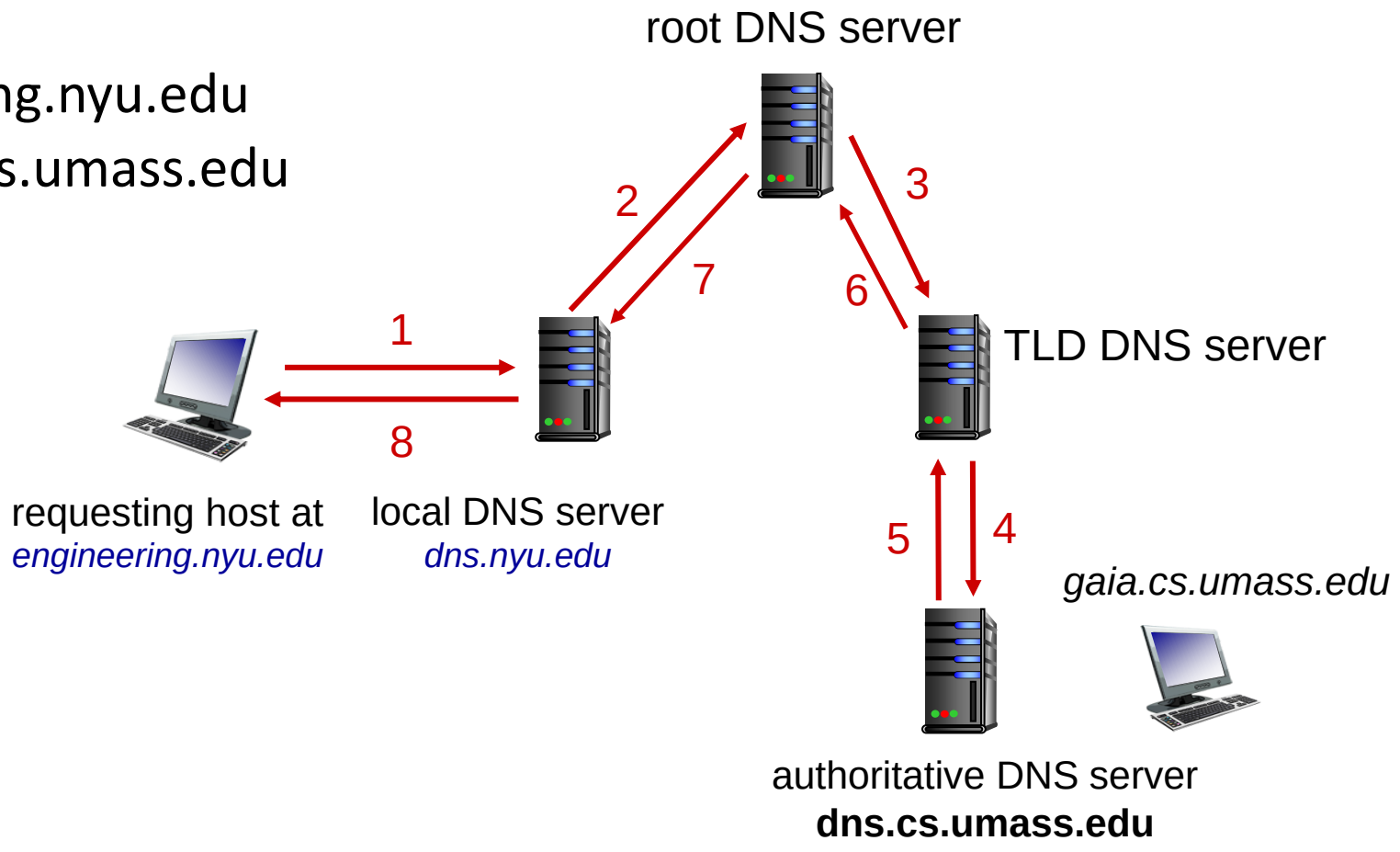


DNS NAME RESOLUTION: RECURSIVE QUERY

Example: host at engineering.nyu.edu wants IP address for gaia.cs.umass.edu

Recursive query:

- puts burden of name resolution on contacted name server
- heavy load at upper levels of hierarchy?



WHY NOT A CENTRAL SERVER?

A central server has practical problems:

- » Single point of failure.
- » High traffic volume.
- » Distant centralized database.
- » Single point of update.
- » Does not scale.

DOMAIN NAME?

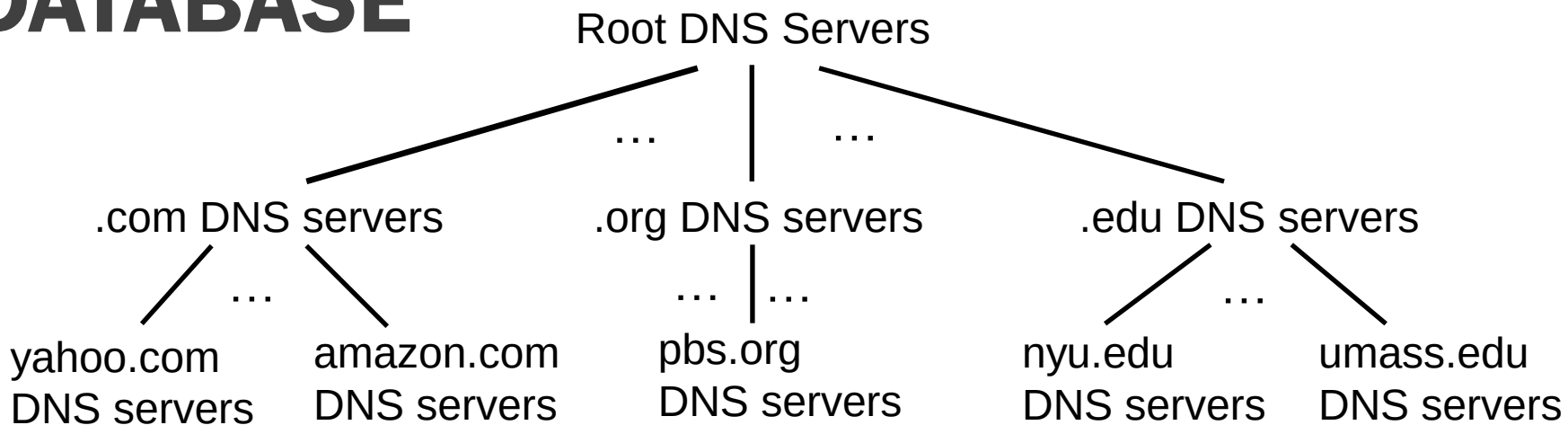
- » Any name registered in the DNS is a domain name.
- » Hierarchical system with multiple levels:

1. Root servers (nameless)
2. TLD
3. Second-level
4. Third-level
5. ...

EXAMPLE MYMOODLE.LNU.SE

- » se is a country-code TLD (ccTLD)
- » lnu is a second-level domain
- » mymoodle is a hostname in the lnu domain

DNS: A DISTRIBUTED, HIERARCHICAL DATABASE



Root

Top Level Domain

Authoritative

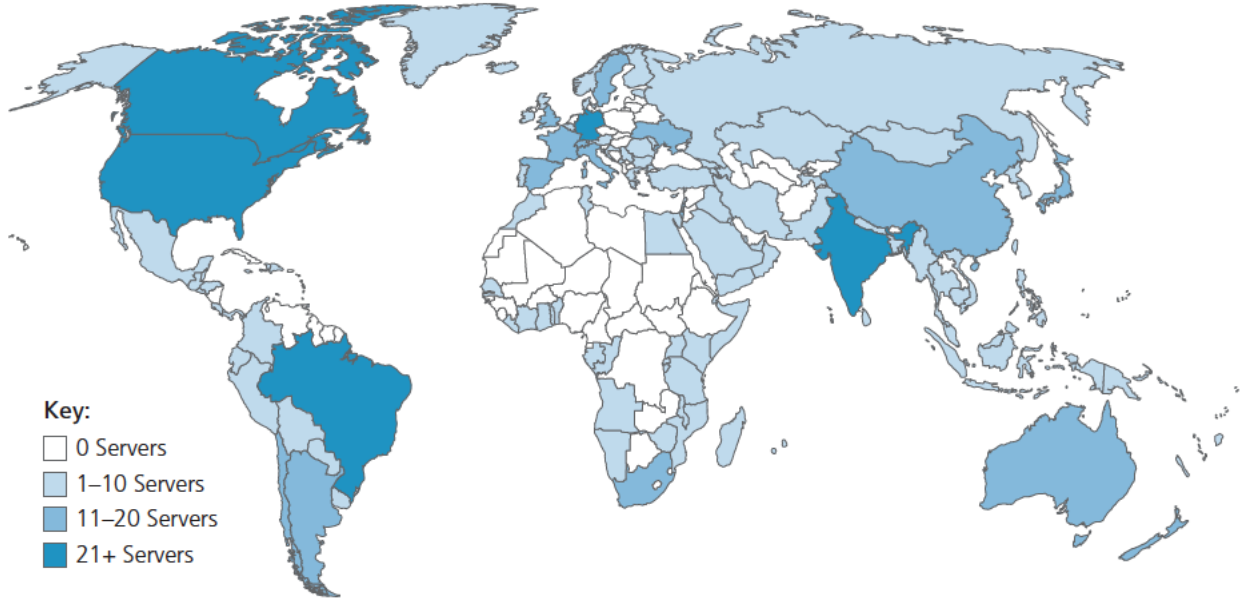
Client wants IP address for www.amazon.com; 1st approximation:

- client queries root server to find .com DNS server
- client queries .com DNS server to get amazon.com DNS server
- client queries amazon.com DNS server to get IP address for www.amazon.com

DNS: ROOT NAME SERVERS

- official, contact-of-last-resort by name servers that can not resolve name
- *incredibly important* Internet function
  - Internet couldn't function without it!
  - DNSSEC – provides security (authentication, message integrity)
- ICANN (Internet Corporation for Assigned Names and Numbers) manages root DNS domain

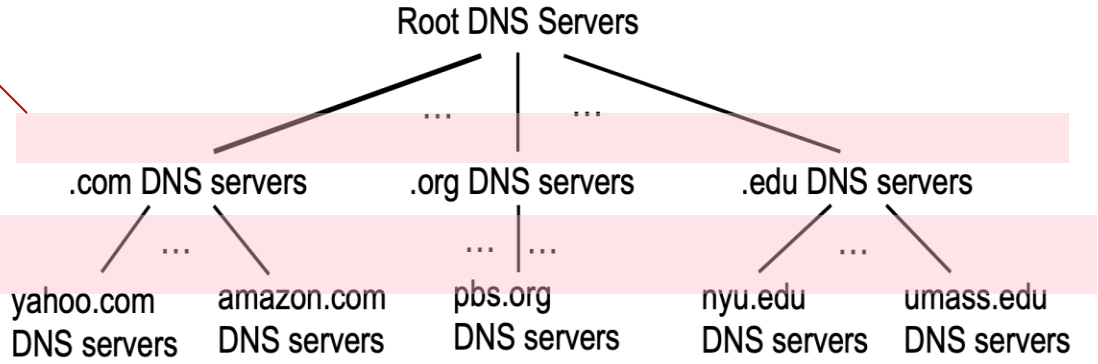
13 logical root name "servers" worldwide each "server" replicated many times (~200 servers in US)



TOP-LEVEL DOMAIN, AND AUTHORITATIVE SERVERS

Top-Level Domain (TLD) servers:

- responsible for .com, .org, .net, .edu, .aero, .jobs, .museums, and all top-level country domains, e.g.: .cn, .uk, .fr, .ca, .jp
- Network Solutions: authoritative registry for .com, .net TLD
- Educause: .edu TLD



authoritative DNS servers:

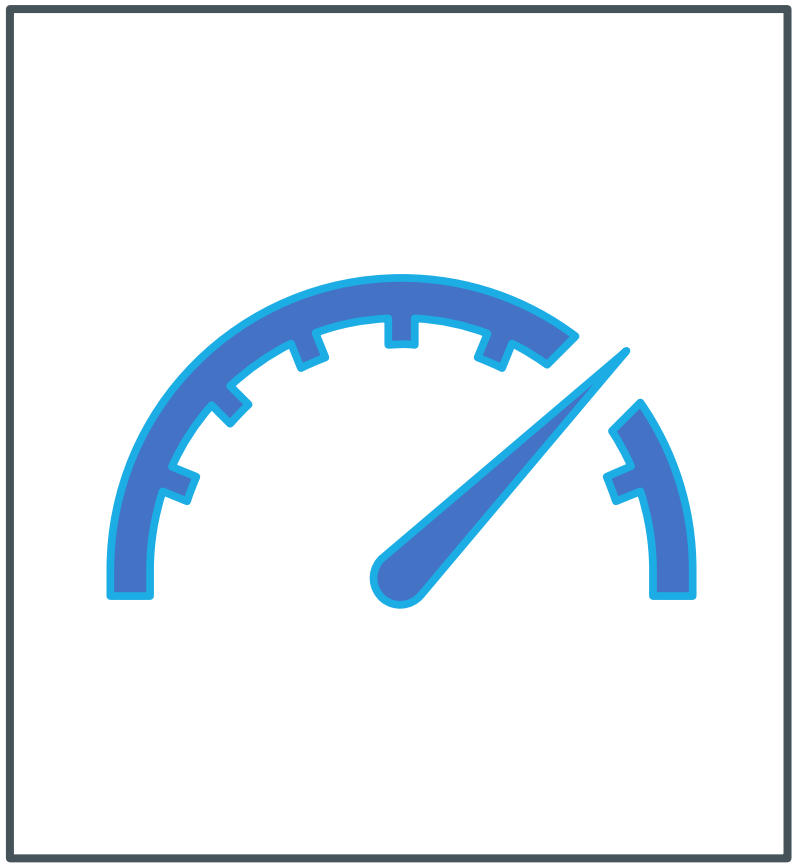
- organization's own DNS server(s), providing authoritative hostname to IP mappings for organization's named hosts
- can be maintained by organization or service provider

LOCAL DNS NAME SERVERS

- when host makes DNS query, it is sent to its *local* DNS server
  - Local DNS server returns reply, answering:
    - from its local cache of recent name-to-address translation pairs (possibly out of date!)
    - forwarding request into DNS hierarchy for resolution
  - each ISP has local DNS name server; to find yours:
    - MacOS: % scutil --dns
    - Windows: >ipconfig /all
- local DNS server doesn't strictly belong to hierarchy

```
:\Users\heghaa>ipconfig/all

indows IP Configuration

  Host Name . . . . . . . . . . . . : WB-0163
  Primary Dns Suffix  . . . . . . . : lnu.se
  Node Type . . . . . . . . . . . . : Peer-Peer
  IP Routing Enabled. . . . . . . . : No
  WINS Proxy Enabled. . . . . . . . : No
  DNS Suffix Search List. . . . . . : soda.lnu.se
                                      client.lnu.se
                                      lnu.se

ireless LAN adapter Local Area Connection* 1:

  Media State . . . . . . . . . . . : Media disconnected
  Connection-specific DNS Suffix  . :
  Description . . . . . . . . . . . : Microsoft Wi-Fi Direct Virtual Adapter
  Physical Address. . . . . . . . . : 38-6 -93-BF-BF- 0
  DHCP Enabled. . . . . . . . . . . : Yes
  Autoconfiguration Enabled . . . . : Yes

ireless LAN adapter Anslutning till lokalt nätverk* 1:

  Media State . . . . . . . . . . . : Media disconnected
  Connection-specific DNS Suffix  . :
  Description . . . . . . . . . . . : Microsoft Wi-Fi Direct Virtual Adapter #2
  Physical Address. . . . . . . . . : 3A-6 -93-BF-BF-DF
  DHCP Enabled. . . . . . . . . . . : Yes
  Autoconfiguration Enabled . . . . : Yes

ireless LAN adapter Wi-Fi:

  Connection-specific DNS Suffix  . :
  Description . . . . . . . . . . . : Killer(R) Wi-Fi 6 AX1650s 160MHz Wireless Network Adapter (201D2W)
  Physical Address. . . . . . . . . : 38-6 -93-BF-BF-DF
  DHCP Enabled. . . . . . . . . . . : Yes
  Autoconfiguration Enabled . . . . : Yes
  Link-local IPv6 Address . . . . . : fe80::b146:95d7:8789:d184%4(Preferred)
  IPv4 Address. . . . . . . . . . . : 192.168.43.251(Preferred)
  Subnet Mask . . . . . . . . . . . : 255.255.255.0
  Lease Obtained. . . . . . . . . . : den 4 februari 2021 08:56:18
  Lease Expires . . . . . . . . . . : den 4 februari 2021 11:49:08
  Default Gateway . . . . . . . . . : 192.168.43.1
  DHCP Server . . . . . . . . . . . : 192.168.43.1
  DHCPv6 IAID . . . . . . . . . . . : 70805651
  DHCPv6 Client DUID. . . . . . . . : 00-01-00-01-27-8F-85-03-00-15-5D-A0-A0-07
  DNS Servers . . . . . . . . . . . : 192.168.43.1
  NetBIOS over Tcpip. . . . . . . . : Enabled
```

DNS CACHING



Performing all these queries take time, and all this before the actual

- communication takes place.
- Caching can substantially reduce overhead:
  - » The top-level servers very rarely change.
  - » Popular sites (e.g., www.google.com) visited often.
  - » Local DNS server often has the information cached

CACHING DNS INFORMATION

- once (any) name server learns mapping, it *caches* mapping, and i*mmediately* returns a cached mapping in response to a query
  - caching improves response time
  - cache entries timeout (disappear) after some time (TTL TIME TO LIVE)
  - TLD servers typically cached in local name servers

DNS RECORDS

DNS: distributed database storing resource records (RR)

RR format: (`name, value, type, ttl`)

type=A

- `name` is hostname
- `value` is IP address

type=NS

- `name` is domain (e.g., foo.com)
- `value` is hostname of authoritative name server for this domain

type=CNAME

- `name` is alias name for some "canonical" (the real) name
- www.ibm.com is really servereast.backup2.ibm.com
- `value` is canonical name

type=MX

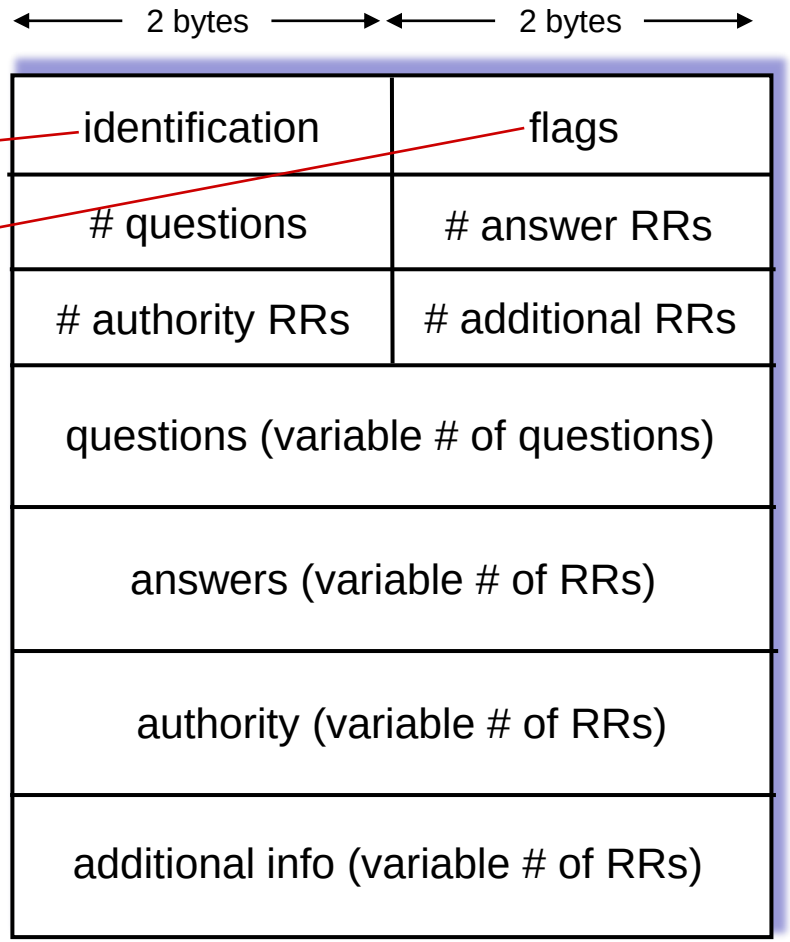
- `value` is name of SMTP mail server associated with `name`

DNS PROTOCOL MESSAGES

DNS *query* and *reply* messages, both have same *format:*

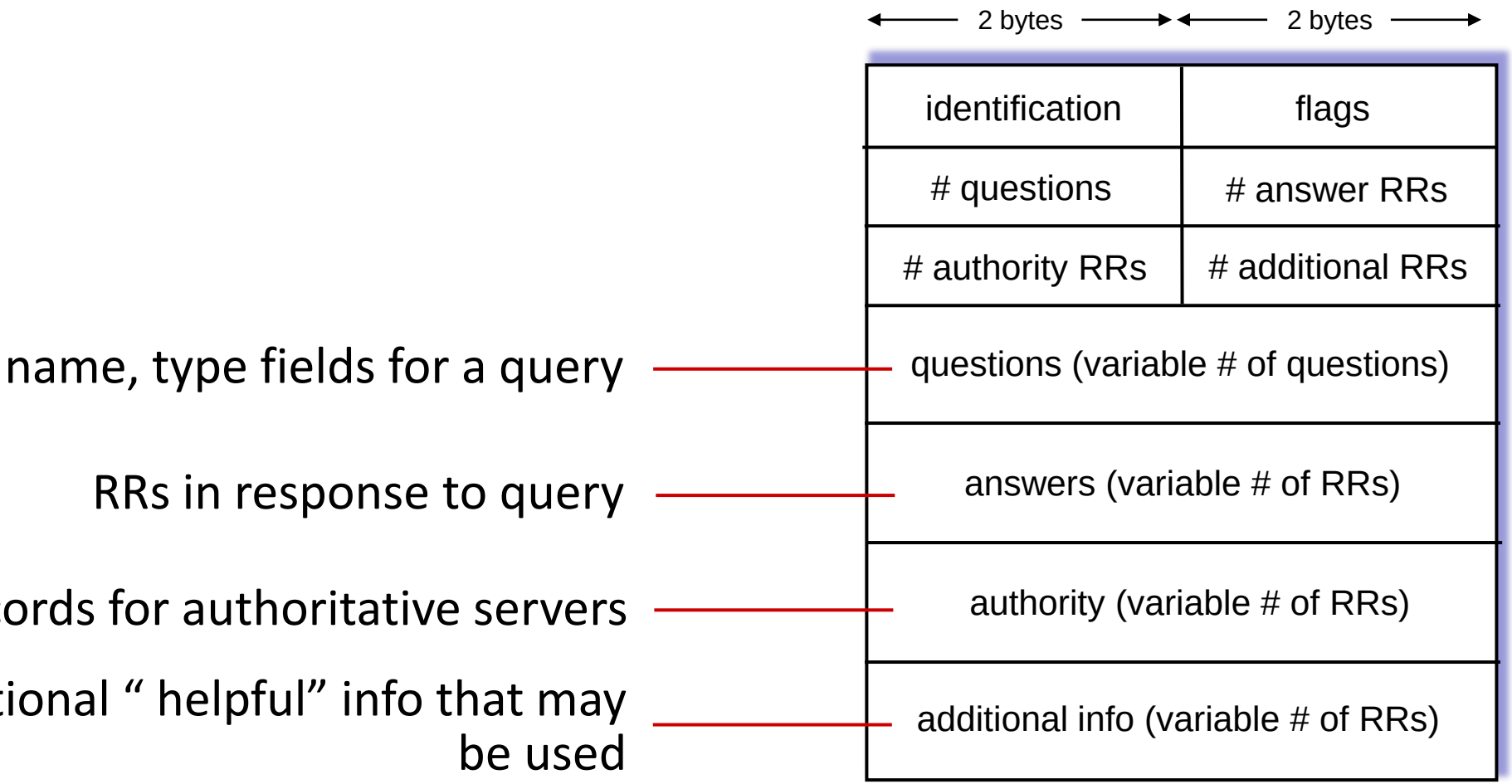
message header:

- identification: 16 bit # for query, reply to query uses same #
- flags:
  - query or reply
  - recursion desired
  - recursion available
  - reply is authoritative



DNS PROTOCOL MESSAGES

DNS *query* and *reply* messages, both have same *format:*



DNS SECURITY

DDoS attacks

- bombard root servers with traffic
  - not successful to date
  - traffic filtering
  - local DNS servers cache IPs of TLD servers, allowing root server bypass
- bombard TLD servers
  - potentially more dangerous

Spoofing attacks

- intercept DNS queries, returning bogus replies
  - DNS cache poisoning
  - RFC 4033: DNSSEC authentication services


NETWORK ADDRESS TRANSLATION (NAT)

IPv4 address

67 . 123 . 45 . 67

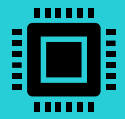
There are 4,294,967,296 public IPv4 addresses available.

wrong

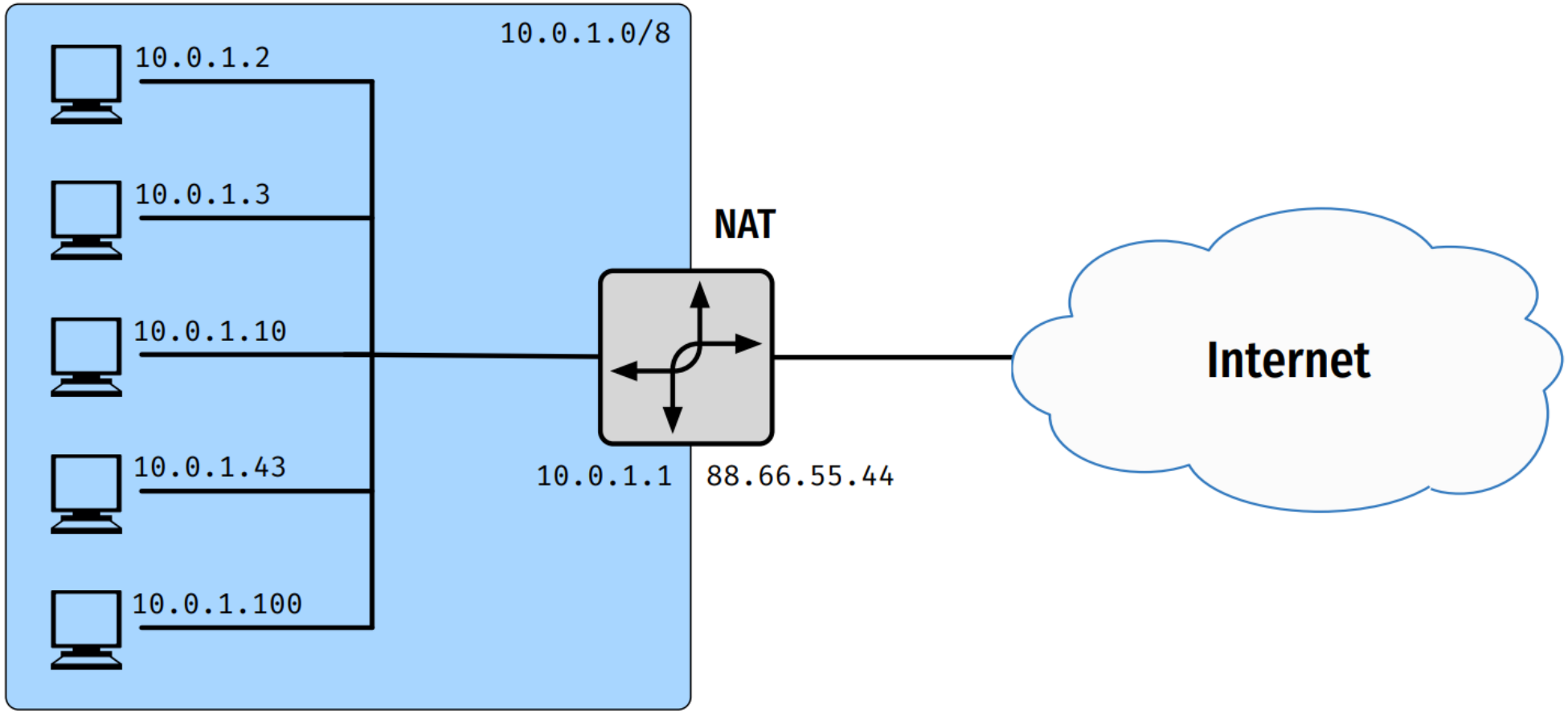
Engineers developed private IP addresses and network address translation (NAT).

NAT

» NAT is a way to map an entire network (or networks) to a single IP address.



» NAT is necessary when the number of IP addresses assigned to you by your Internet Service Provider is less than the total number of computers that you wish to provide Internet access for.


10.0.1.0/8
10.0.1.2
10.0.1.3
10.0.1.10
10.0.1.43
10.0.1.100
NAT
10.0.1.1
88.66.55.44
Internet

IP HEADER TRANSLATORS

- Local network addresses not globally unique, e.g., private IP addresses in 10.0.0.0/8.

NAT rewrites the IP addresses to make the "inside" look like a single IP address (and changes header checksums accordingly).

- » Outbound traffic: rewrite the source IP address.
- » Inbound traffic: rewrite the destination IP address.

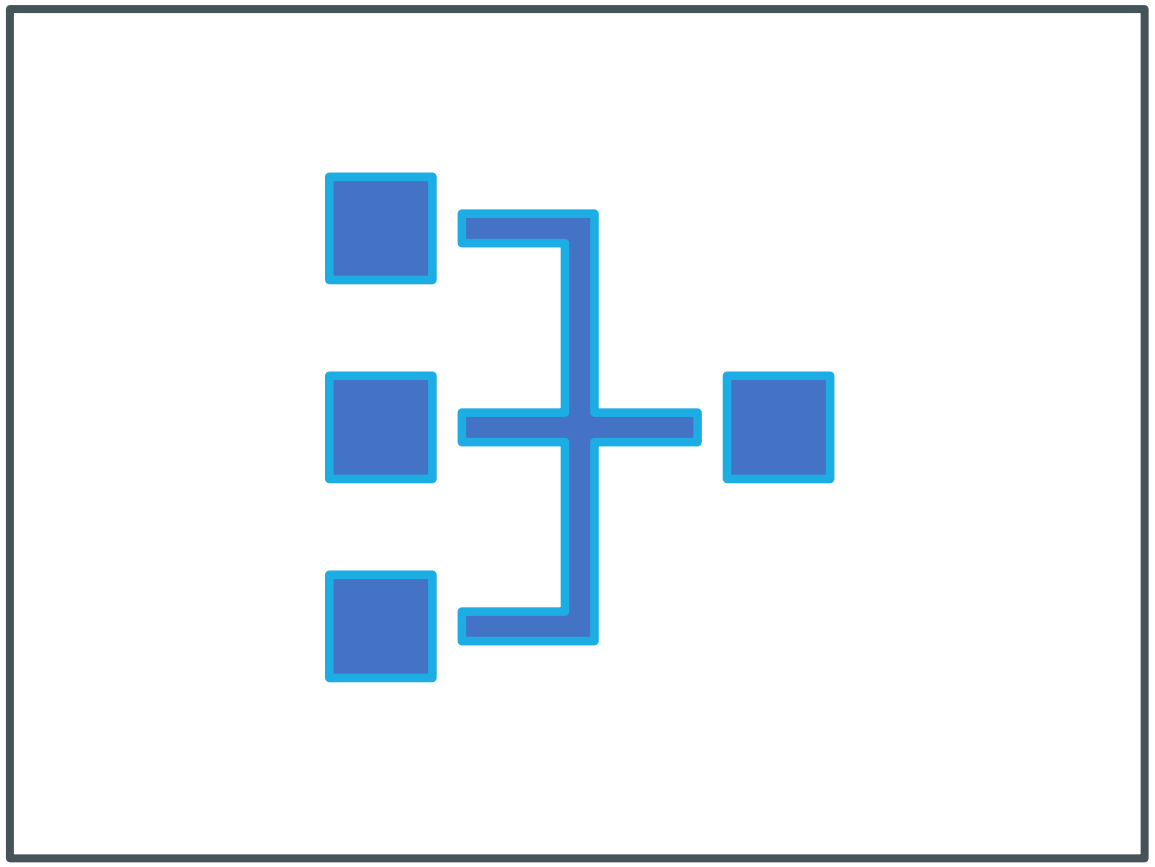
WHAT IF TWO HOSTS CONTACT THE SAME SITE?

- » Suppose hosts contact the same destination, e.g., both hosts open a socket with local port 3345 to destination 128.119.40.186 on port 80.
- » NAT gives packets same source address. All packets have source address 138.76.29.7.
- » Destination cannot differentiate between senders, traffic cannot get back to the correct host.

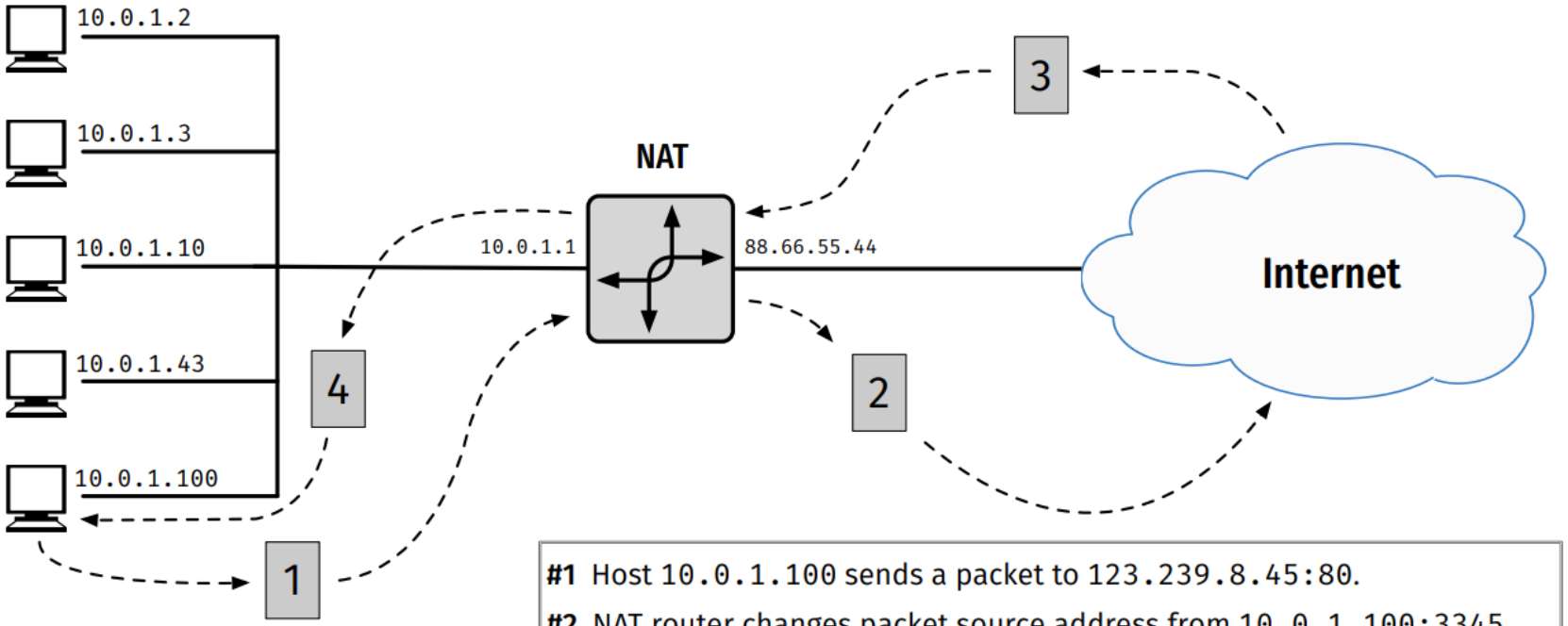
PORT-TRANSLATING NAT

- Map outgoing packets:
  - » Replace source address with NAT address.
  - » Replace source port number with a new port number.
  - » Remote hosts respond using (NAT address, new port #).
- Maintain a translation table:
  - » Store a mapping from (source address, port #) to (NAT address, new port #).

PORT-TRANSLATING NAT



- » Map incoming packets:
- » Consult the translation table.
- » Map the destination address and port number.
- » Local host receives the incoming packet.



#1 Host `10.0.1.100` sends a packet to `123.239.8.45:80`.

#2 NAT router changes packet source address from `10.0.1.100:3345` to `88.66.55.44:5001` and updates the translation table.

#3 Reply arrives with destination address `88.66.55.44:5001`.

#4 NAT router changes packet destination address from `88.66.55.44:5001` to `10.0.1.100:3345`.

Network Address Translation

10.0.0.2

NAT is used in routers.

NAT translates a set of IP addresses to another set of IP addresses.

NAT helps preserve the limited amount of IPv4 public IP addresses.

Two different types of IPv4 addresses.

Public

66 . 94 . 234 . 13

Publicly registered on the internet.

Must have a public IP to access the internet.

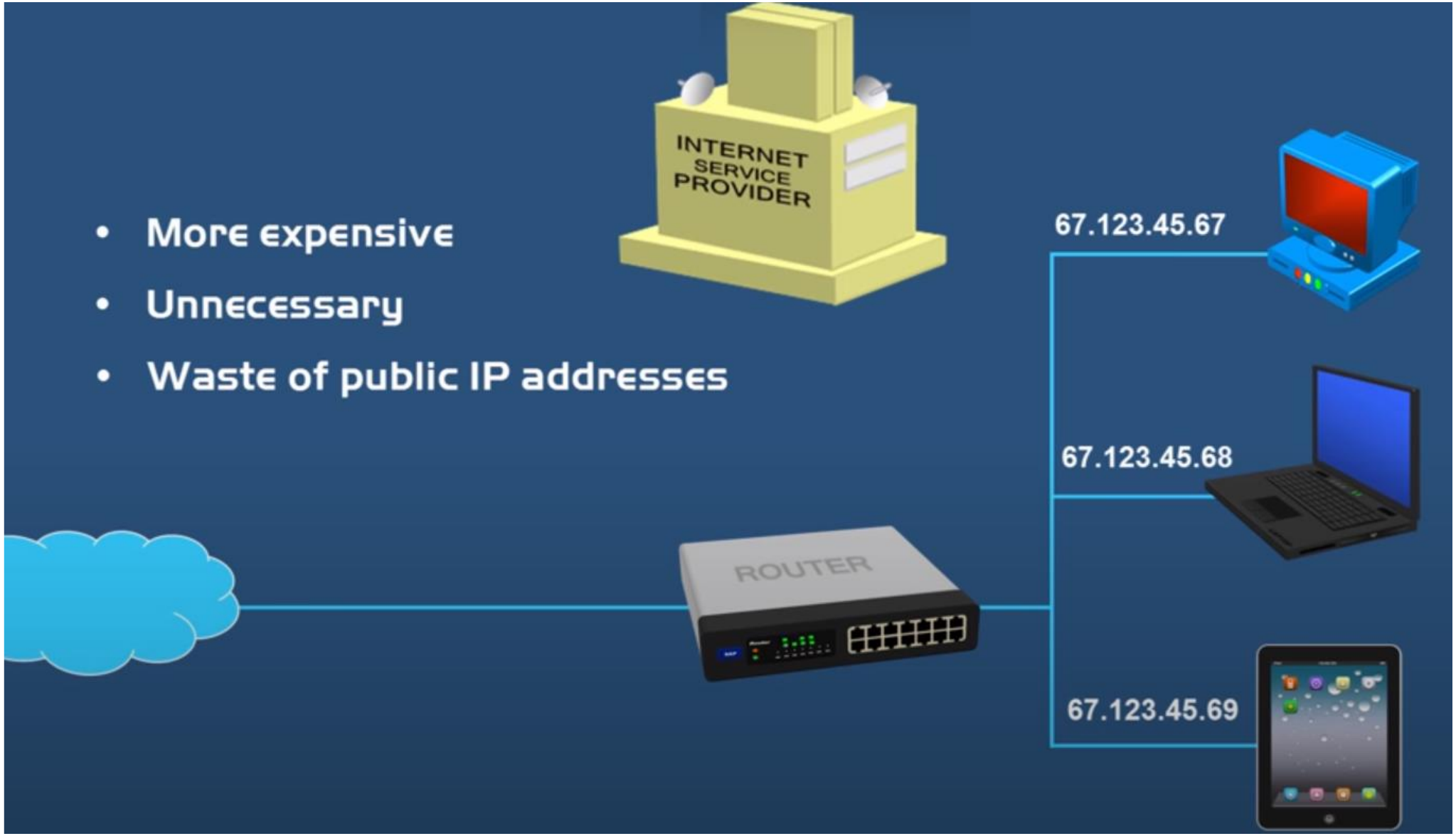
Private

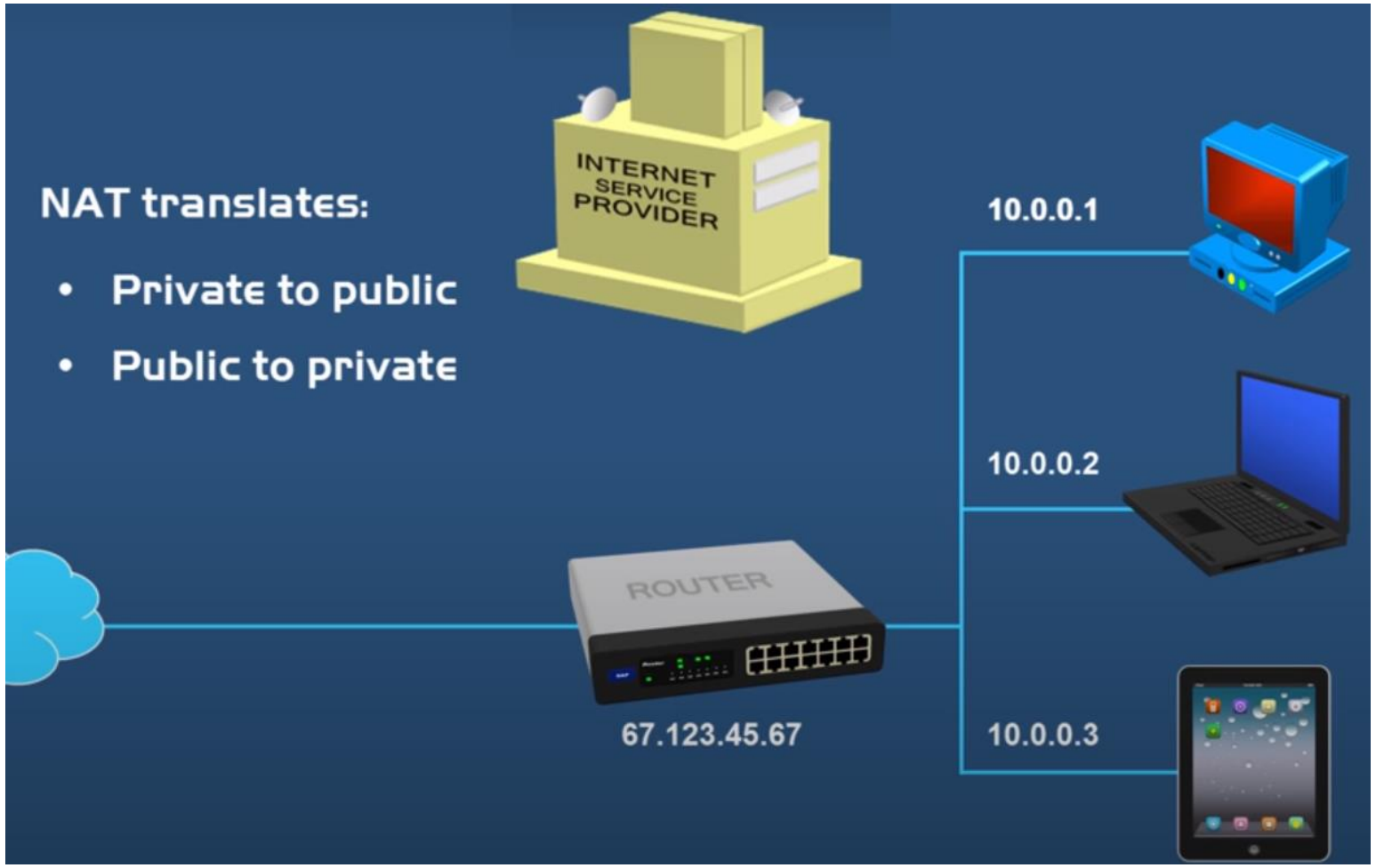
10 . 0 . 0 . 1

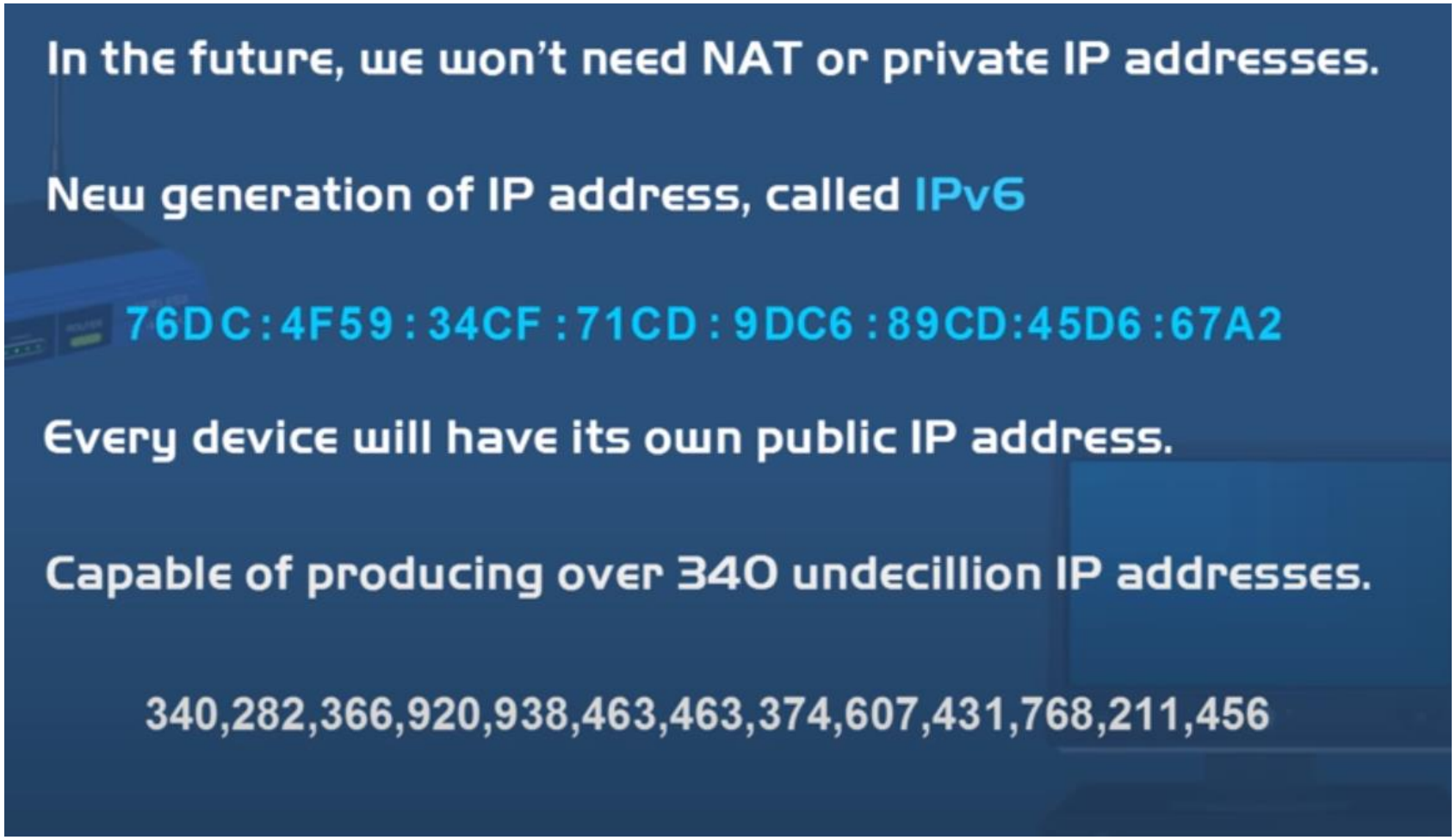
Not publicly registered.

Cannot directly access the internet with a private IP.

Only used internally.


INTERNET SERVICE PROVIDER
• More expensive
• Unnecessary
• Waste of public IP addresses
67.123.45.67
67.123.45.68
67.123.45.69
ROUTER


NAT translates:
• Private to public
• Public to private
INTERNET SERVICE PROVIDER
ROUTER
67.123.45.67
10.0.0.1
10.0.0.2
10.0.0.3


In the future, we won't need NAT or private IP addresses.
New generation of IP address, called IPv6
76DC:4F59:34CF:71CD:9DC6:89CD:45D6:67A2
Every device will have its own public IP address.
Capable of producing over 340 undecillion IP addresses.
340,282,366,920,938,463,463,374,607,431,768,211,456

INTERNET PROTOCOL

(DHCP, ARP, AND ICMP)

MAC ADDRESS VS. IP ADDRESS

- » IP addresses:

» Configured, or learned dynamically.

» Like a postal mailing address.

» Hierarchical name space of 32 bits (e.g., 12.178.66.9).

» Not portable, and depends on where the host is attached.

» Used to get a packet to destination IP subnet

MAC ADDRESS VS. IP ADDRESS

- MAC addresses:

» Hard-coded in read-only memory when adapter is built.

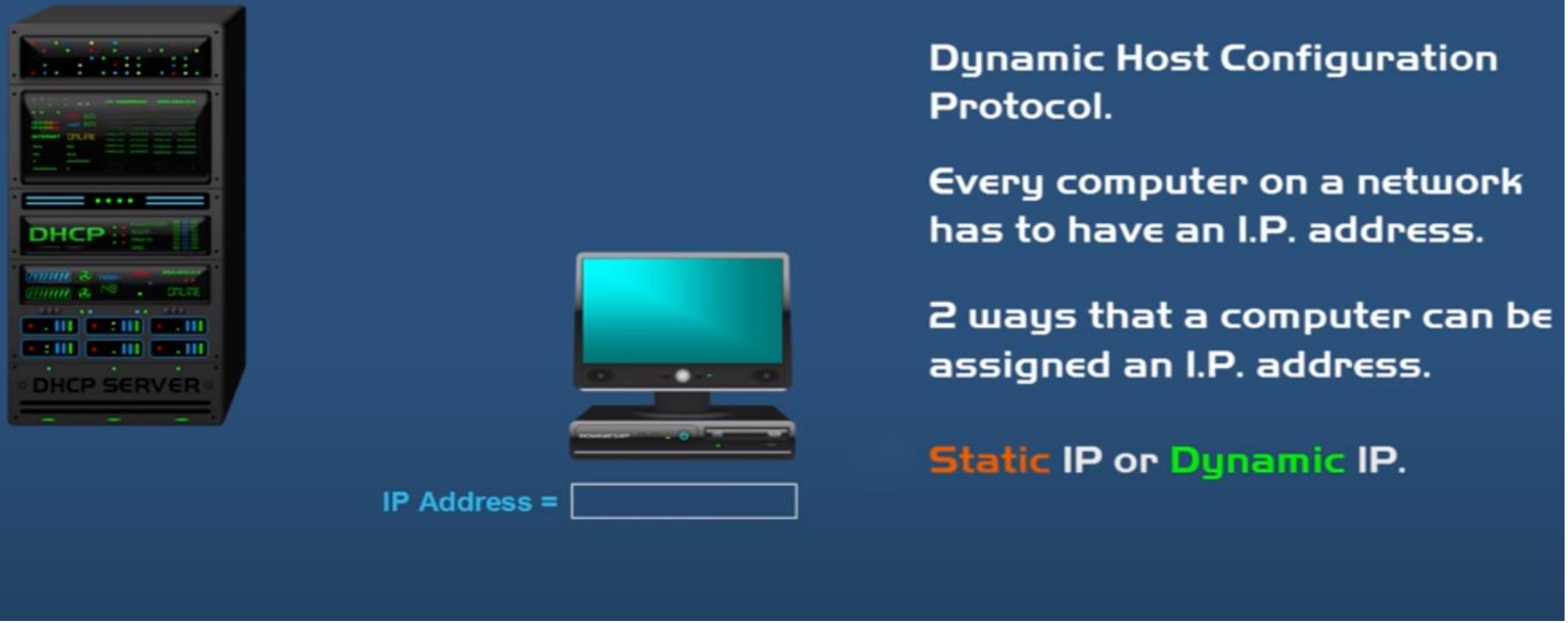
» Like a Swedish "personnummer" (or social security number).

» Flat name space of 48 bits (e.g., 00-0E-9B-6E-49-76).

» Portable, and can stay the same as the host moves.

» Used to get packet between interfaces on same network.

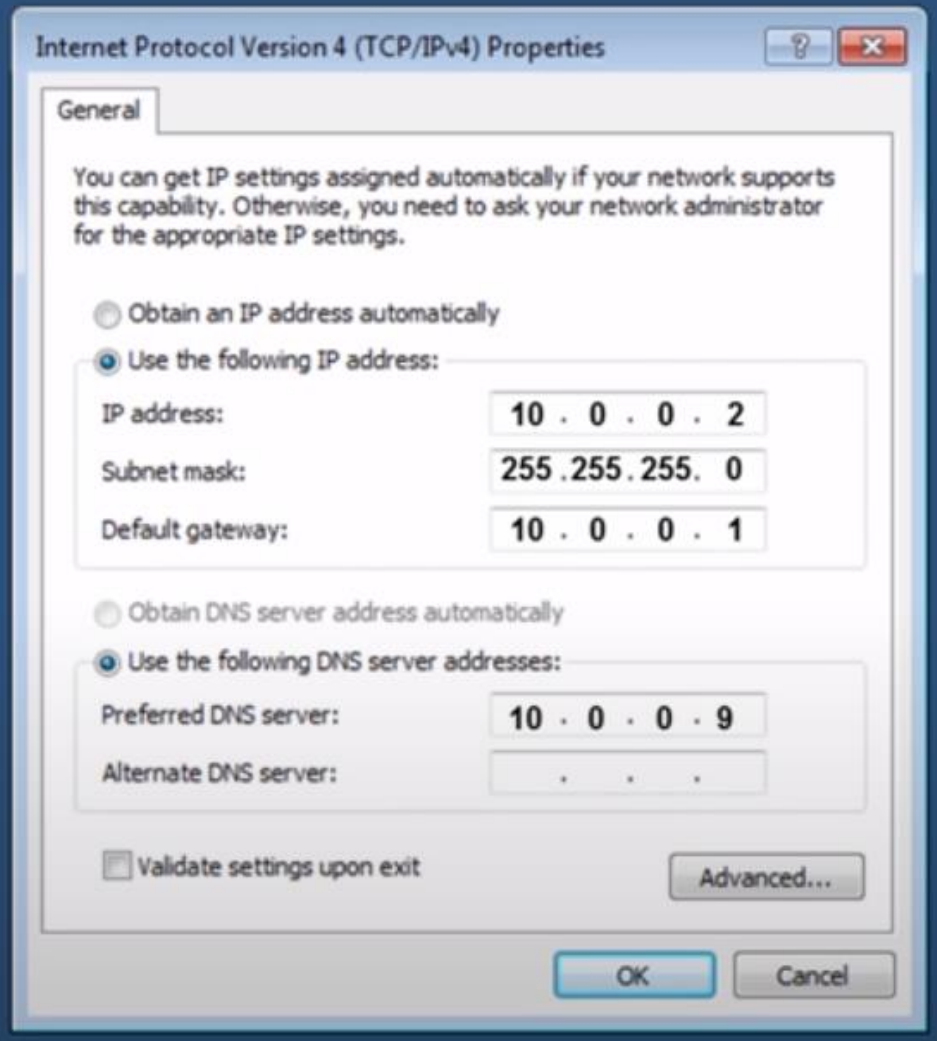
DHCP

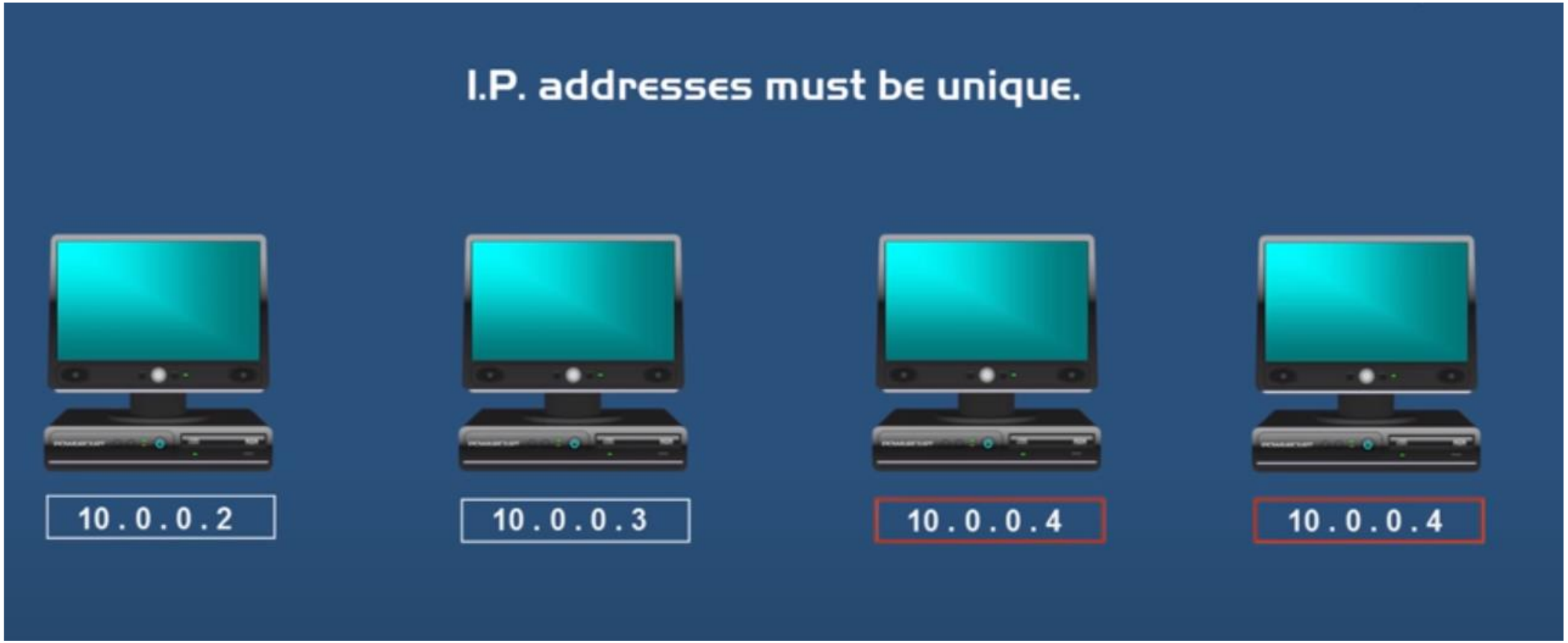

DHCP
DHCP SERVER
IP Address =
Dynamic Host Configuration Protocol.
Every computer on a network has to have an I.P. address.
2 ways that a computer can be assigned an I.P. address.
Static IP or Dynamic IP.

Think about a large network with hundreds of machine to enter static IP on every machine manually, with the condition all the IP addresses must be unique

IP Address = 10 . 0 . 0 . 2

A static IP is where a user assigns an I.P. address manually.

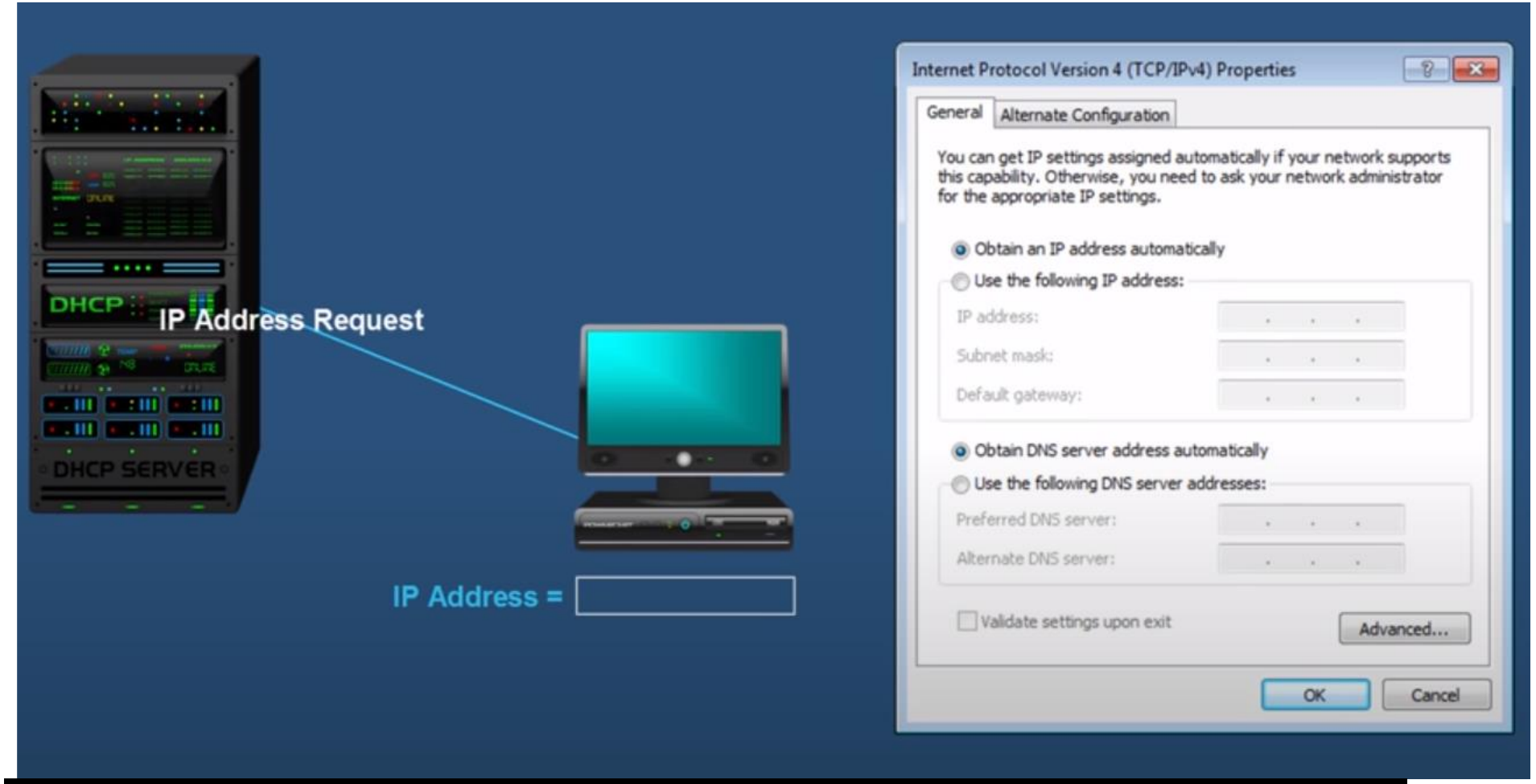



I.P. addresses must be unique.
10 . 0 . 0 . 2
10 . 0 . 0 . 3
10 . 0 . 0 . 4
10 . 0 . 0 . 4

A dynamic IP is where a computer gets an I.P. address from a DHCP server.

A DHCP server automatically assigns a computer an:

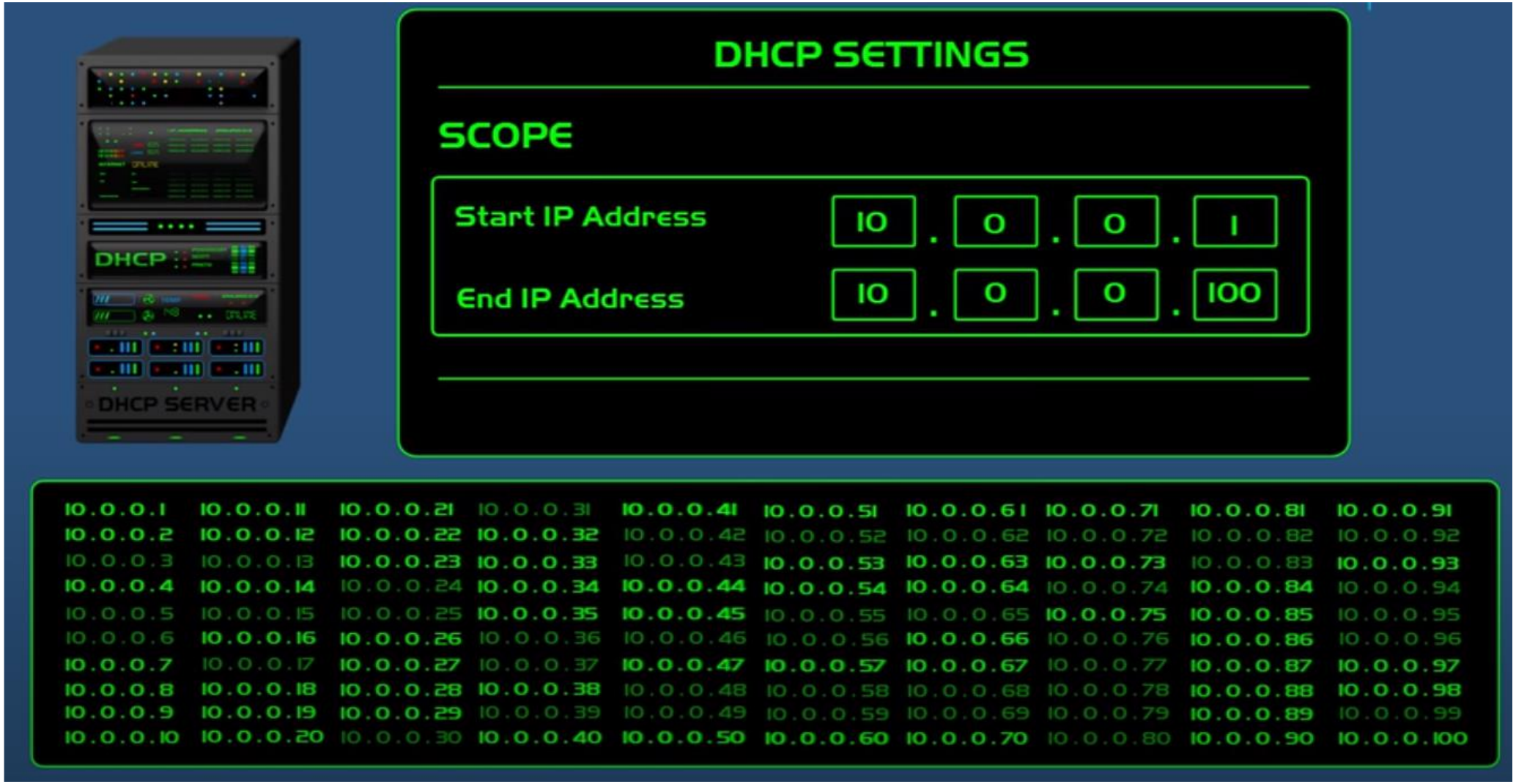
- I.P. address
- Subnet mask
- Default gateway
- DNS server



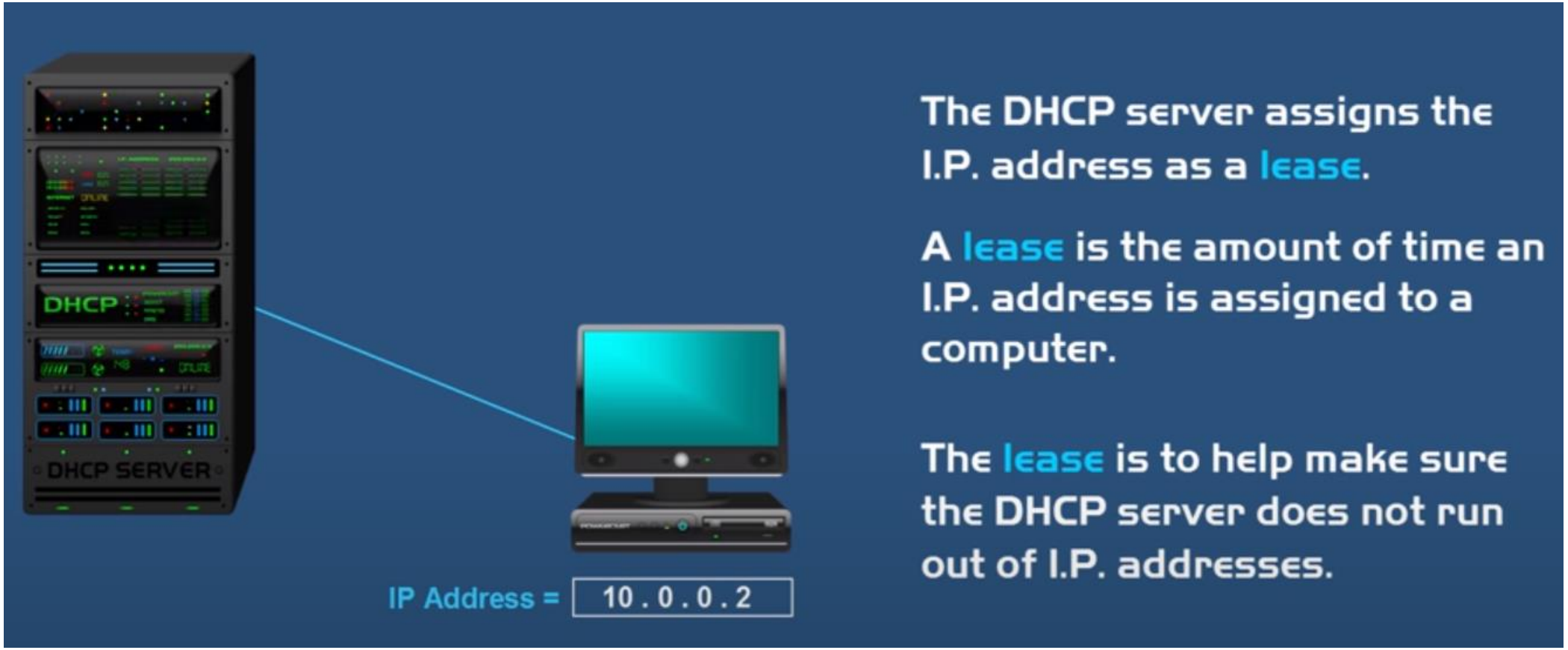
Computer broadcast the request for the IP to DHCP server when dynamics is selected. Then DHCP server assign the IP address to client from the pool of IP addresses

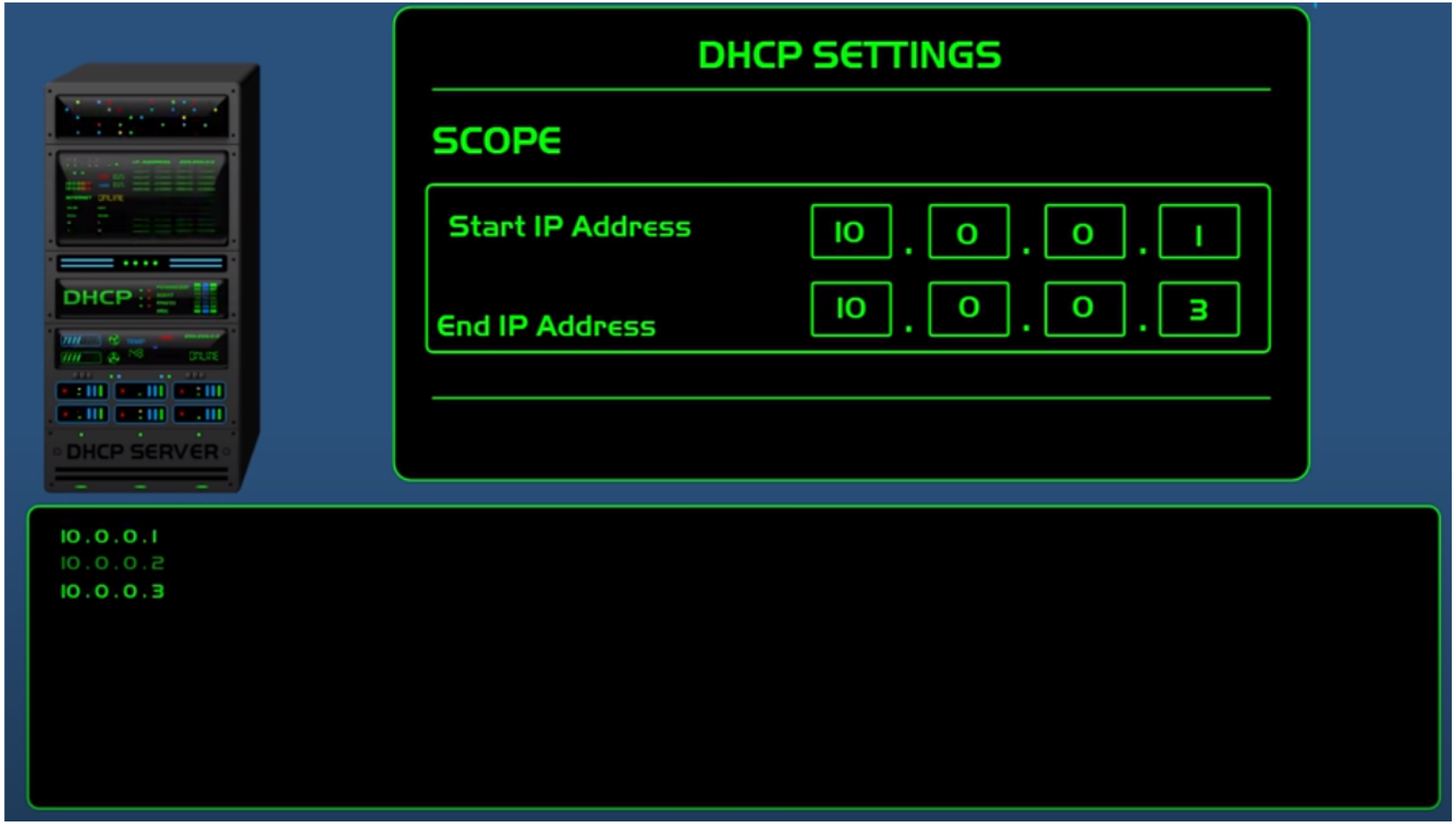
```
  Media State . . . . . . . . . . . : Media disconnected
  Connection-specific DNS Suffix  . :
  Description . . . . . . . . . . . : Microsoft Wi-Fi Direct Virtual Adapter #2
  Physical Address. . . . . . . . . : D6-6D-6D-[redacted]-CB-47
  DHCP Enabled. . . . . . . . . . . : Yes
  Autoconfiguration Enabled . . . . : Yes

ireless LAN adapter Wi-Fi:

  Connection-specific DNS Suffix  . : client.lnu.se
  Description . . . . . . . . . . . : Killer(R) Wireless-AC 1550i Wireless Network Adapter (9560NGW)
  Physical Address. . . . . . . . . : D4-6D-6D-[redacted]-47
  DHCP Enabled. . . . . . . . . . . : Yes
  Autoconfiguration Enabled . . . . : Yes
  Link-local IPv6 Address . . . . . : fe80::104a:[redacted]e9:7190:e265%8(Preferred)
  IPv4 Address. . . . . . . . . . . : 172.26.[redacted].148(Preferred)
  Subnet Mask . . . . . . . . . . . : 255.255.240.0
  Lease Obtained. . . . . . . . . . : Tuesday, February 2, 2021 3:44:02 PM
  Lease Expires . . . . . . . . . . : Sunday, February 7, 2021 6:23:03 PM
  Default Gateway . . . . . . . . . : 172.26.128.1
  DHCP Server . . . . . . . . . . . : 172.25.8.56
  DHCPv6 IAID . . . . . . . . . . . : 131362157
  DHCPv6 Client DUID. . . . . . . . : 00-01-00-01-26-E8-[redacted]-99-D8-C4-97-BE-E0-38
  DNS Servers . . . . . . . . . . . : 194.47.199.143
                                      194.47.199.142
  NetBIOS over Tcpip. . . . . . . . : Enabled
  Connection-specific DNS Suffix Search List :
                                      lnu.se
```

ipconfig/all

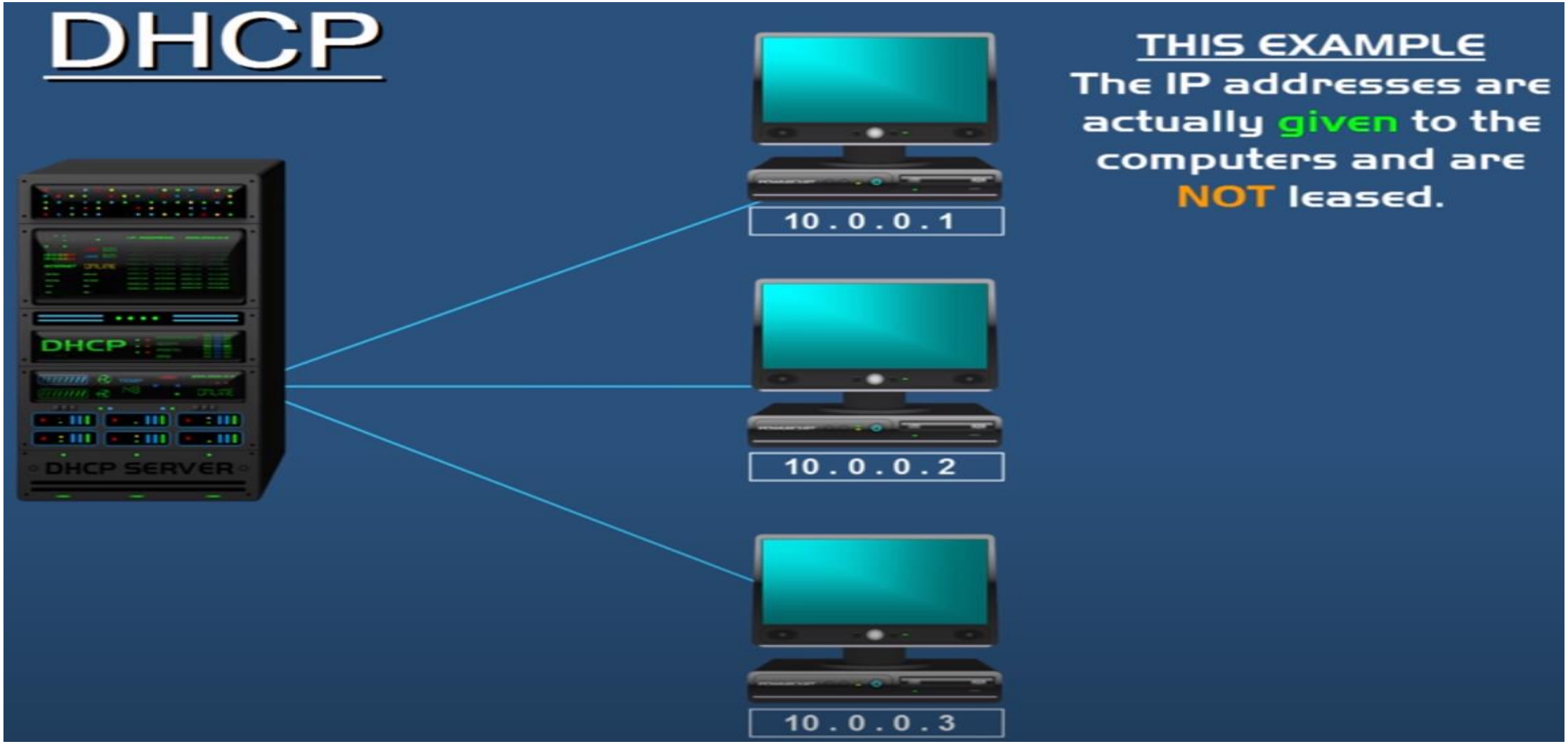


DHCP server assigns the IP to the client from the POOL like here its 1 to 100, this pool is customizable

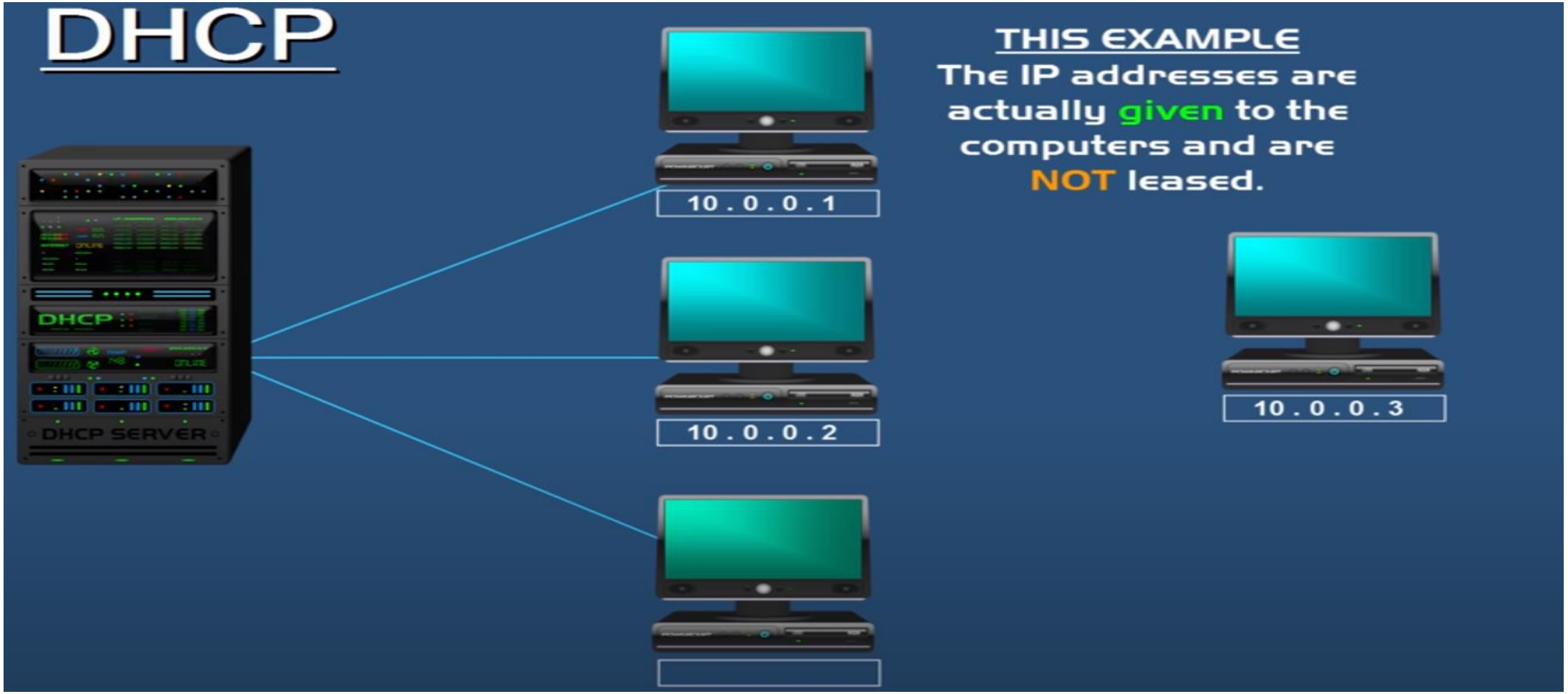

DHCP
DHCP SERVER
IP Address = 10 . 0 . 0 . 2
The DHCP server assigns the I.P. address as a lease.
A lease is the amount of time an I.P. address is assigned to a computer.
The lease is to help make sure the DHCP server does not run out of I.P. addresses.



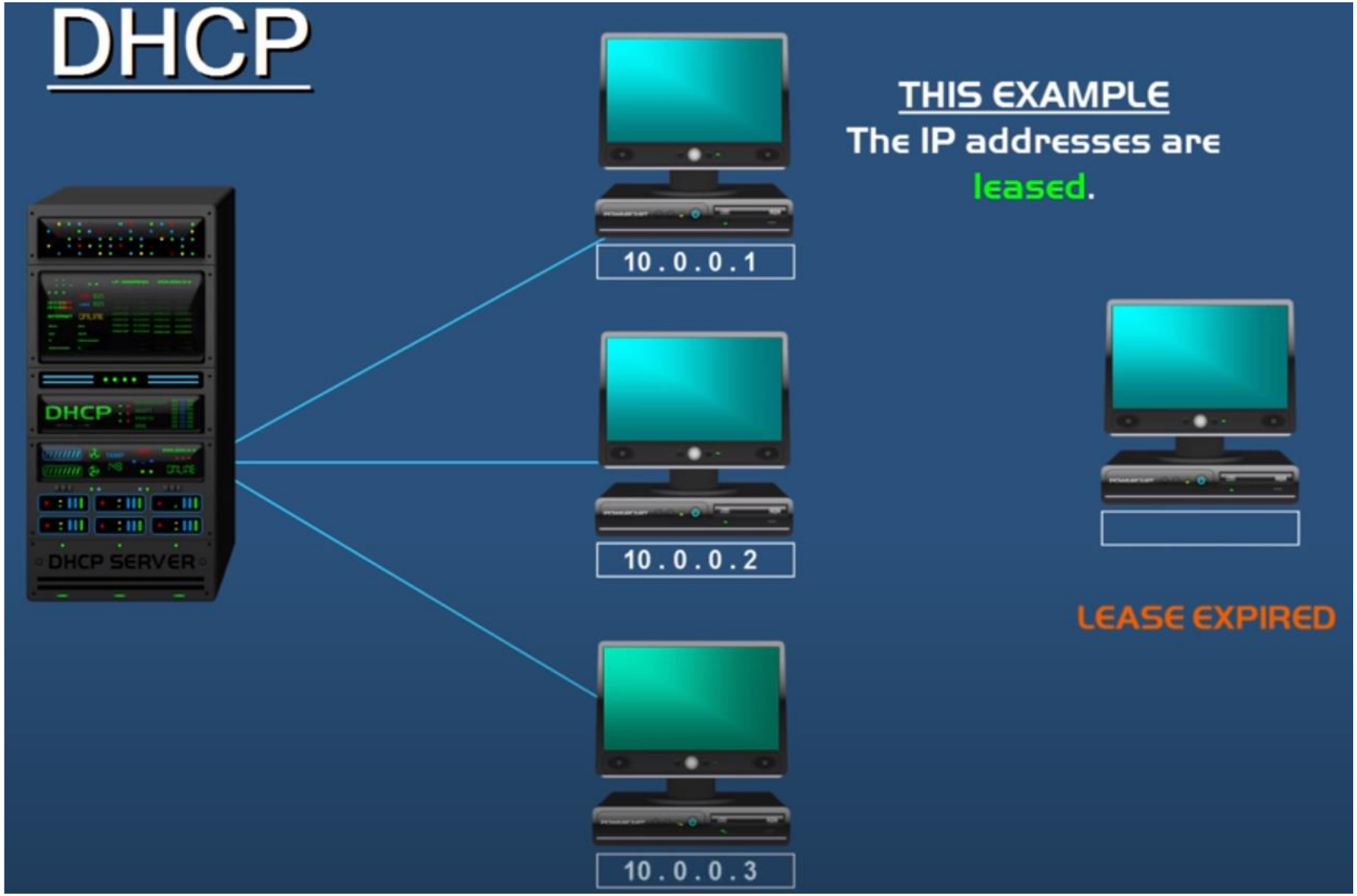
Example. Just three IP addresses DHCP have in the pool.



Where we allotted the IP to the computer instead of lease



No one computer left the network , not using IP anymore. So new machine want to use it ! But how ? As the IP was given to previously connected machine. So the best solution is lease


DHCP
THIS EXAMPLE
The IP addresses are
leased.
DHCP
DHCP SERVER
10 . 0 . 0 . 1
10 . 0 . 0 . 2
10 . 0 . 0 . 3
LEASE EXPIRED

DHCP SETTINGS

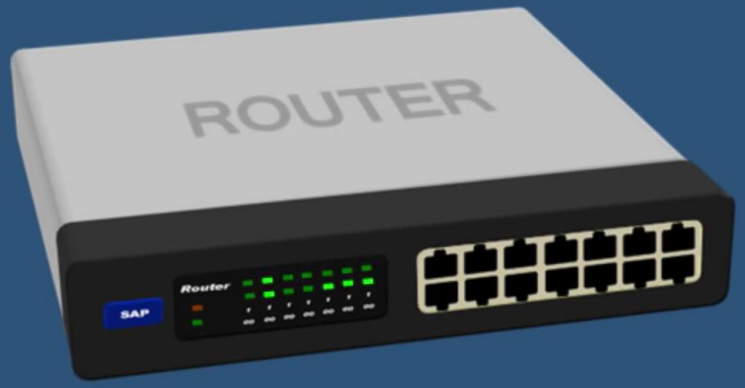
ADDRESS RESERVATION

IP Address	Device Name	MAC Address
10 . 0 . 0 . 1	MY-PC	00:17:30:46:72:04

A reservation ensures that a specific computer or device will always be given the same I.P. address.

DHCP

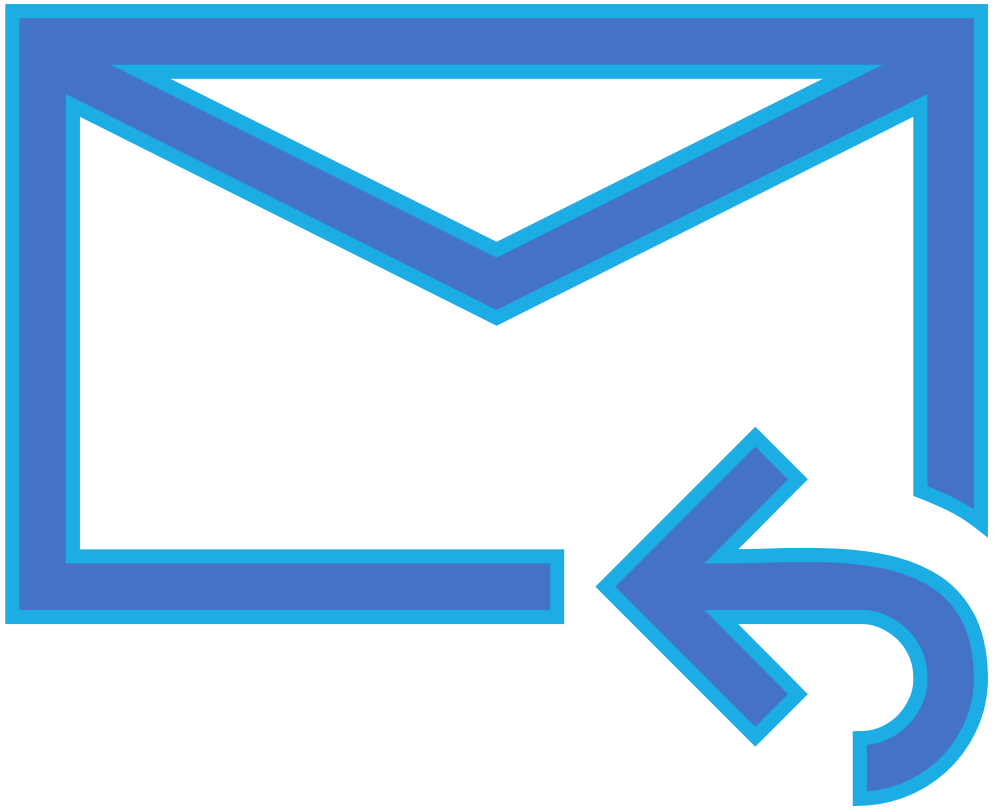
Reservations are typically given to special devices or computers, such as network printers, servers, routers, etc.



DHCP is a service that runs on a server, such as a Microsoft server or a Linux server.

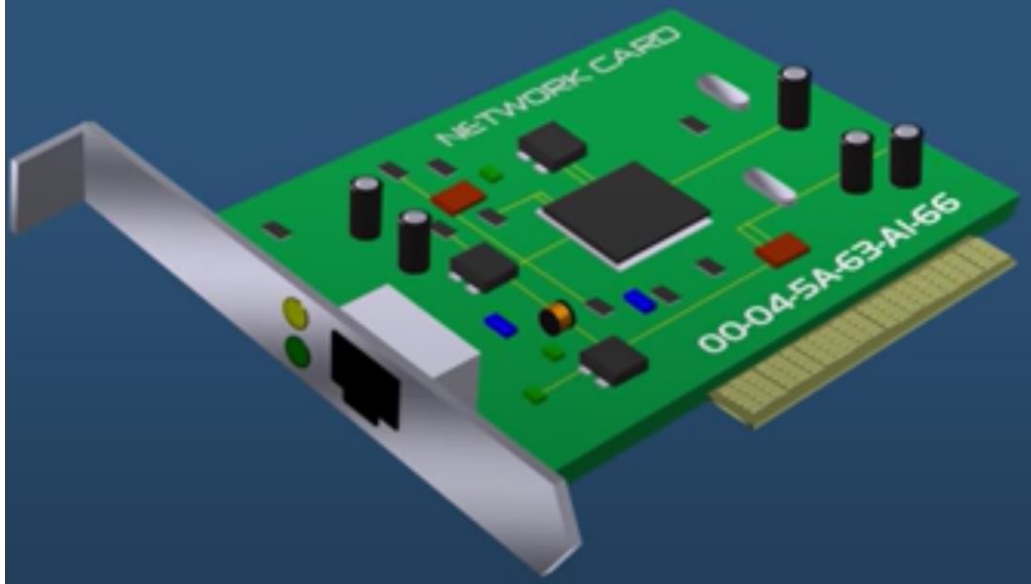
It's also a service that runs on routers.

ADDRESS RESOLUTION PROTOCOL



Address Resolution Protocol

Used to resolve IP addresses to MAC addresses.

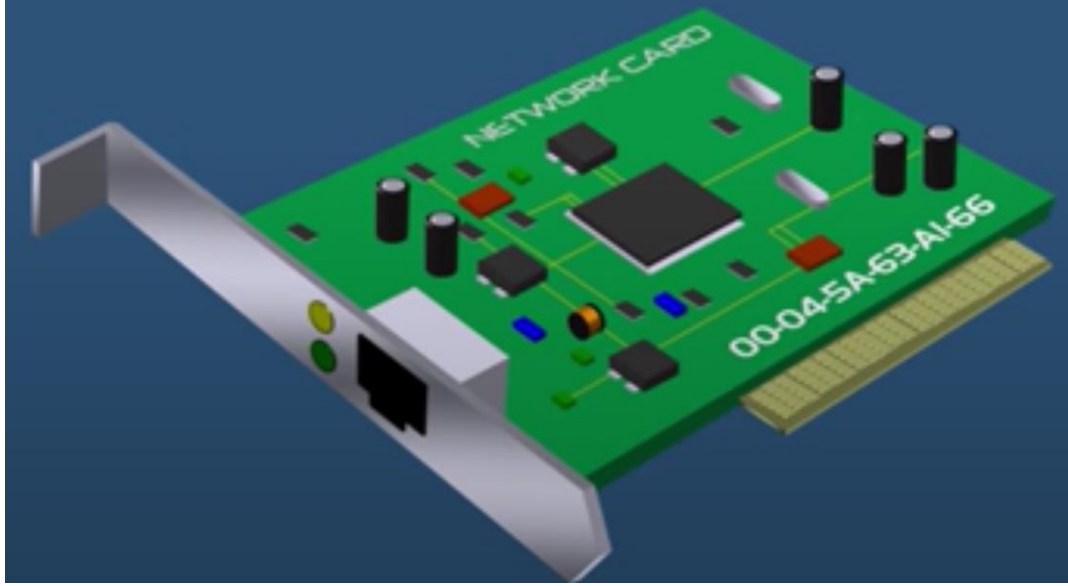


The MAC address is the physical address of the device.

00-04-5A-63-AI-66

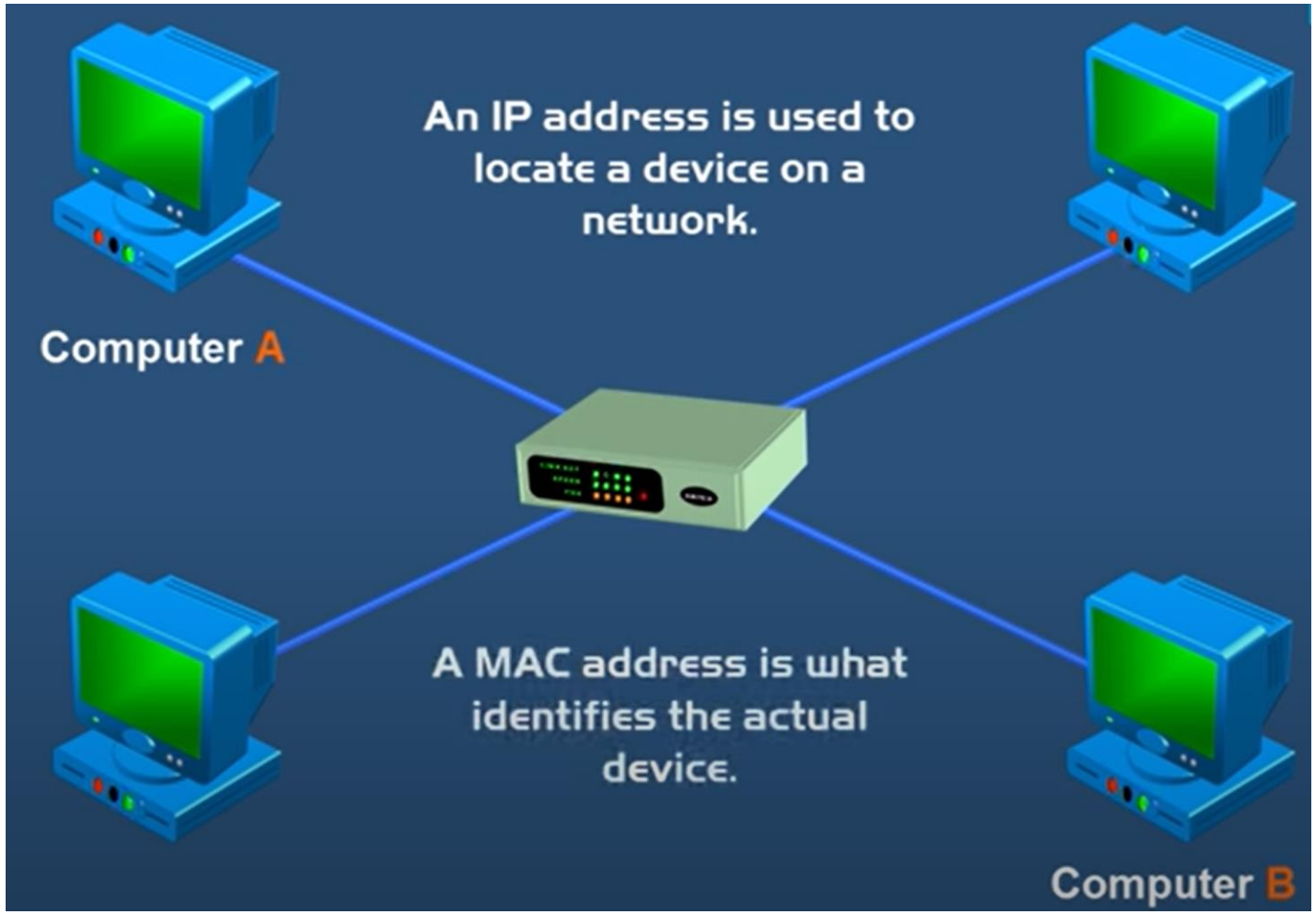
Address Resolution Protocol

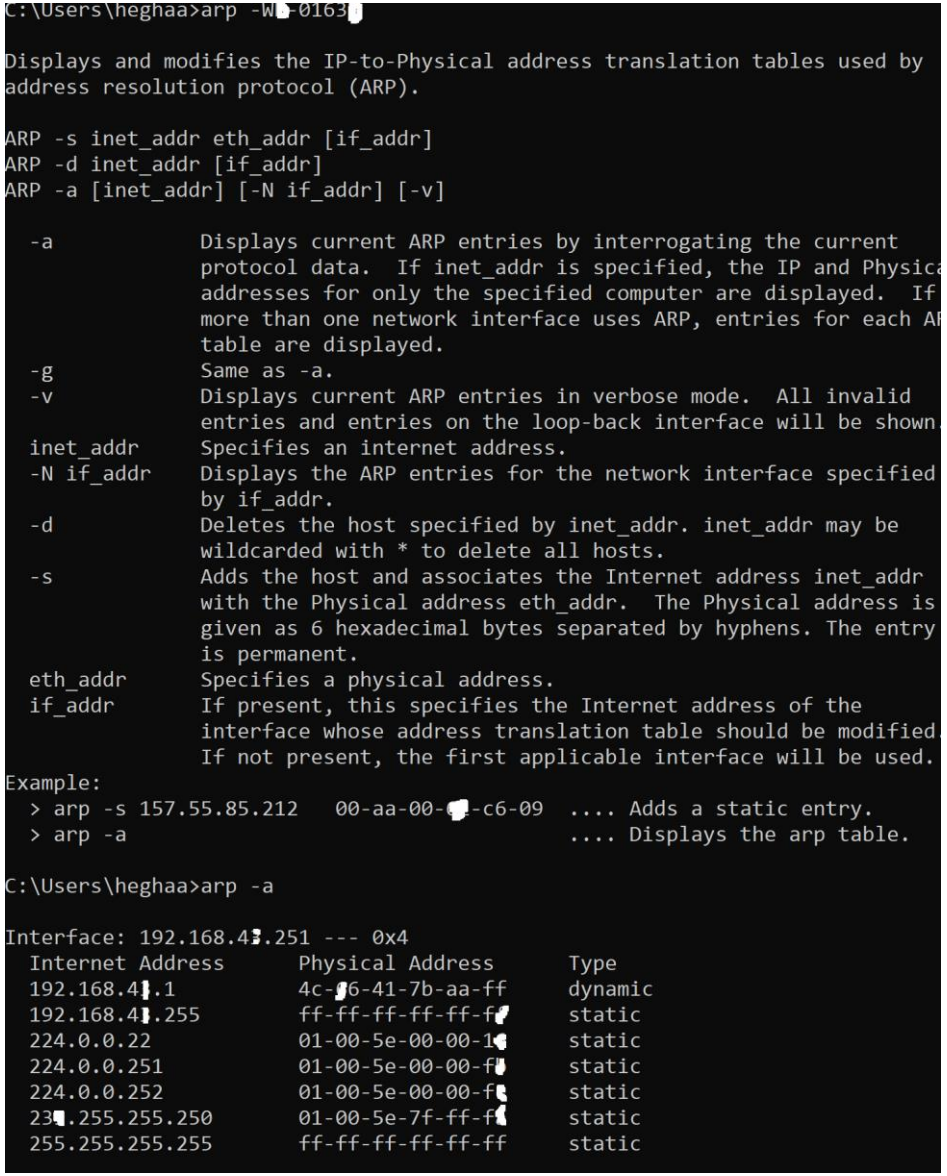
Used to resolve IP addresses to MAC addresses.



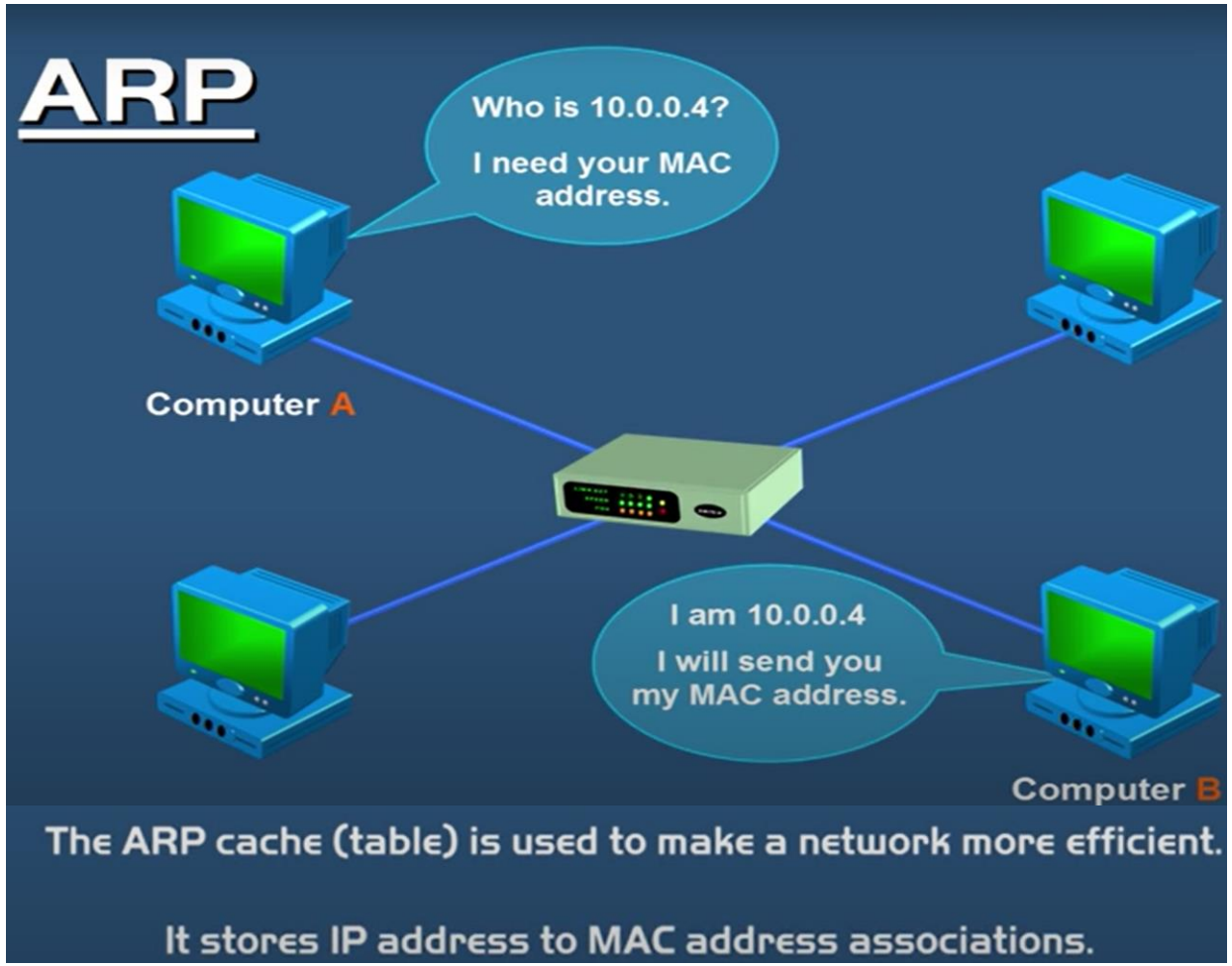
Devices need the MAC address for communication on a local area network.

Devices use ARP to acquire the MAC address for a device.


An IP address is used to locate a device on a network.
Computer A
A MAC address is what identifies the actual device.
Computer B


C:\Users\heghaa>arp -w
Displays and modifies the IP-to-Physical address translation tables used by
address resolution protocol (ARP).
ARP -s inet_addr eth_addr [if_addr]
ARP -d inet_addr [if_addr]
ARP -a [inet_addr] [-N if_addr] [-v]
-a Displays current ARP entries by interrogating the current
-g Same as -a.
-v Displays current ARP entries in verbose mode. All invalid
inet_addr Specifies an internet address.
-N if_addr Displays the ARP entries for the network interface specified
-d Deletes the host specified by inet_addr. inet_addr may be
-s Adds the host and associates the Internet address inet_addr
eth_addr Specifies a physical address.
if_addr If present, this specifies the Internet address of the
Example:
> arp -s 157.55.85.212 00-aa-00-
> arp -a .... Displays the arp table.
C:\Users\heghaa>arp -a
Interface: 192.168.4
Internet Address Physical Address Type
192.168.4 .1 4c- 6-41-7b-aa-ff dynamic
192.168.4 .255 ff-ff-ff-ff-ff- static
224.0.0.22 01-00-5e-00-00- static
224.0.0.251 01-00-5e-00-00- static
224.0.0.252 01-00-5e-00-00- static
23 .255.255.250 01-00-5e-7f-ff- static
255.255.255.255 ff-ff-ff-ff-ff-ff static

Broadcasting Of The IP To Know The MAC



2 different types of ARP entries: Dynamic and Static

A dynamic entry is created automatically when a device sends out a broadcast message out on the network.

Dynamic entries are not permanent. They are flushed out periodically.

A static entry is where someone manually enters an IP to MAC address association using the ARP command line utility.

Static entries are often used to reduce any unnecessary ARP broadcast traffic on a network.

FILE TRANSFER PROTOCOL (FTP)

- The file is a fundamental storage abstraction. The file transfer protocol (and program) is used to copy files between computers under TCP/IP.
  - » Transfer any type of data, including documents, images, music, or stored video.
  - » Download files (transfer from server to client) or upload files (transfer from client to the server).
  - » Allows each file to have ownership and access restrictions and honors the restrictions.
  - » Allows a client to obtain the contents of a directory (i.e., a folder).

FILE TRANSFER PROTOCOL (FTP)

» The control messages exchanged between an FTP client and server are sent as ASCII text.

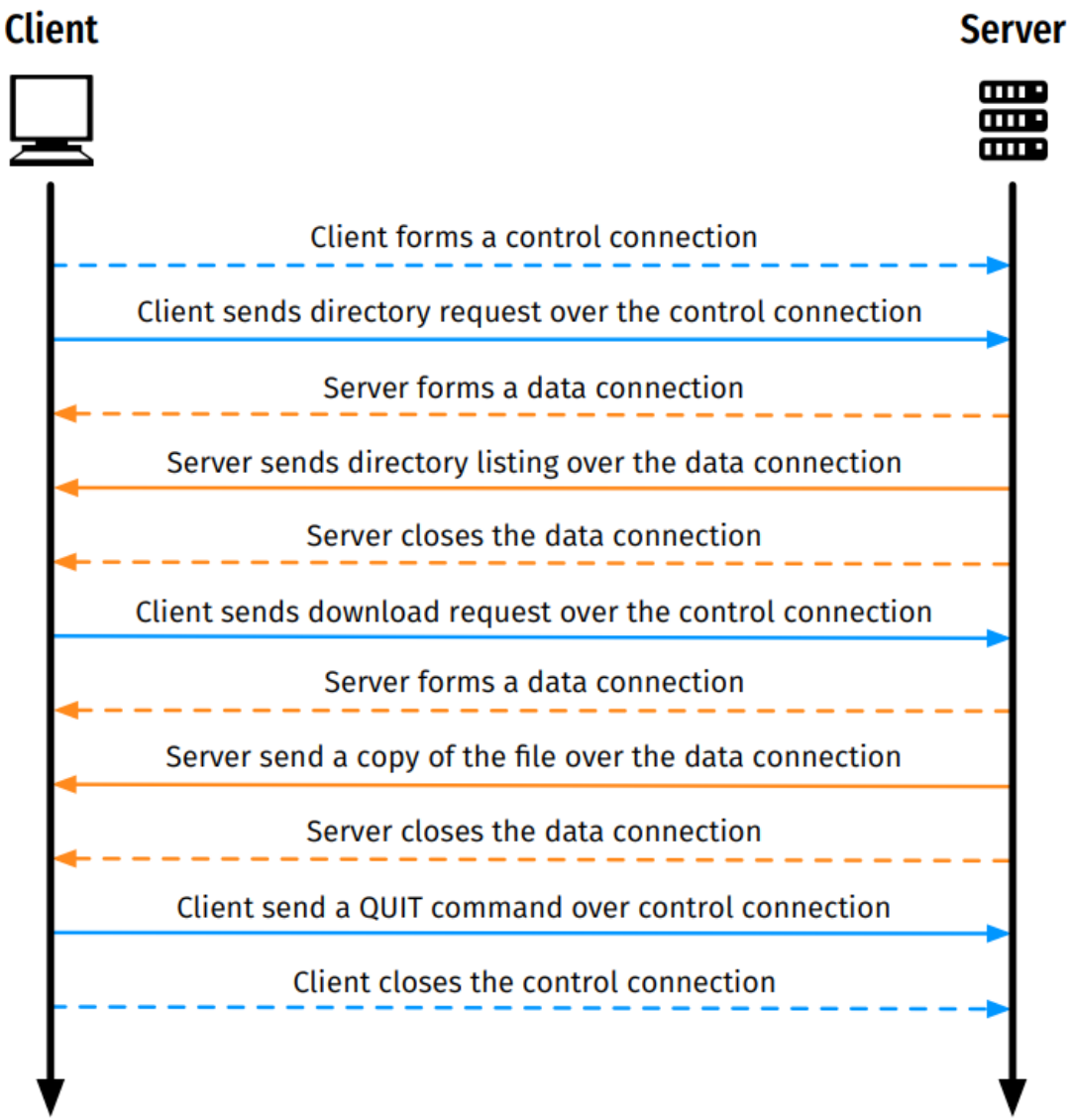
» FTP hides the details of individual computer operating systems, and can transfer a copy of a file between an arbitrary pair of computers.

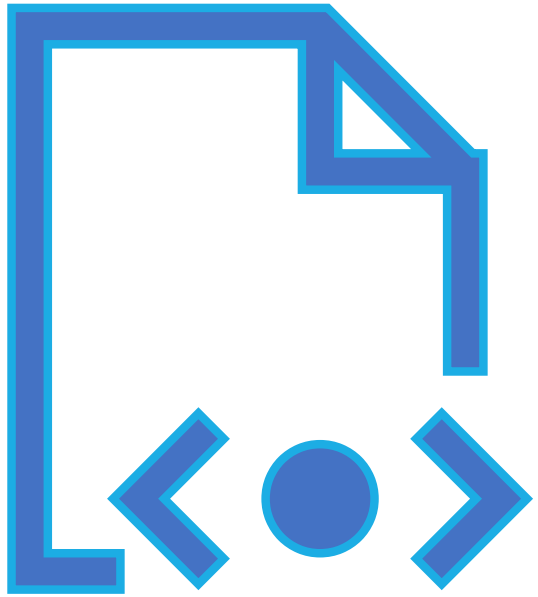
FTP COMMUNICATION PARADIGM

- » An FTP server does not send responses over the same connection on which the client sends requests.
- » Instead, the connection that the client creates, called a control connection, is reserved for commands.
- » Each time the server needs to download or upload a file, the server (not the client) opens a new connection. To distinguish them from the control connection, the connections used to transfer files are called data connections.

FTP COMMUNICATION PARADIGM

- » When opening a data connection, the client acts like a server (i.e., waits for the data connection) and the server acts like a client (i.e., initiates the data connection).
- » After it has been used for one transfer, the data connection is closed. If the client sends another request, the server opens a new data connection.


Client
Server
Client forms a control connection
Client sends directory request over the control connection
Server forms a data connection
Server sends directory listing over the data connection
Server closes the data connection
Client sends download request over the control connection
Server forms a data connection
Server send a copy of the file over the data connection
Server closes the data connection
Client send a QUIT command over control connection
Client closes the control connection



HYPERTEXT TRANSFER PROTOCOL (HTTP)

MAIN COMPONENTS: HTML

- » HyperText Markup Language (HTML)
  - » Representation of hyptertext documents in ASCII format.
  - » Format text, reference images, embed hyperlinks.
  - » Interpreted by Web browsers when rendering a page.

- » Web page
  - » Base HTML file referenced objects (e.g., images).
  - » Each object has its own URL.

READING INSTRUCTIONS

» CH. 4: ALL » CH. 23: ALL

REFERENCES

- https://www.net.t-labs.tu-berlin.de/teaching/computer_networking
- https://techterms.in/
- https://www.youtube.com/channel/UCJQJ4GjTiq5lmn8czf8oo0Q
- http://www.whatis.com
- http://www.webopedia.com
- Understanding Data Communications & Networks, Shay (1999)
- http://www.daemon.org/ip.html