# Assignments

- Nick is grading your assignments and they will be returned to you on Monday in class.

# HPC Networks


# ARPANET

- On October 4, 1957, the Soviet Union (USSR) launched the first satellite ever, shocking the United States. This was a major victory for the Soviets in the cold war.
- In response the US founded ARPA (Advanced Research Projects Agency) in February of the following year.
- ARPA's mission was transformational technologies (like the first space satellite).
- Periodically US Presidents add or subtract Defense from the front (DARPA).

# ARPANET

- In the early 60s Licklider's idea was that everyone could benefit from a computer assistant.

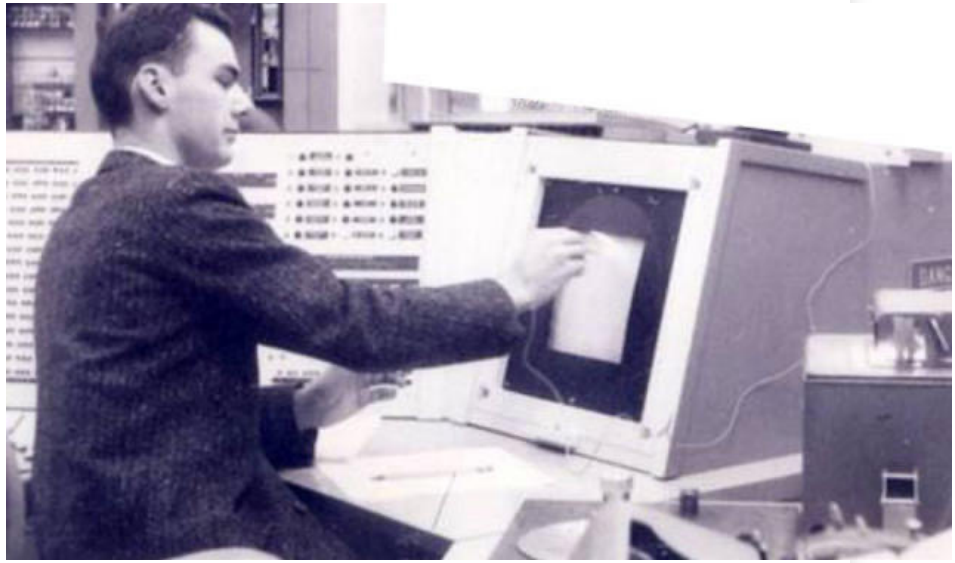
His consisted of:

1. Computer Science Departments
2. Graphics
3. Artificial Intelligence
4. Timesharing computers
5. Networking

Bob Taylor (Psychology and CS)

Leonard Kleinrock (UCLA Prof CS)

Joseph Licklider (Psychology and CS)



Larry Roberts

# ARPANET

- After Sputnik a major concern for the US Military was that a circuit-switching telephone network could be interrupted by destroying the exchanges.
- Licklider's solution was what he called the Intergalactic Computer Network (ICGN) (in a 1963 memo) coupled with the packet switching network described in Leonard Kleinrock's PhD dissertation.
- The idea was that computers could communicate by breaking down messages into fragments.
- Each fragment would find its own path to the destination independently.
- This would be harder to interrupt.
- Circuit switching dedicates a hardware line between sender and receiver.

Joseph Licklider (Psychology and CS)

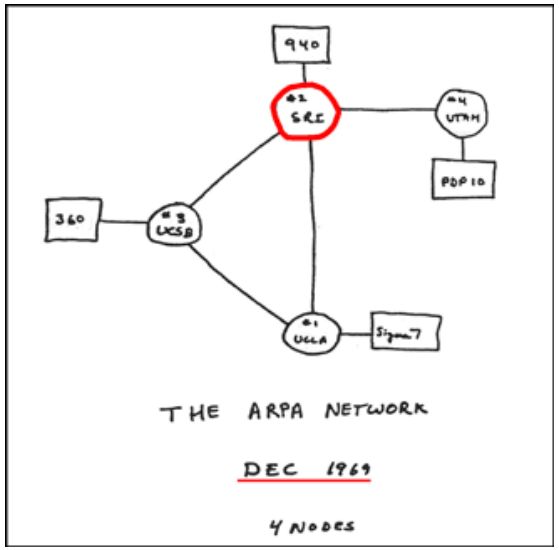
# ARPANET

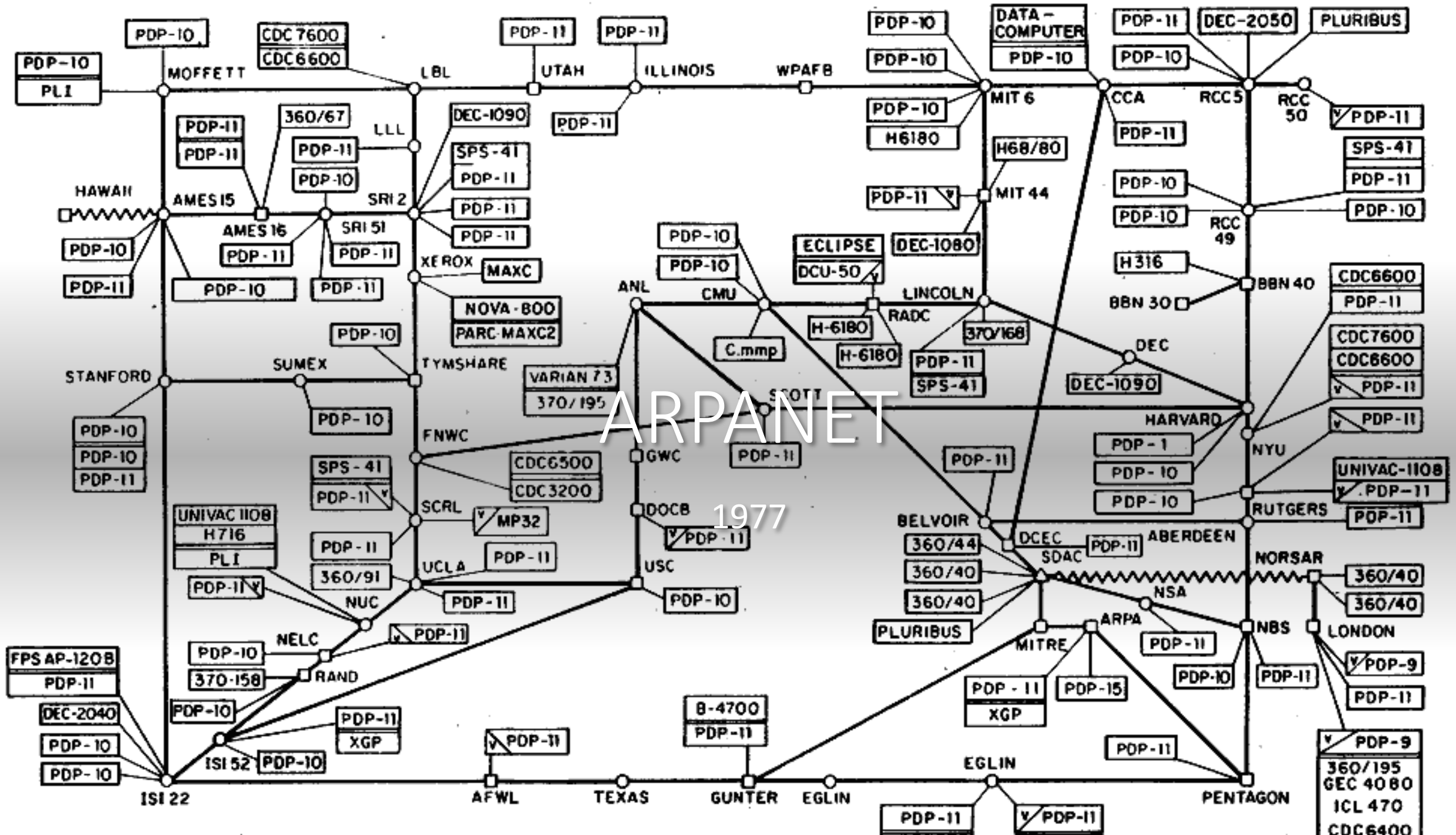
- 1969; "As of now, computer networks are still in their infancy. But as they grow up and become more sophisticated, we will probably see the spread of 'computer utilities,' which, like present electric and telephone utilities, will service individual homes and offices across the country."
- 1999: "What I did not conceive of then was that my 92-year-old mother would be using the Internet today."

Leonard Kleinrock (UCLA Prof CS)

# ARPANET

- ARPANet connected 4 computers in 1969
- University of California Los Angeles (UCLA)
  - Network Monitoring.
- Stanford Research Institute (SRI)
  - Doug Engelbart's Human Intellect Augmentation System.
- University of California Santa Barbara
  - Interactive graphics.
- University of Utah
  - Advanced 3D graphics.





ARPANET
1977
MOFFETT
LBL
UTAH
ILLINOIS
WPAFB
MIT 6
CCA
RCC 5
RCC 50
MIT 44
RCC 49
HAWAII
AMES 15
AMES 16
SRI 2
SRI 51
XEROX
MAXC
NOVA-800
PARC-MAXC2
LLL
ANL
CMU
ECLIPSE
DCU-50
DEC-1080
LINCOLN
RADC
H-6180
370/168
C.mmp
VARIAN 73
370/195
SCOTT
DEC
DEC-1090
HARVARD
NYU
BBN 40
BBN 30
H316
STANFORD
SUMEX
TYMSHARE
FNWC
GWC
SCRL
MP32
DOCB
UCLA
USC
NUC
CDC6500
CDC3200
UNIVAC 1108
H716
PLI
BELVOIR
DCEC
SDAC
ABERDEEN
RUTGERS
NORSAR
NSA
ARPA
MITRE
NBS
LONDON
PLURIBUS
360/44
360/40
NELC
RAND
ISI 22
ISI 52
AFWL
TEXAS
GUNTER
EGLIN
PENTAGON
FPS AP-120B
DEC-2040
370-158
XGP
B-4700
360/195
GEC 4080
ICL 470
CDC6400

# Network Control Protocol (NCP)

- First Packet Switching network.
- Previously communication was don’t through circuit switching.
  - Problems with circuit-switching. 1) Most of the time the channel is not used, but it is tied up. For example, waiting for the user to type the next letter in their command. Literally a mechanical circuit is made at a telephone exchange. Think modems where one computer literally called the phone number of another computer. Or if the computers were near each other, you would connect them with a serial cable (not a USB because they were not a bus).
- In packet switching a computer message is broken down into small pieces (packets). All the hardware is connected together all the time. The packets each take an independent path between sender and receiver.
- More efficient and more resistant to hardware failure.
- First packet-switching network use: Login from University of California Los Angeles Room 3420 to a computer at the Stanford Research Institute (320 miles).
- This was the first use of the term “login” and the first message was “lo” (the system crashed).

# Network Control Protocol (NCP)

In a circuit-switching network where there are 5 people at one location and 5 at another if they all want to talk to one other person then there have to be 5 separate circuits. If they all want to talk at the same time there would have to be 25 dedicated hardware connections.

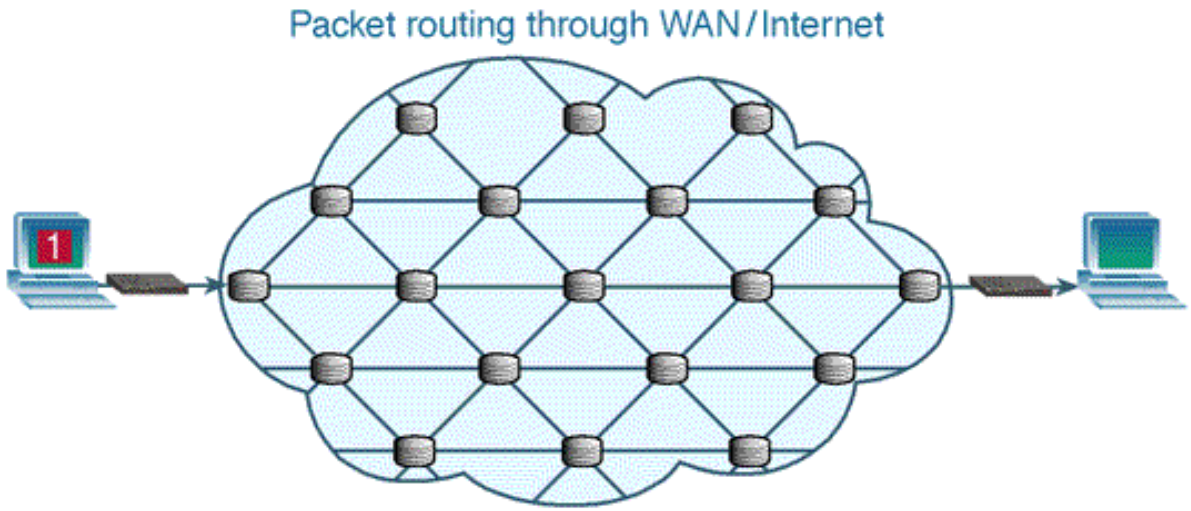
With a packet switching network there only needs to be one hardware circuit with all the computers listening to it at the same time.

Or if you want resilience then have multiple hardware connections between sites that take different physical routes. Then if one route is knocked out, or becomes congested, the packets can take the remaining, or fastest route.

A packet switching network works much like the interstate system where packets are cars.

Each computer only pays attentions to packets addressed to it.

ARPANET replaced NCP with the Internet Protocol (IP)



# Local Area Networks

- Everything above is considered a WAN (Wide Area Network).

- Parallel technological developments were happening with computers that were near each other.
- This might seem strange but communication mostly made sense for long distance connections.
- For computers in the same building or campus it was silly to send an email or remotely login (why not walk?)

# Local Area Networks (LAN)

- But as computing devices multiplied connecting them locally made sense.
- These devices could be anything from a supercollider at a university producing millions of atomic particle products, a printer, or a VT100 terminal.
- Two approaches were developed to meet the need for an easy way to connect devices near each other.
- Token ring networks used coax cable and a round-robin approach. Each device on the LAN has a token saying it's allowed to talk. (Think of a talking stick). The token is passed from device to device around the ring of connections. That way every device gets a chance to speak and no devices try to talk at the same time.
- Ethernet is based on carrier-sensing
- CSMA/CD (Carrier-Sense Multiple Access with Collision Detection)

# Local Area Networks (LAN)

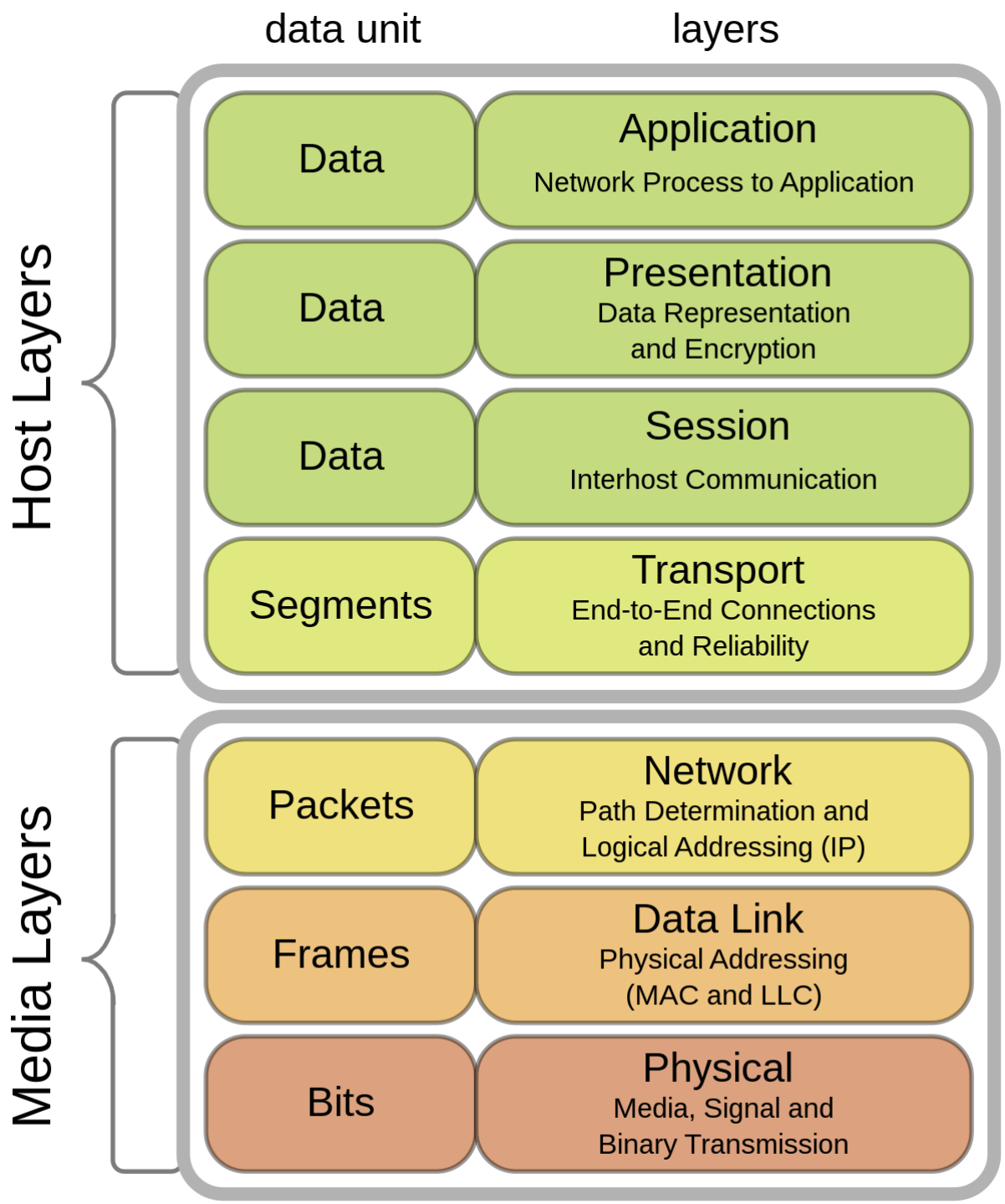
- CSMA/CD (Carrier-Sense Multiple Access with Collision Detection)
- As opposed to token ring systems, CSMA devices listen to the hardware line. When they don't hear anything they can try to talk.

  "**Listen Before Talk**" principle
- Sometimes two or more devices try to talk at the same time. This means there are electrical signals encoding different messages sent at the same time on the same wire, resulting in the messages being corrupted.
- The first device to detect the message collision broadcasts a "jam" message indicating that no device should transmit. All devices wait a random period of time and try again.
- Messages are divided into **frames** and those frames are addressed to MAC addresses.
- Token ring networks tried to be high quality and assure quality transmissions.
- Ethernet allowed network corruption and had a randomized recovery scheme.
- Ethernet won because it was cheaper.

# Network Stack

Open Systems Interconnect (OSI) Model

- The lowest level is the actual hardware.
- At the top is the layer that talks to programs that wants to communicate (a web browser or email client for example)



# Network Stack

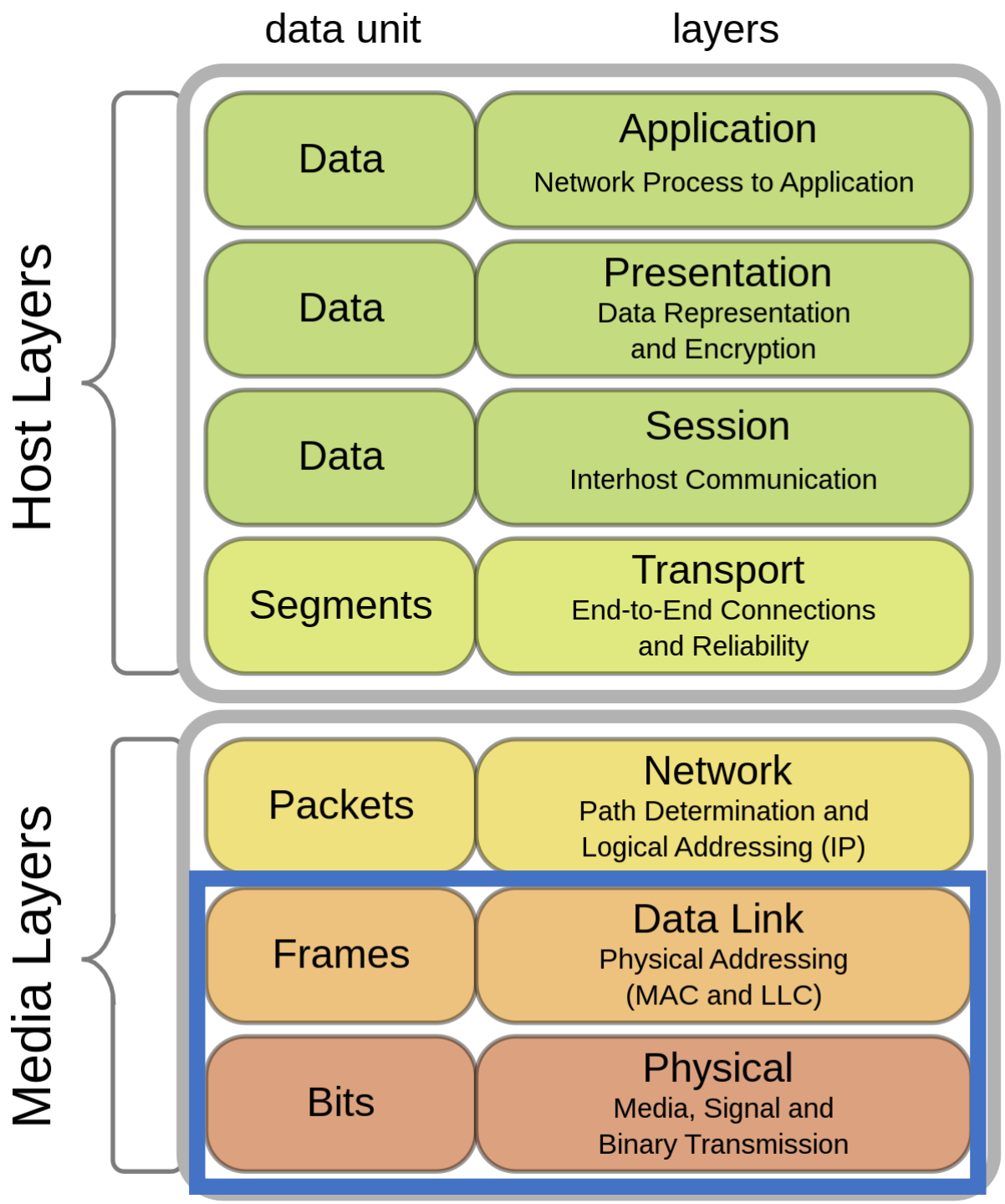
Open Systems Interconnect (OSI) Model

## Ethernet

Operates at the Media Access Control sublayer between the physical and data
link layers.

Each device has an ethernet address or MAC (media access control).

Format: XX:XX:XX:XX:XX:XX



# Network Stack

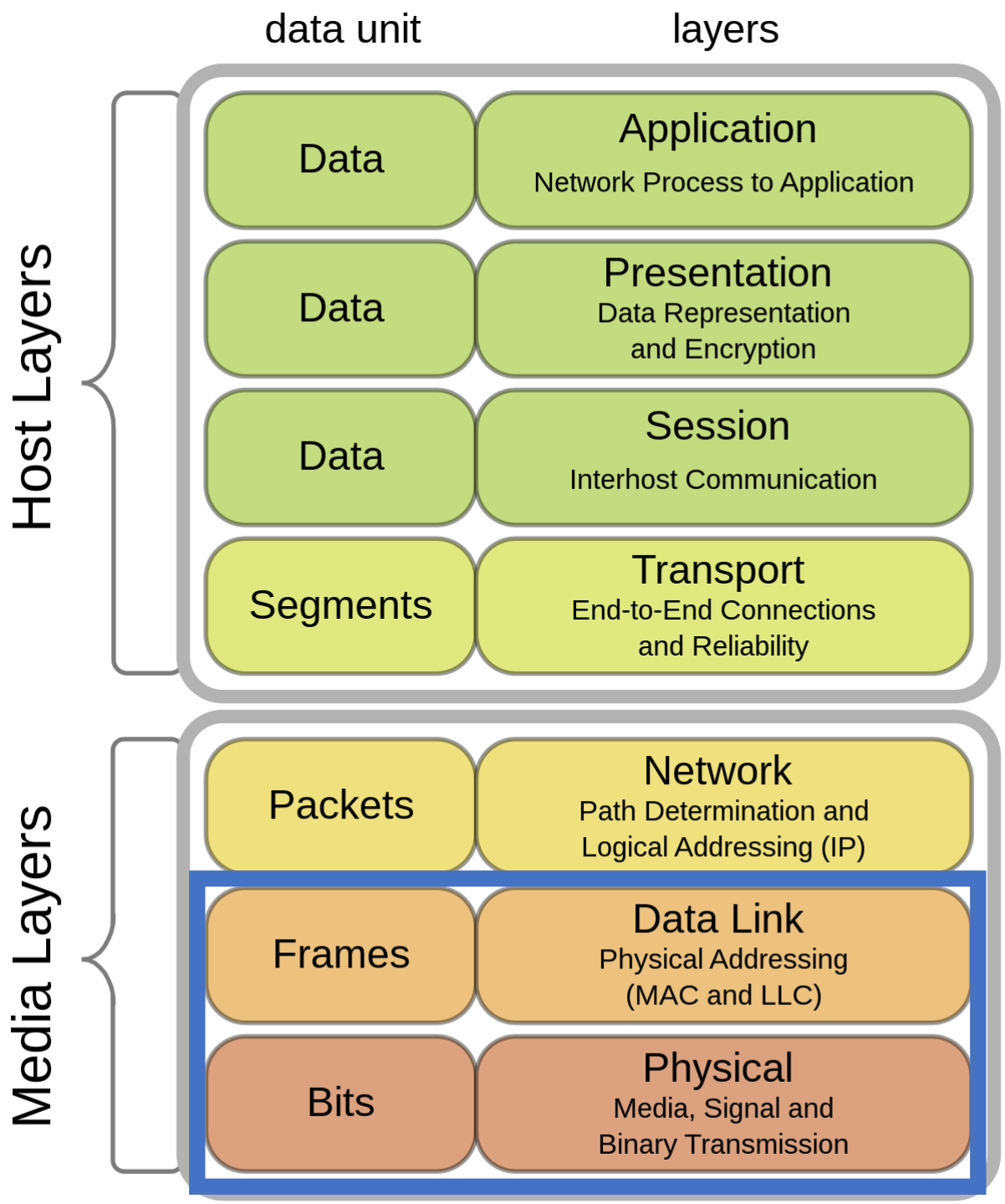
Open Systems Interconnect (OSI) Model

## Ethernet

Operates at the Media Access Control (IEEE 802.2) and link (802.3) sublayers.

MAC addresses are physical addresses set by the hardware manufacturer.

Eg: d4:ae:52:8b:72:8c



```
[matthew@moonshine ~]$ ip a
1: lo: <LOOPBACK,UP,LOWER_UP> mtu 65536 qdisc noqueue state UNKNOWN group default
qlen 1000
    link/loopback 00:00:00:00:00:00 brd 00:00:00:00:00:00
    inet 127.0.0.1/8 scope host lo
       valid_lft forever preferred_lft forever
    inet6 ::1/128 scope host
       valid_lft forever preferred_lft forever
2: eno1: <BROADCAST,MULTICAST,UP,LOWER_UP> mtu 1500 qdisc mq state UP group default
qlen 1000
    link/ether d4:ae:52:8b:72:8c brd ff:ff:ff:ff:ff:ff
    altname enp1s0f0
    inet 129.24.245.16/22 brd 129.24.247.255 scope global noprefixroute eno1
       valid_lft forever preferred_lft forever
    inet6 fe80::d6ae:52ff:fe8b:728c/64 scope link noprefixroute
       valid_lft forever preferred_lft forever
```

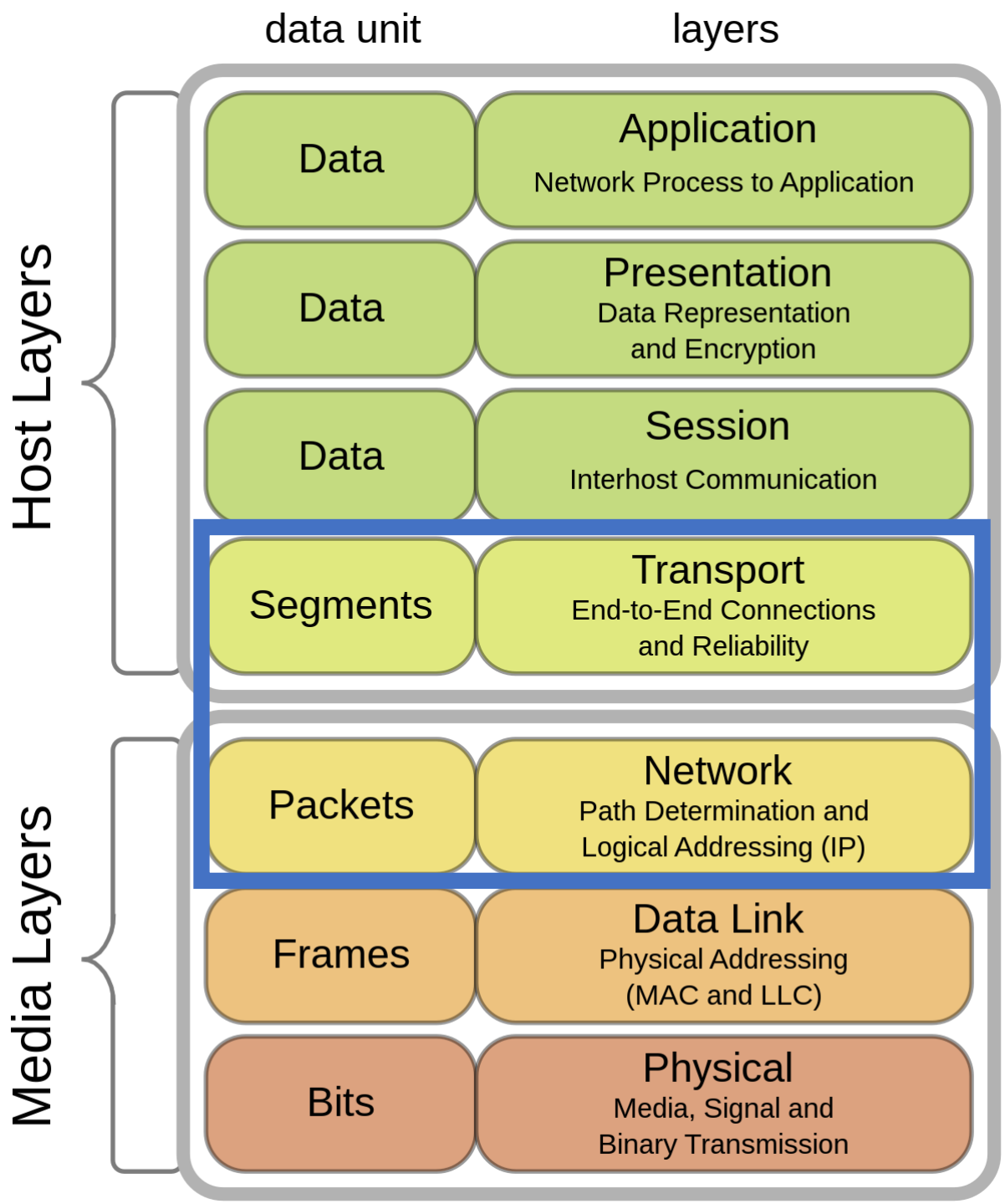
# Network Stack

Open Systems Interconnect (OSI) Model

Actual messages are handled at the transport and network layers with packets.

Examples are TCP(or UDP)/IP and the now defunct SPX/IPX.

These use logical addresses (such as IP addresses) not hardware addresses.



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    inet 127.0.0.1/8 scope host lo
       valid_lft forever preferred_lft forever
    inet6 ::1/128 scope host
       valid_lft forever preferred_lft forever
2: eno1: <BROADCAST,MULTICAST,UP,LOWER_UP> mtu 1500 qdisc mq state UP group default
qlen 1000
    link/ether d4:ae:52:8b:72:8c brd ff:ff:ff:ff:ff:ff
    altname enp1s0f0
    inet 129.24.245.16/22 brd 129.24.247.255 scope global noprefixroute eno1
       valid_lft forever preferred_lft forever
    inet6 fe80::d6ae:52ff:fe8b:728c/64 scope link noprefixroute
       valid_lft forever preferred_lft forever
```

# Example – Reading google.com

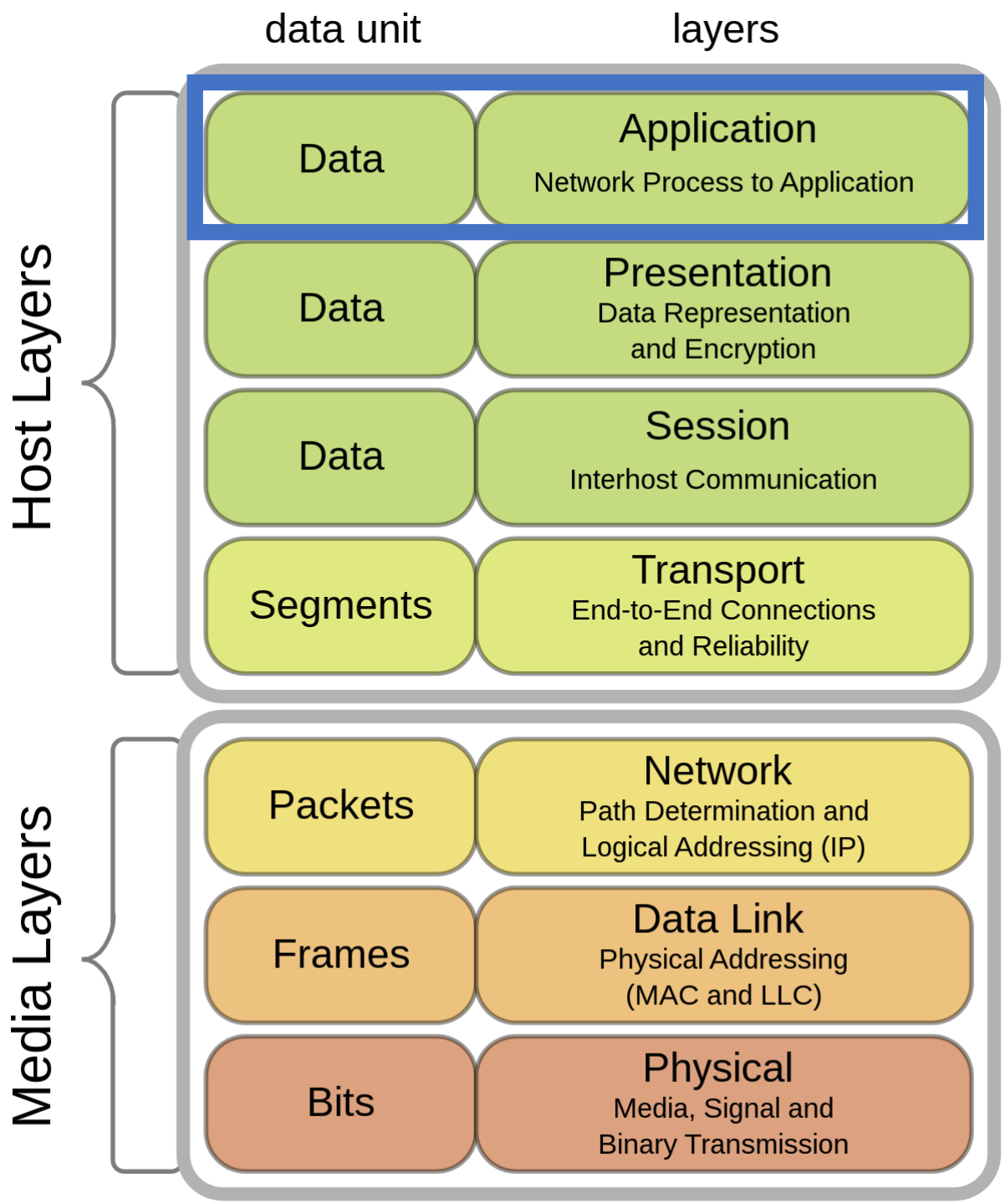
The web browser application asks a DNS (Domain Name Service) server to return the IP address of “google.com”.

DNS is just a big lookup table of all the names people have associated with domain names. Could also be a local hosts file entry.

The DNS server’s IP address is set when you configure your network interface.

This all happens in layer 7.

To be clear the web browser is not in the application layer – but it talks to the application layer of the network stack.



BBC Earth | Environment, Clin

bbc.com/future-planet

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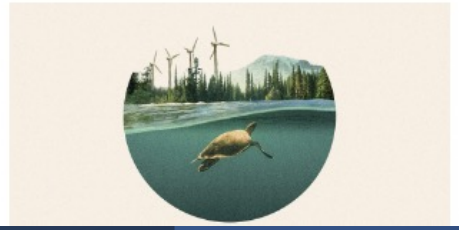
# Earth

## Climate change will bring megafloods to California

The state is beginning to experience "hydroclimate whiplash," where the climate veers wildly between extreme dryness and extreme wetness.

Stunning shot of polar bear drifting to sleep wins award

The paradox of the 'gentle protest'



Example – Reading http://fricke.co.uk web page.

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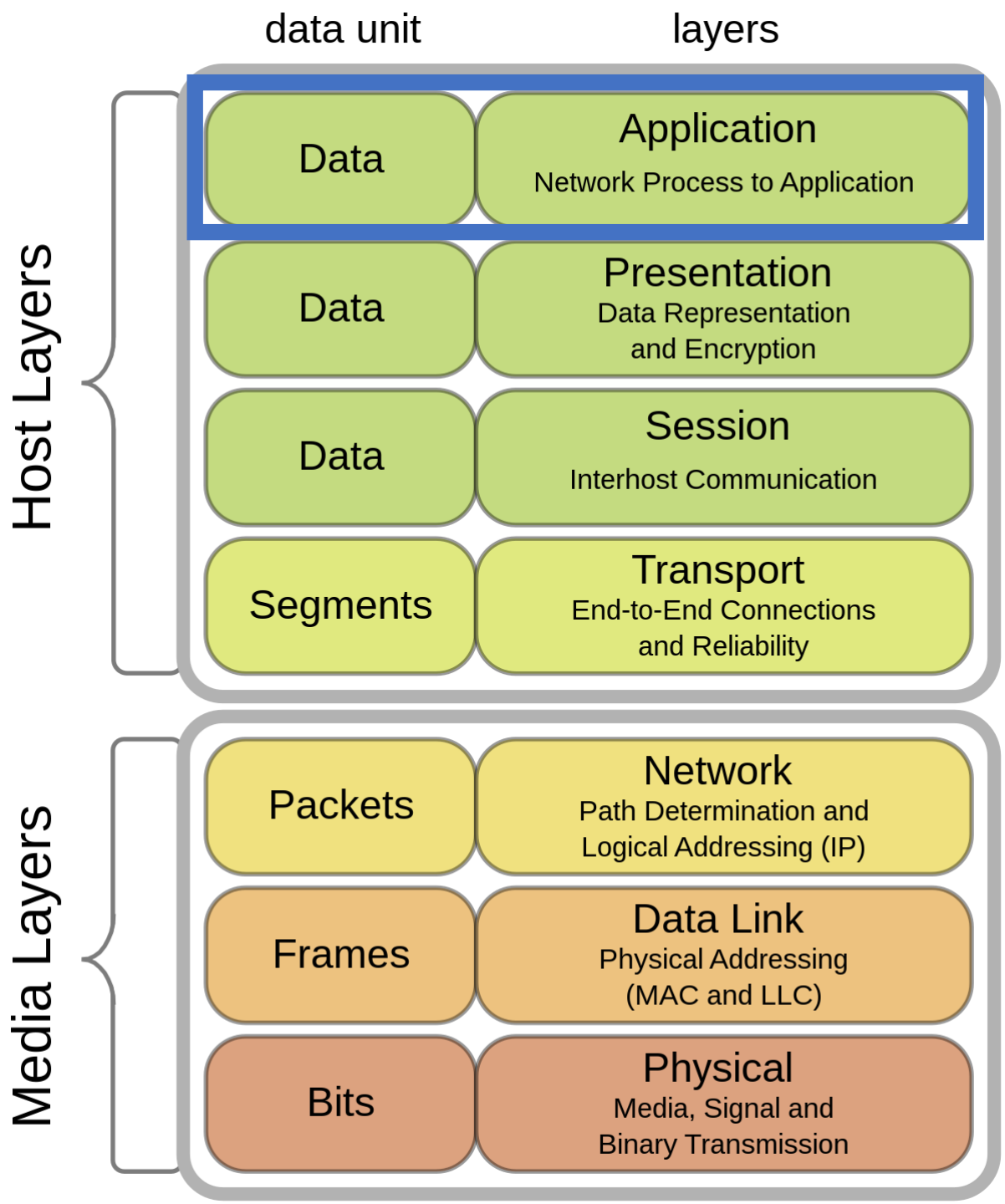
Log into your cluster and run
dig google.com

To see the result of a DNS query.

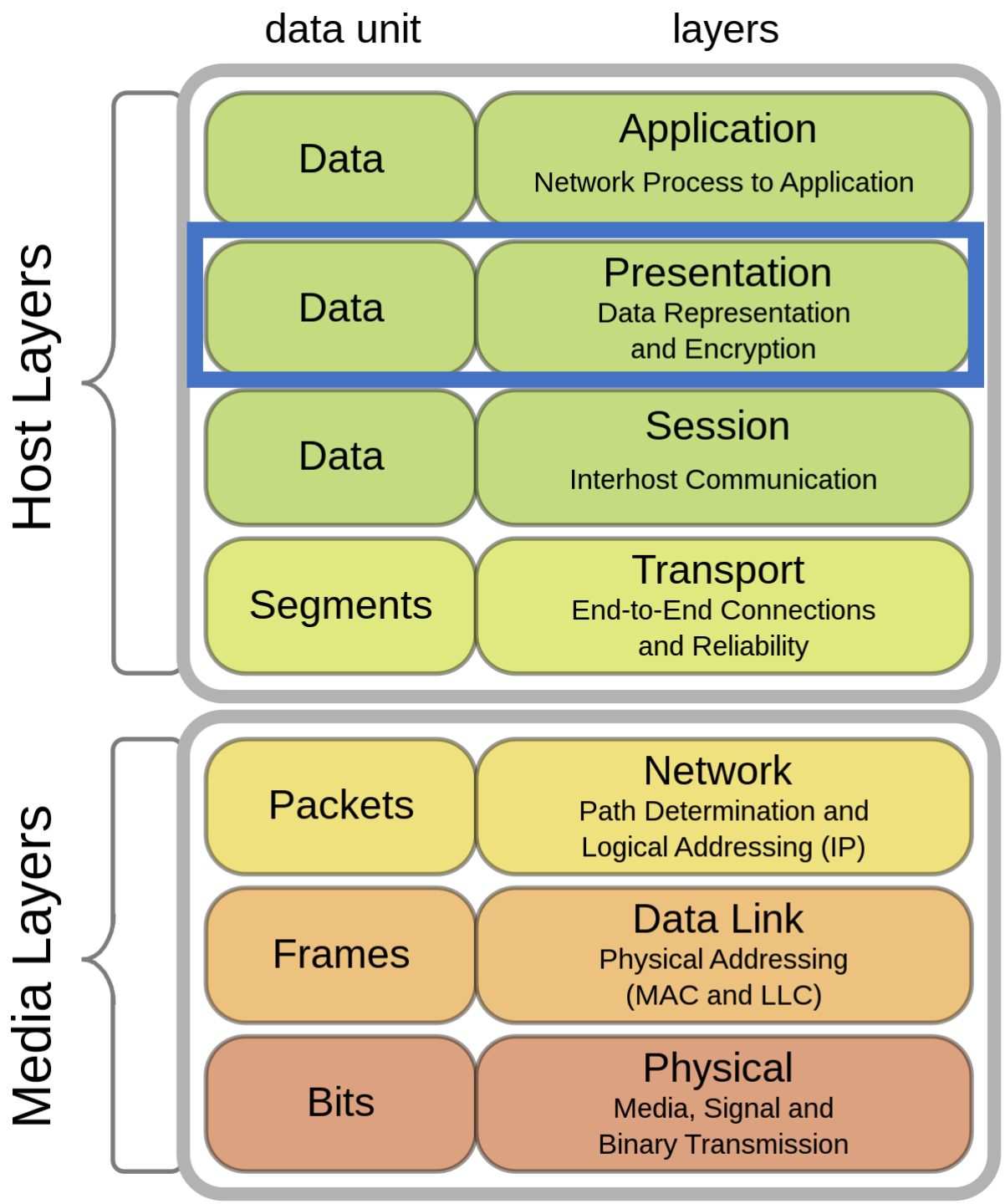


# Example – Reading http://fricke.co.uk web page.

The presentation layer is responsible for making sure the data encoding matches.

If it were https instead of http above then the presentation layer (6) would do the encryption/decryption.

If the data were compressed for transmission then compression and decompression would also happen in layer 6.



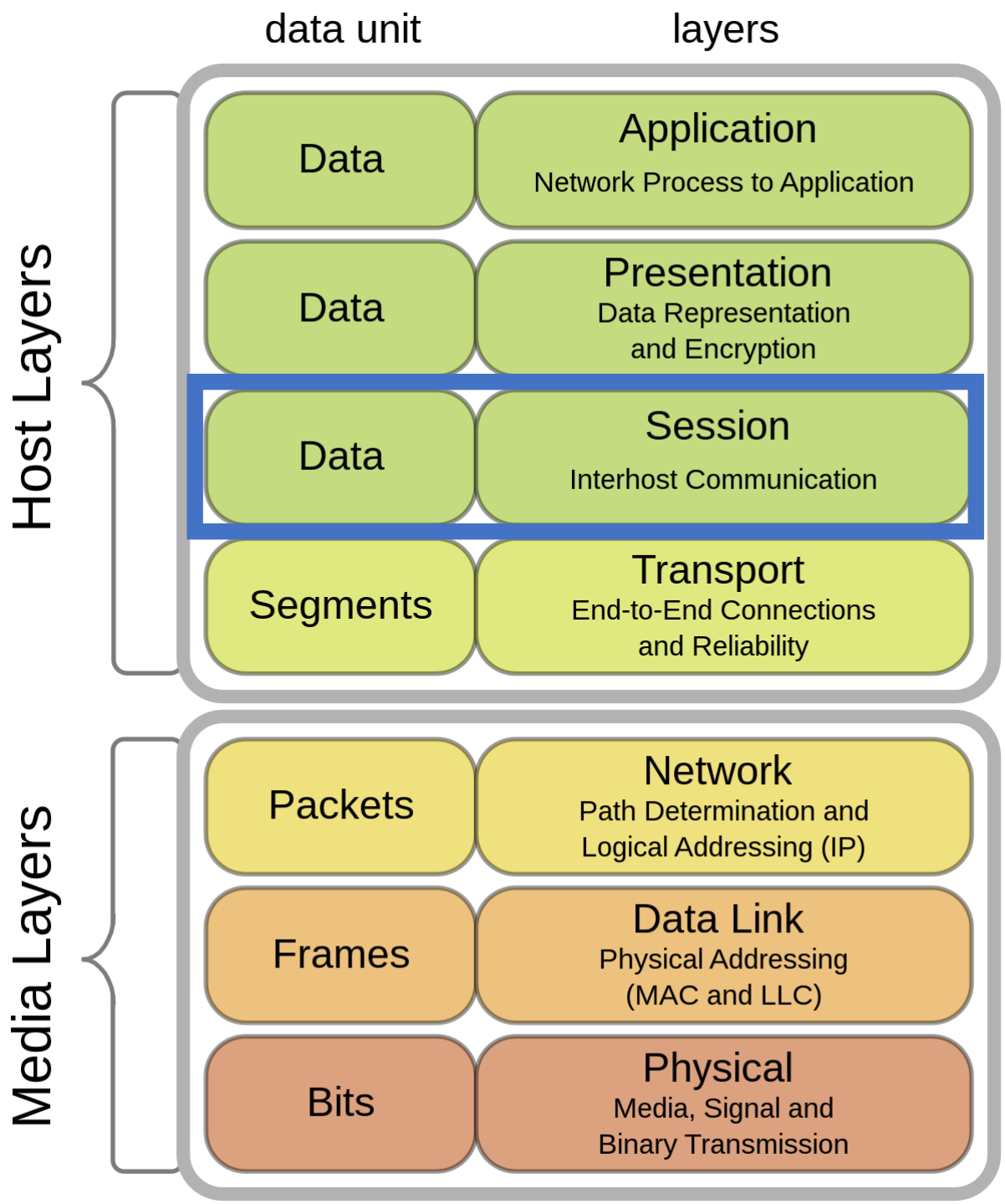
# Example – Reading http://fricke.co.uk web page.

The hypertext transfer protocol (HTTP) uses TCP (transmission control protocol). TCP connections include error checking to make sure the data that was sent arrived OK.

That means every time a message is sent to a web server the client waits for the web server to send a confirmation message. This kind of connection is managed in the session layer.

The user datagram protocol (UDP) is the alternative. It sends data without caring if it arrived. For example, a video stream where a few missing pixels wouldn't matter might use UDP.

(The OSI model is an idealization. In reality, the top three OSI layers are combined into one TCP/UDP application layer.)



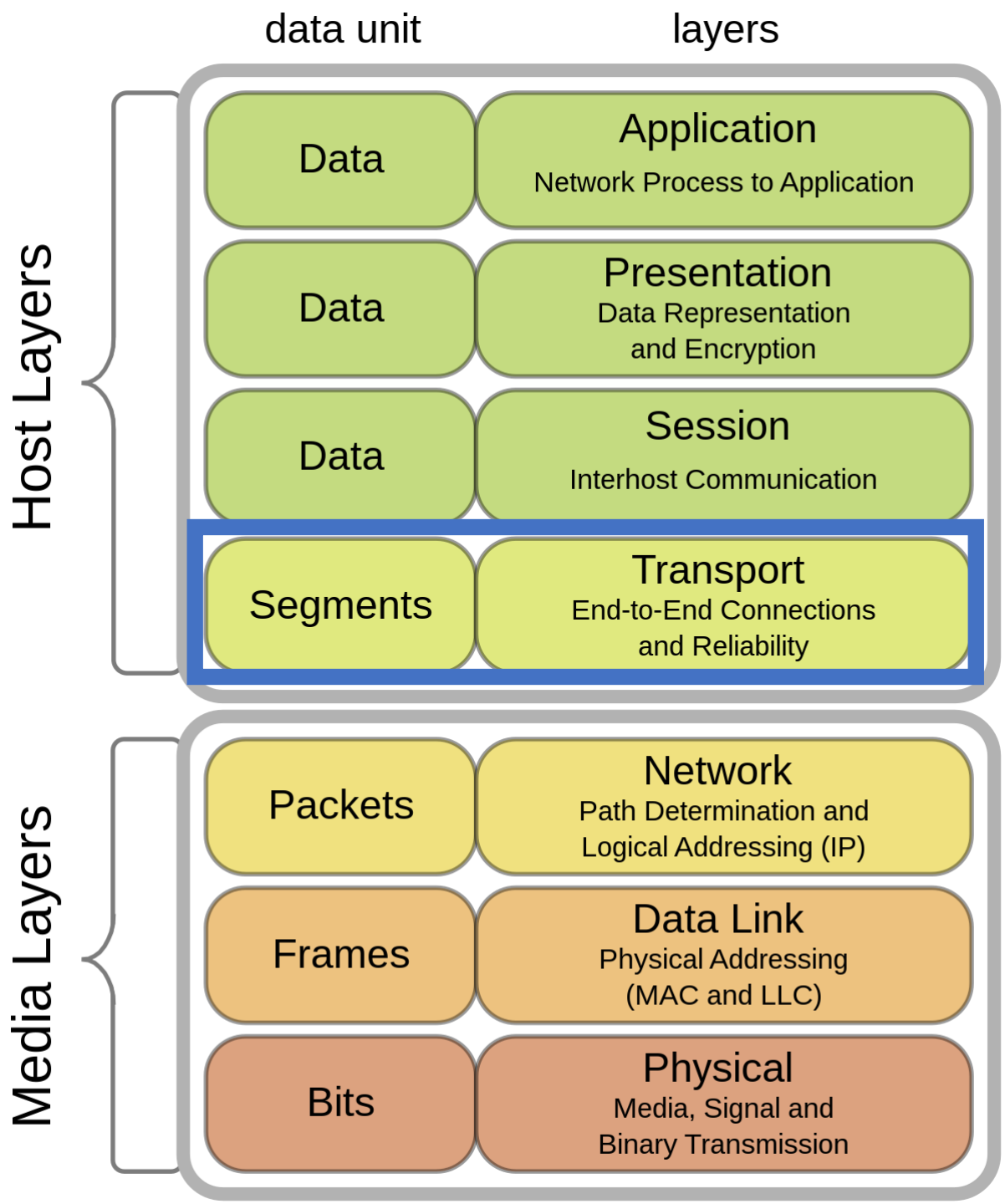
# Example – Reading http://fricke.co.uk web page.

The transport layer is responsible for taking the data written by the application, and encrypted/compressed, etc by the presentation layer and breaking it up into segments.

Segmentation is needed if the maximum transmission size of the network is greater than the amount of data being sent. (E.g. TCP max packet size is 64K).

Ethernet frames are only 1500 bytes. (though there are jumbo frames).

When receiving a message, the transport layer assembles segments into the right order for the application layers above. It also checks that all the expected segments arrived.

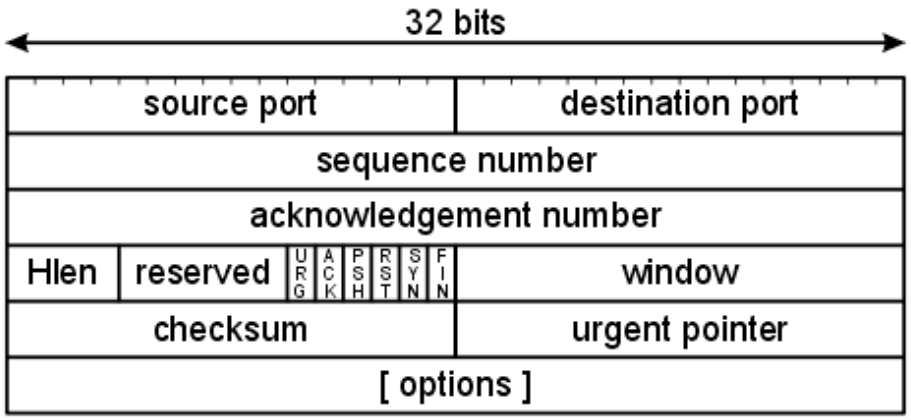


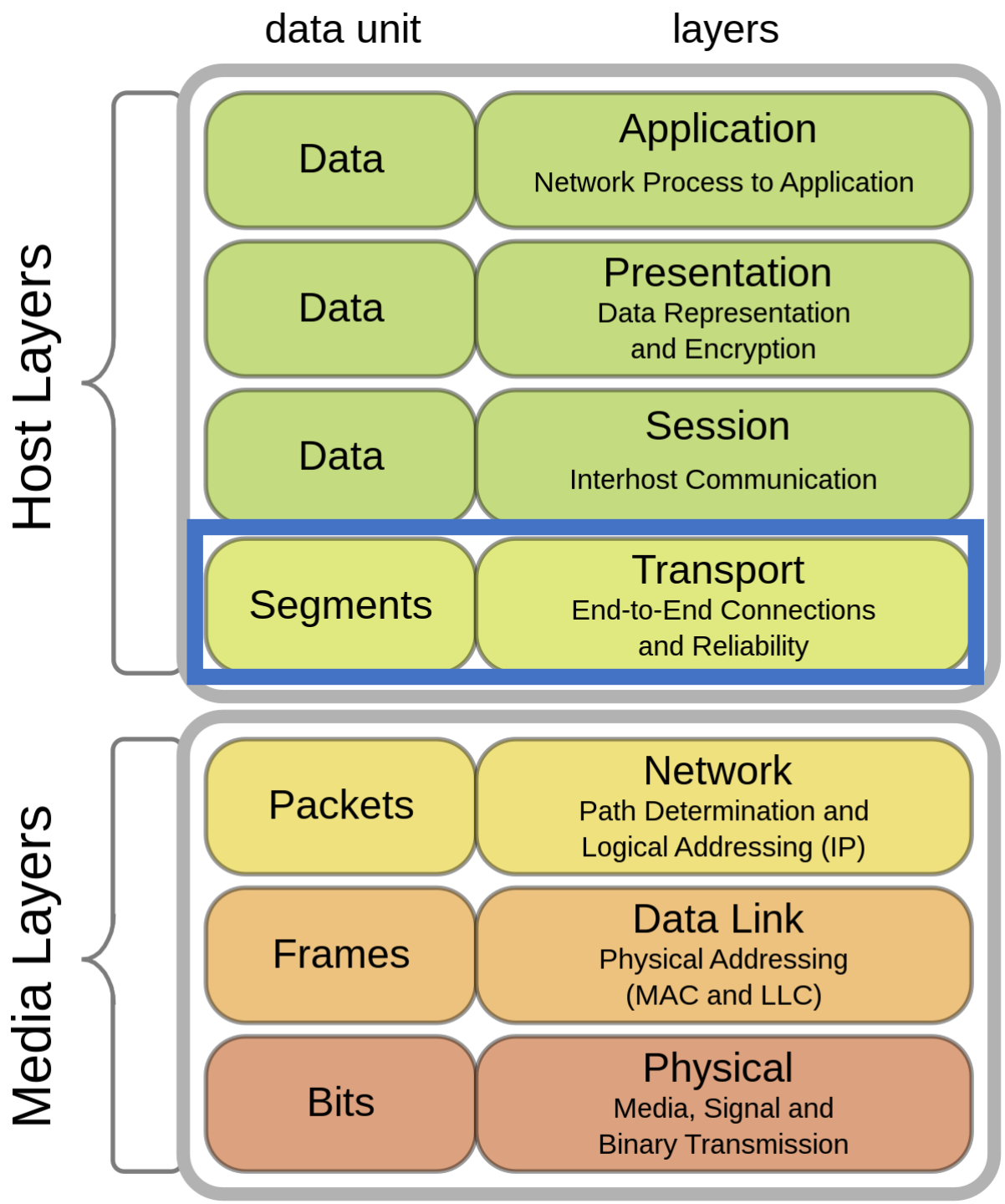
# Example – Reading http://fricke.co.uk web page.

The transport layer is responsible for taking the data written by the application, and encrypted/compressed, etc by the presentation layer and breaking it up into segments.

The segments have some headers added. For example, the destination port (http servers listed on port 80) and the sequence number of the segment – since they may arrive out of order. Since this is http the segment will have a TCP header

TCP header format



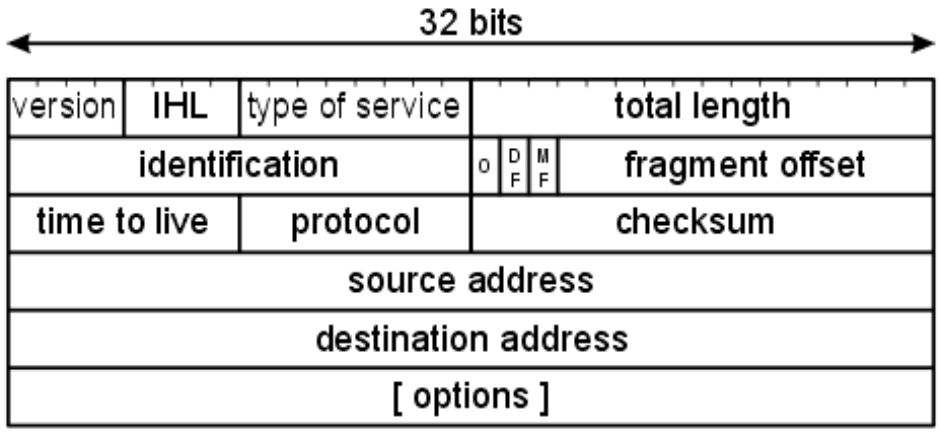
# Example – Reading http://fricke.co.uk web page.

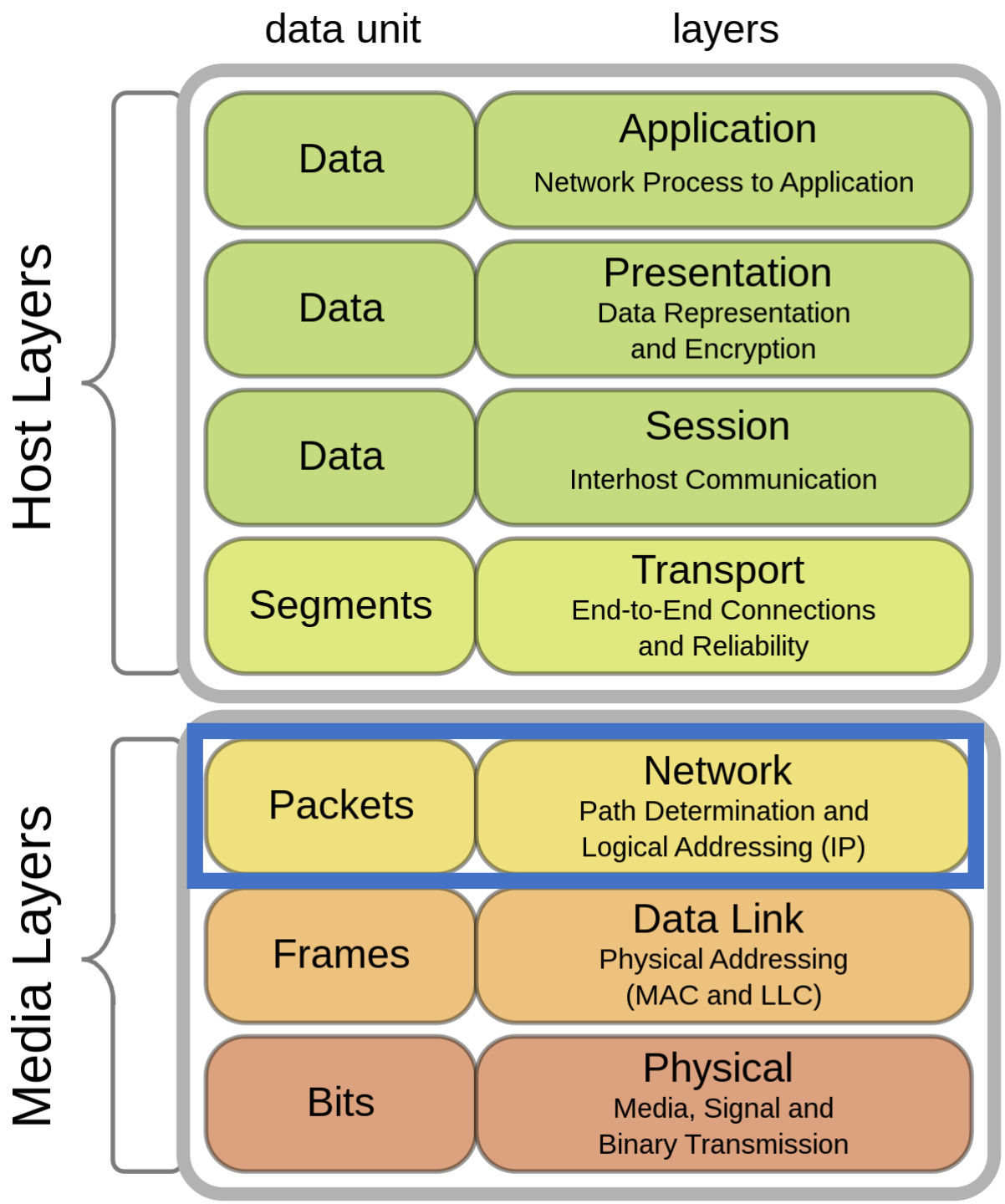
Now that the data the application wants to send has been chopped up into segments, they are converted to packets.

A packet is a segment of data, but with the destination logical address added.

In this case the logical address is the IP address given by the DNS lookup earlier.

IP header format



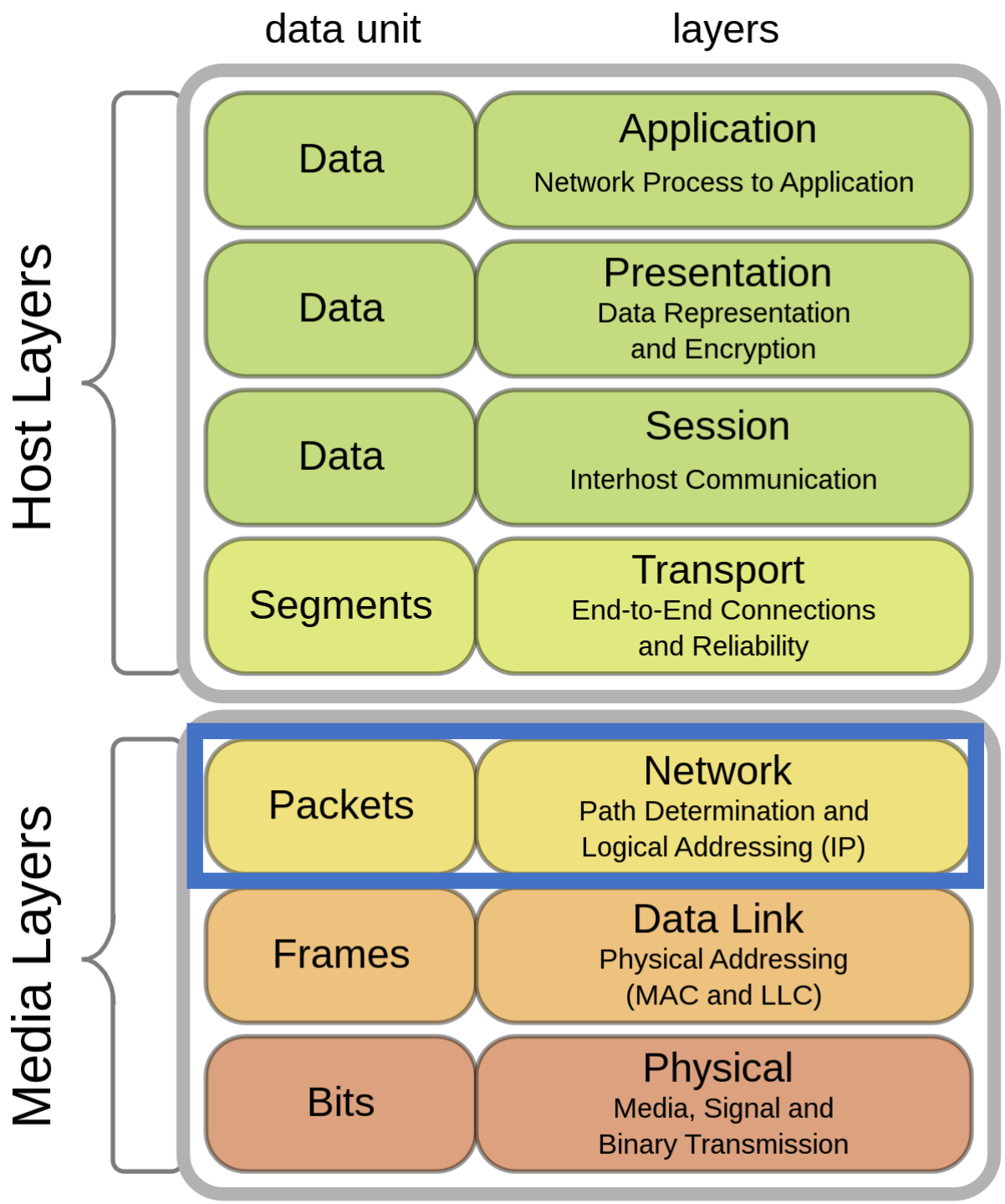
Example – Reading
http://fricke.co.uk web page.

Warning: the network layers are no longer being processed on the same computer. The "layer" can consist of various network devices working together.

If the destination IP address is on the same subnet as the sender, then the IP address can be translated to the destination devices MAC address for ethernet to handle immediately.

If the destination IP address is not on the same subnetwork, then the "gateway's" MAC address is used and we begin routing.

IP addresses are translated to MAC addresses by the address resolution protocol (ARP in layer 2, data link).



# ARP (Address Resolution Protocol)

- On your cluster enter this command:

cat /proc/net/arp

To view the address resolution table that maps MAC addresses to IP addresses.

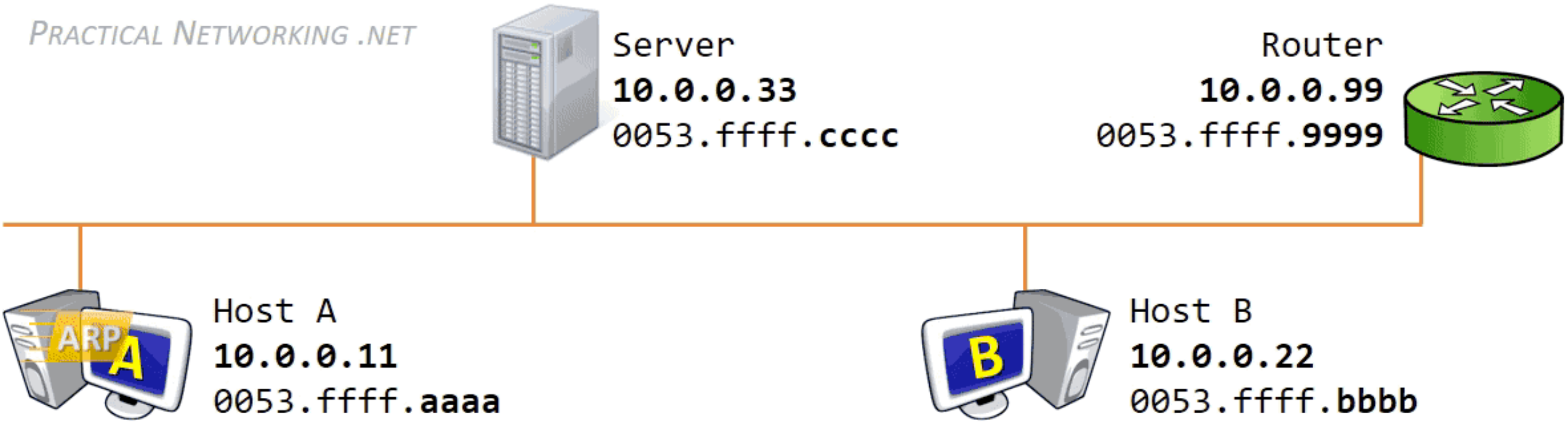
The command

Arp

Gives you some display options an allows you to manipulate the table.

Network devices like layer 3 switches also maintain ARP tables. That is done so they only send data to the devices that have matching MAC and IP addresses. This is not for security! It is only for efficiency. ARP tables are often incomplete or out of date, then the switch just sends everyone the data hoping it gets to the right MAC address.

# ARP (Address Resolution Protocol)




## The ARP table is not built in the same way as DNS tables.

DNS tables are usually entered manually – and you usually have to pay someone to route a domain name to your IP.

ARP just asks. That's OK because ARP only asks on the local network.

# Example – Reading http://fricke.co.uk web page.

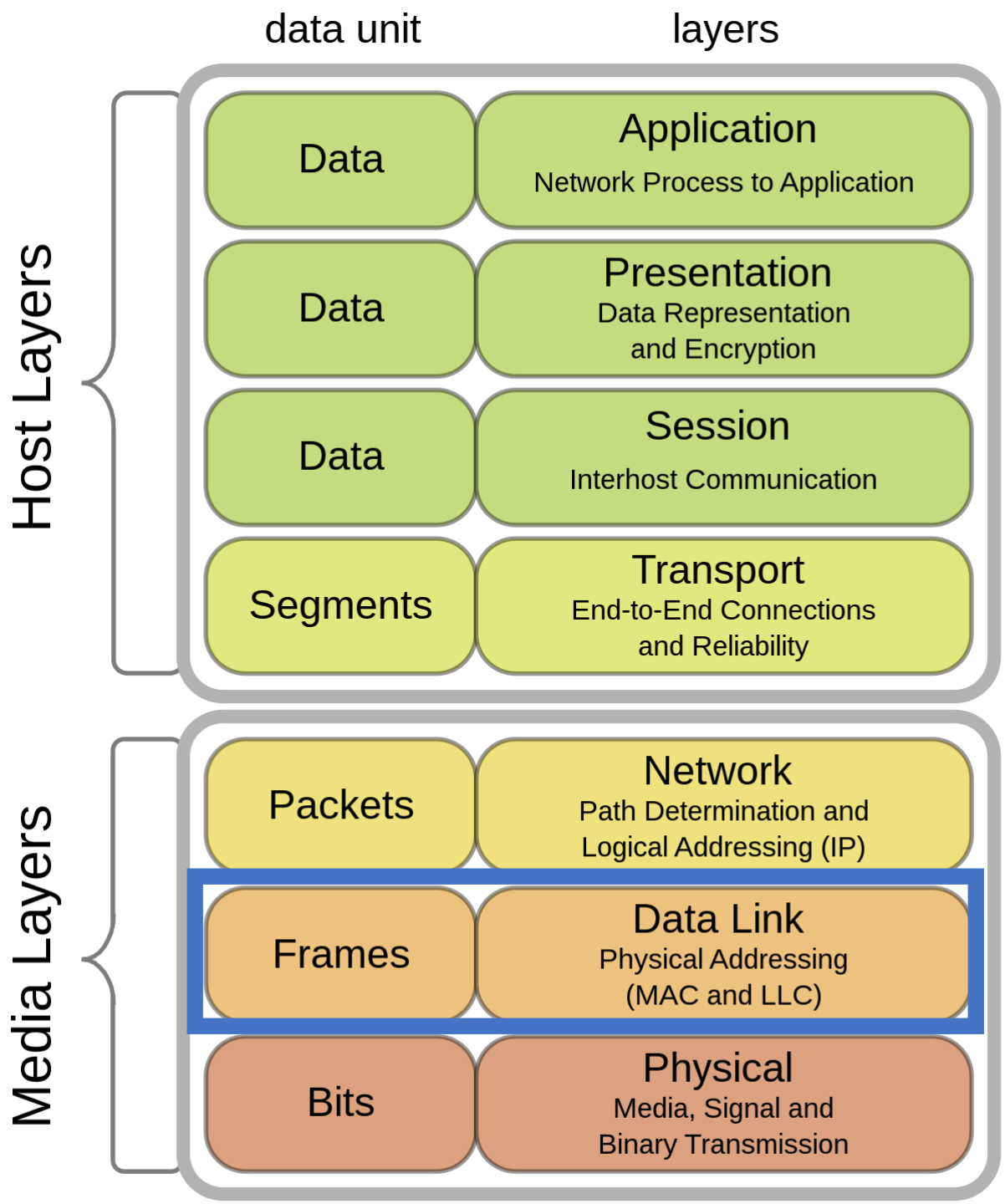
Warning: the network layers are no longer being processed on the same computer. The "layer" can consist of various network devices working together.

OK, so now we have a mapping from the IP (internet protocol) address to the MAC address, so we can add that MAC address to our packet header and move on to the datalink layer and the domain of the Ethernet protocol.

IEEE 802.3

| 7 | 1 | 6 | 6 | 2 | 46-1500 | 4 |
|---|---|---|---|---|---|---|
| Preamble | SOF | Destin. address | Source address | length | 802.2 PDU | FCS |

SOF: Start of Frame
FCS: Frame Check Sequence



# Why does any of this matter?

Example,

You will often hear HPC network engineers talking about layer 2 and layer 3 switches. Layer 2 switches do not know about IP addresses only MAC addresses.

There is a kind of attack called ARP poisoning*.

If I told you that “I suspect my layer 2 switch had been ARP poisoned”, would that make sense?

*ARP poisoning is when an attacker changes the ARP table so your IP address resolves to their computers MAC address so they can masquerade as your machine. It’s also legitimately used when network administrators want to listen to your traffic to debug it. Sometimes it’s used for seamless server rollover redundancy so a server can take traffic from a failed server.

# Why does any of this matter?

Example,

Layer 2 switches don’t have ARP tables since they don’t deal in IP to MAC translation. Layer 3 switches do though.

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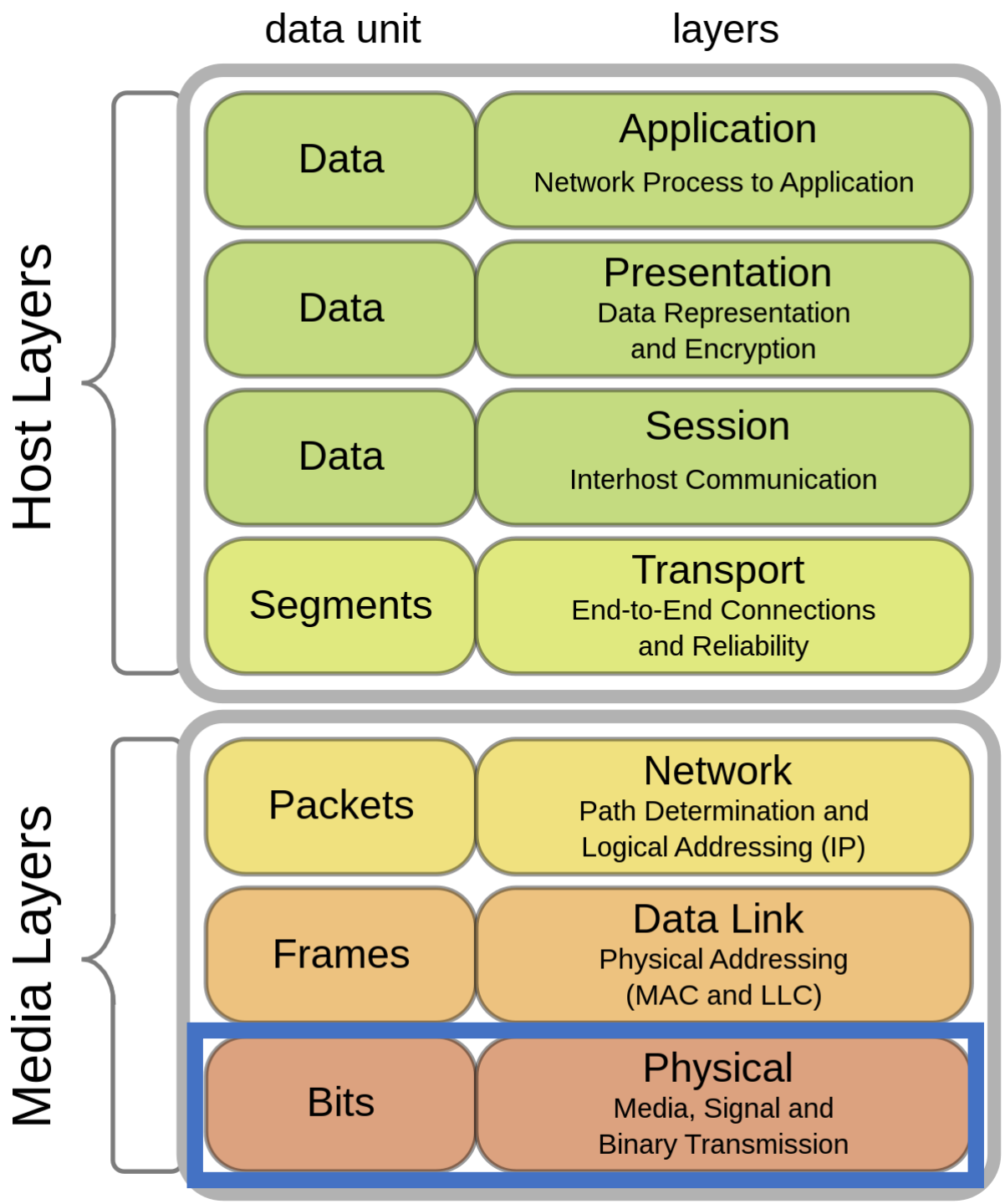
# Example – Reading http://fricke.co.uk web page.

Finally, we have constructed a complete packet (consisting of segments and frames) that we can send to the NIC (network interface card).

The NIC sends electrical or light signals onto the wire depending on whether we have a copper or fiber optic connection.

The NIC with a matching MAC address records those signals and we begin working up the stack to decode everything.

If the destination MAC address is a gateway then the packet is routed to the next destination on its way to the destination network.



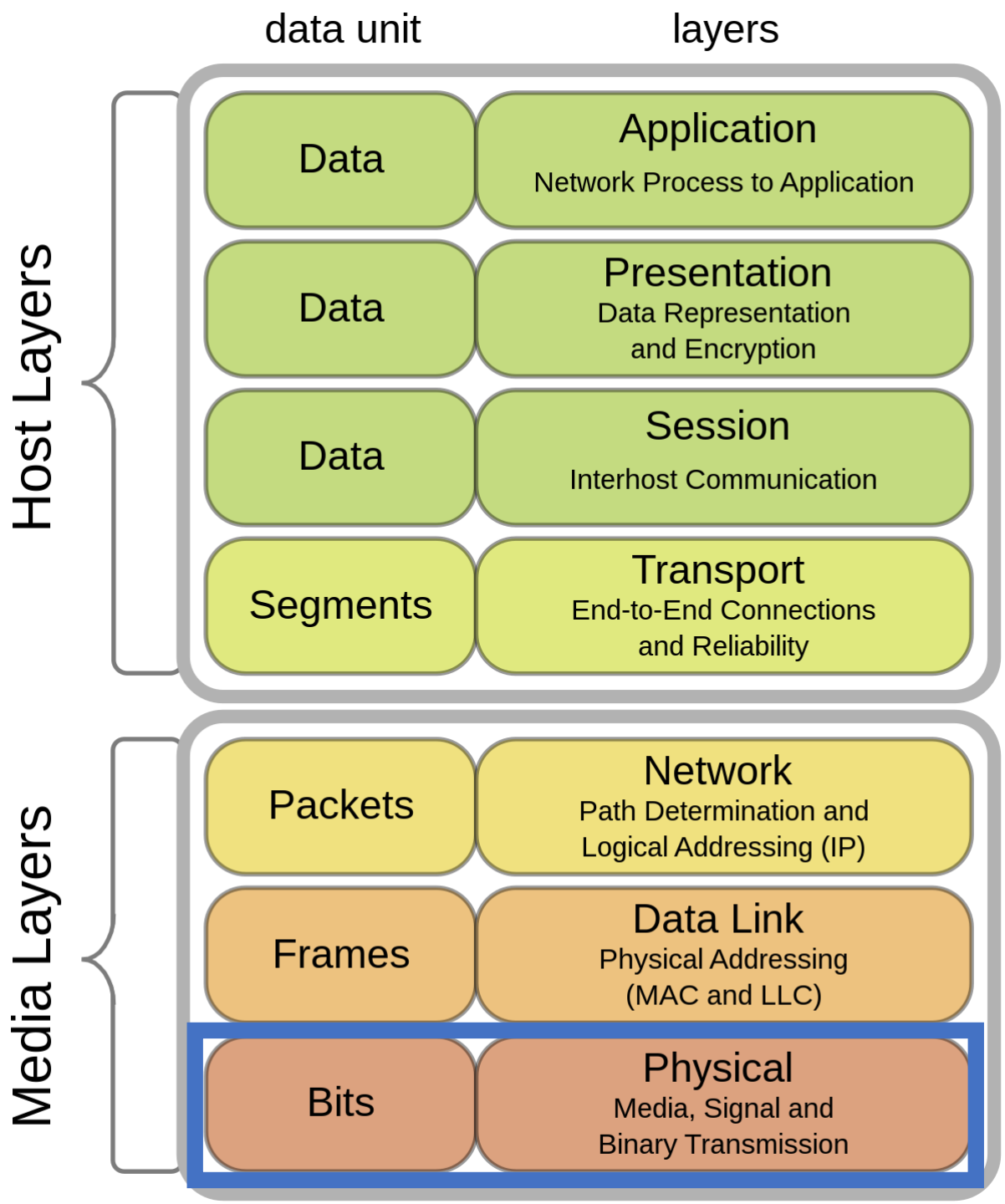
# Example – Reading http://fricke.co.uk web page.

There are many protocols that may be used to route the packet to it's final destination.

Each router rewrites the outermost header of your packet with the next destination.

When your packet moves from one major internet provider to another they will use BGP (Border Gateway Protocols*) to choose the next path.

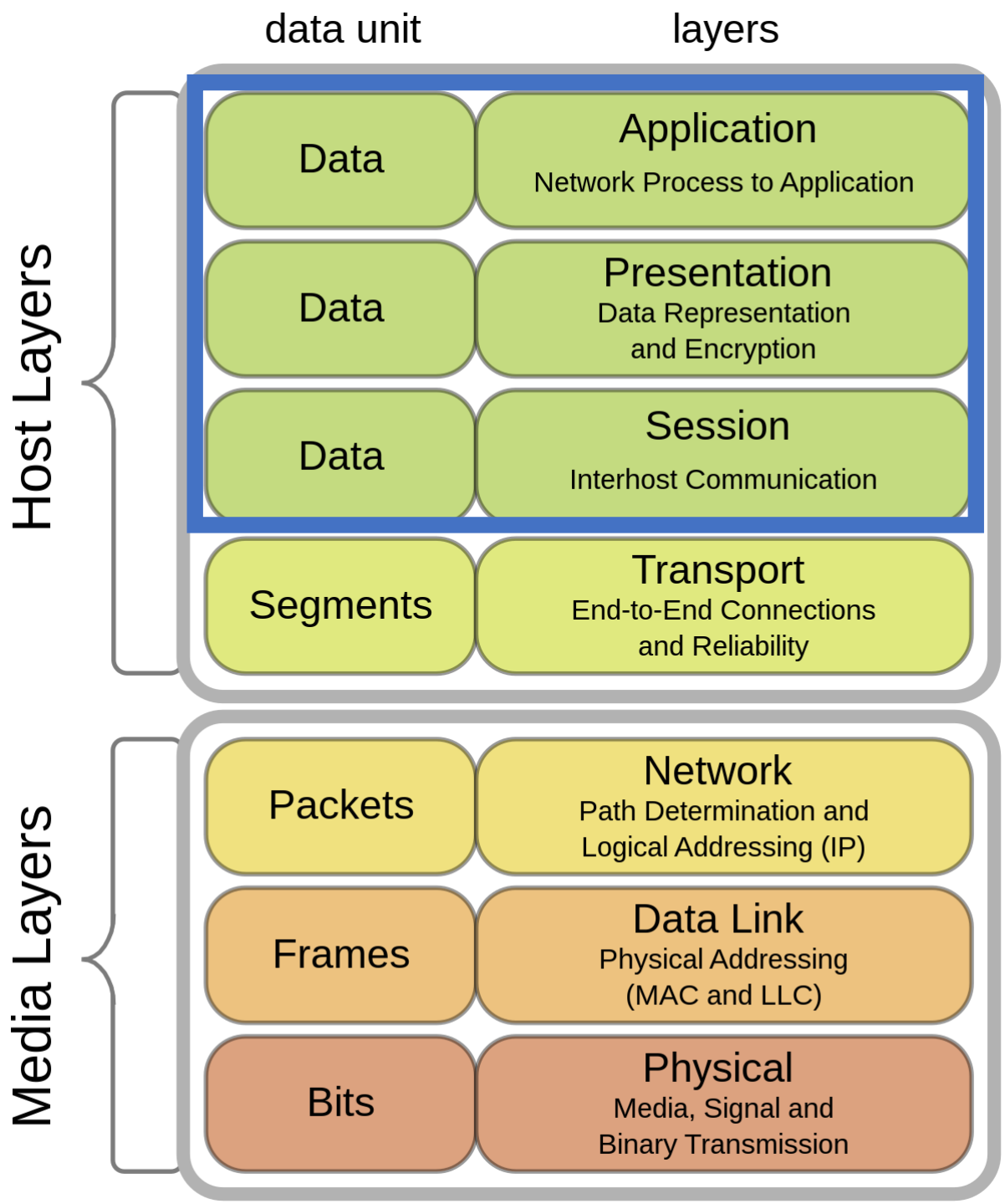
Also known as the "three-napkin protocol"



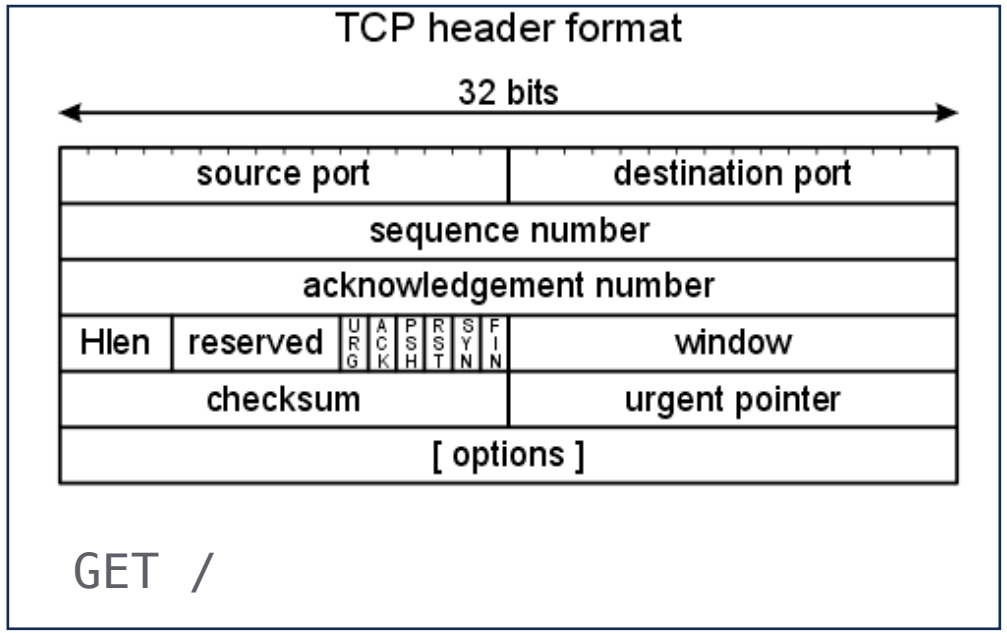
Example – Reading
http://fricke.co.uk web page.

```
GET /
```

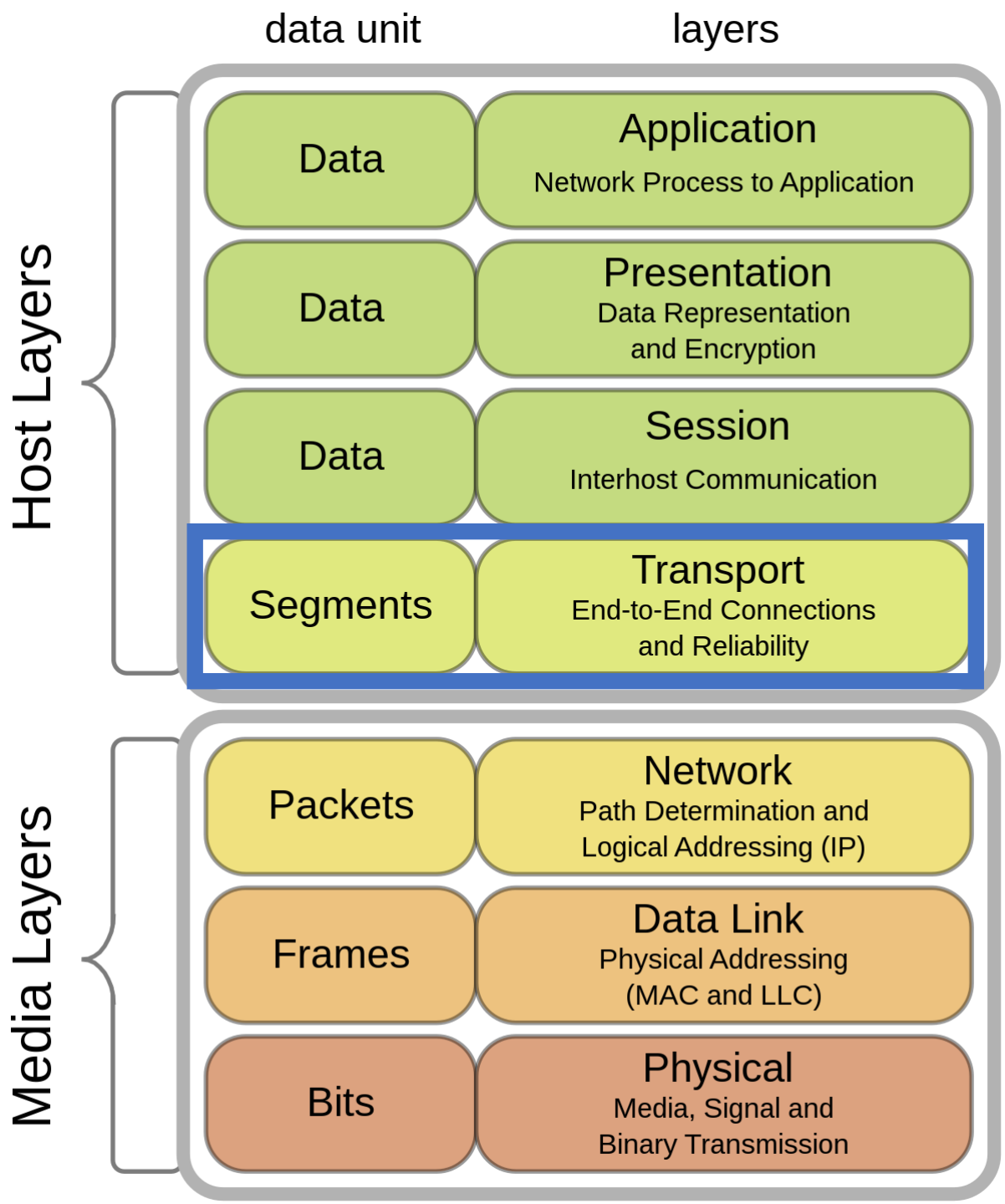
Let's go through the layers to construct a packet



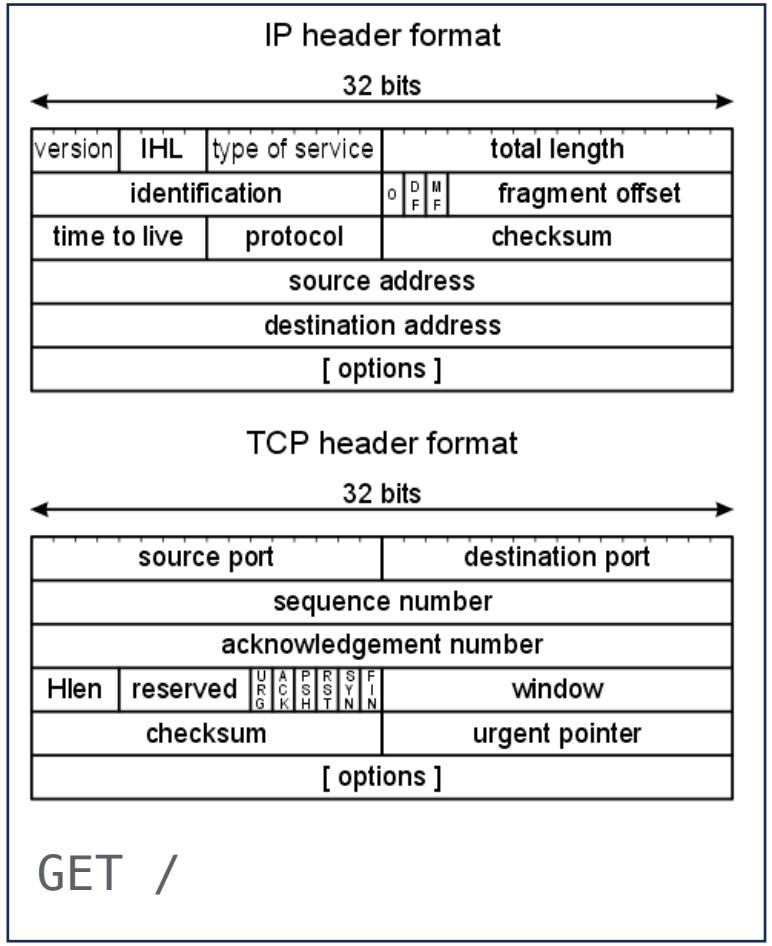
# Example – Reading http://fricke.co.uk web page.



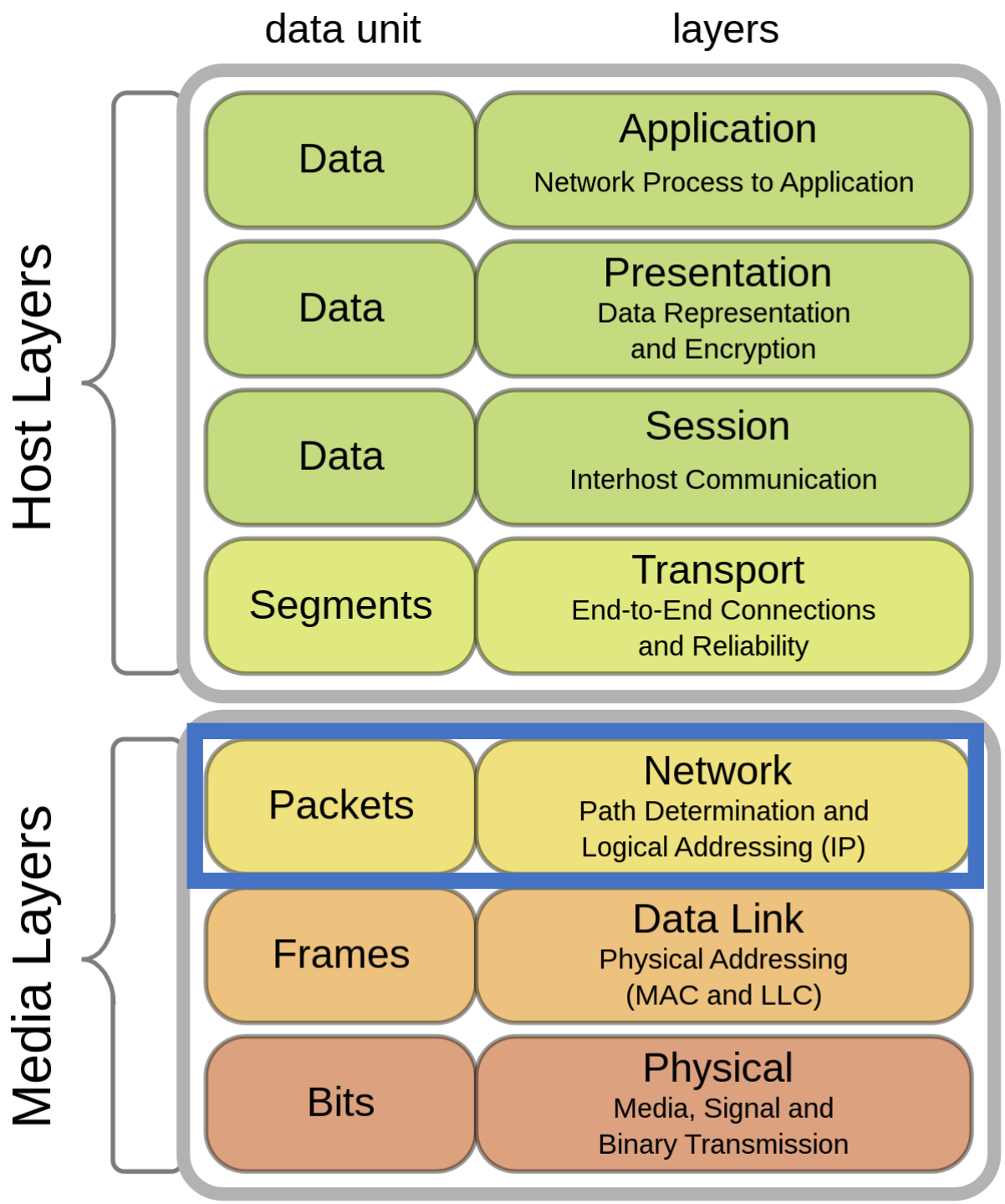

Let's go through the layers to construct a packet



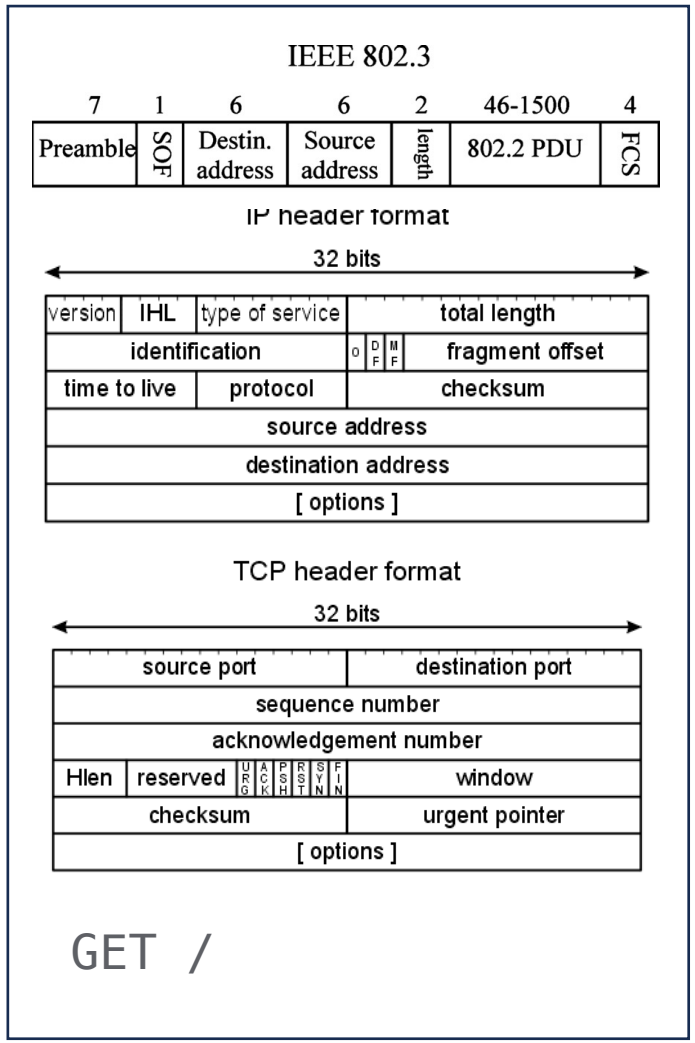
# Example – Reading http://fricke.co.uk web page.




Let's go through the layers to construct a packet



# Example – Reading http://fricke.co.uk web page.

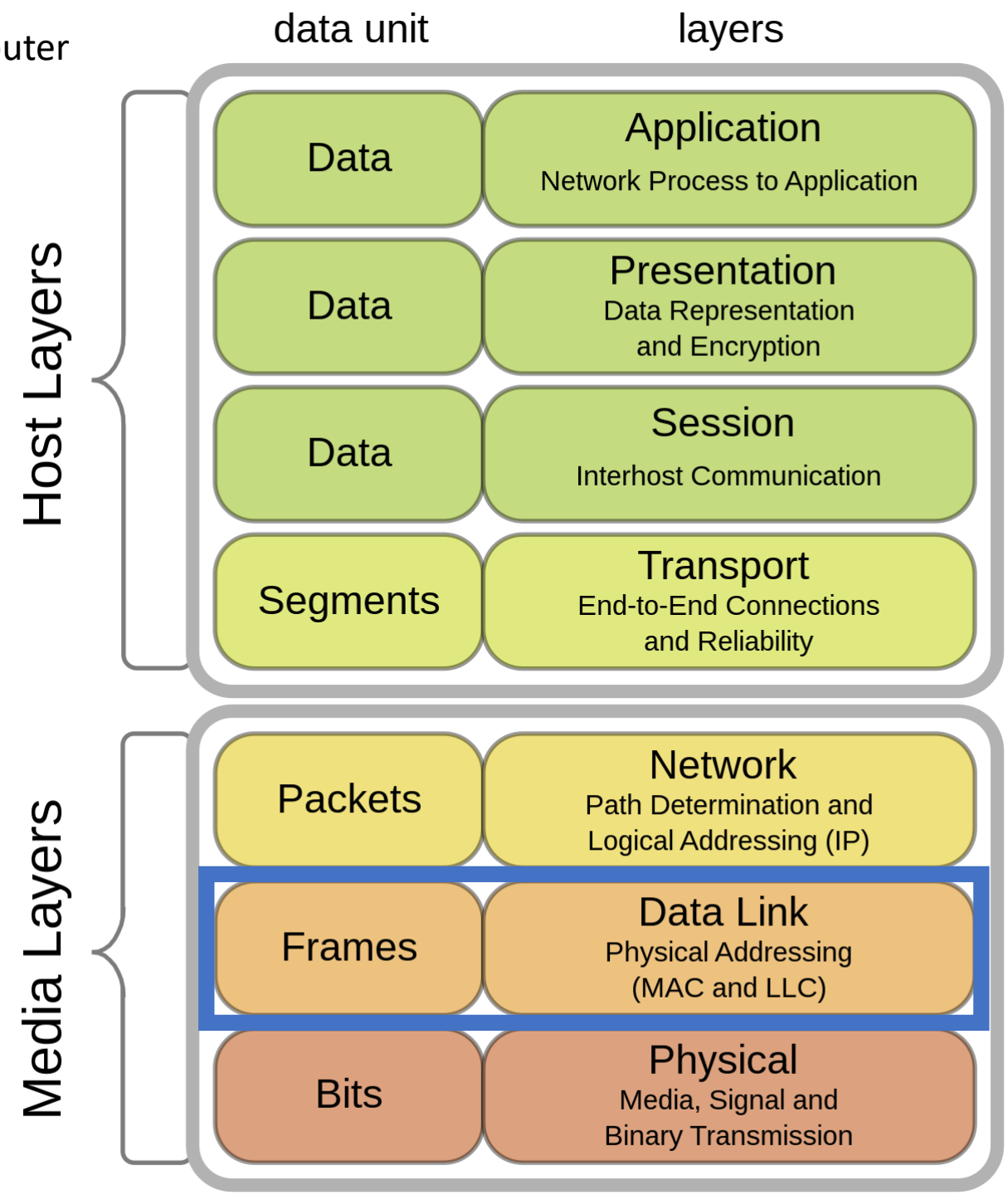



MAC Addresses

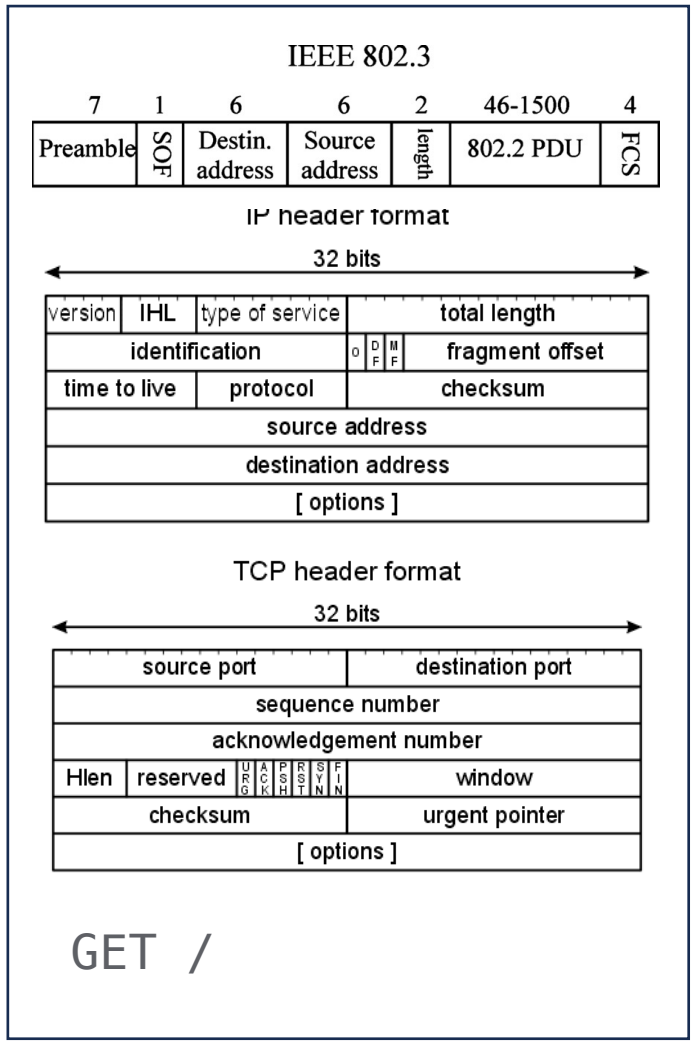
IP Addresses

Port

Let's go through the layers to construct a packet



# Example – Reading http://fricke.co.uk web page.

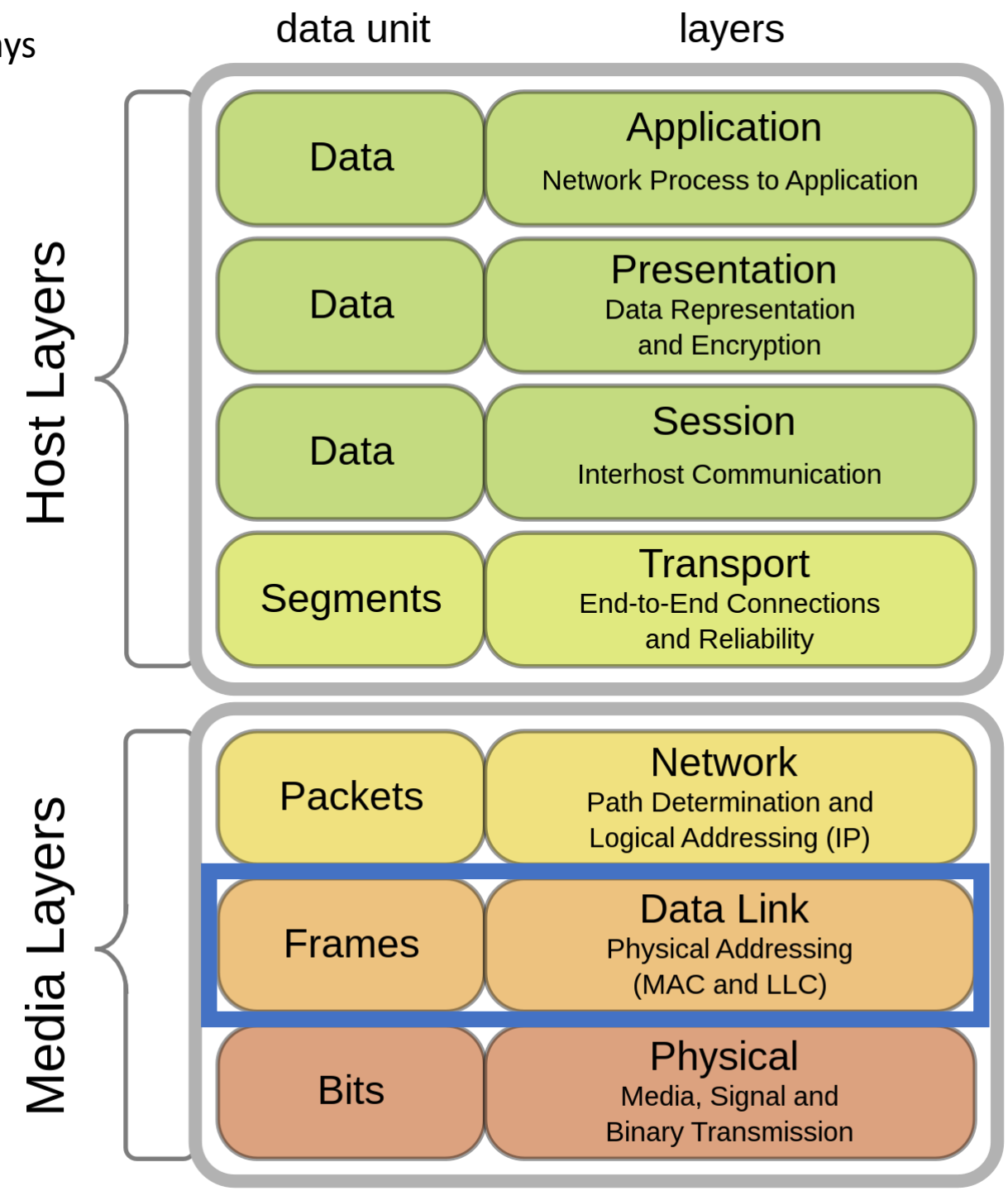



Every time the packet passes through a router the ethernet header is rewritten

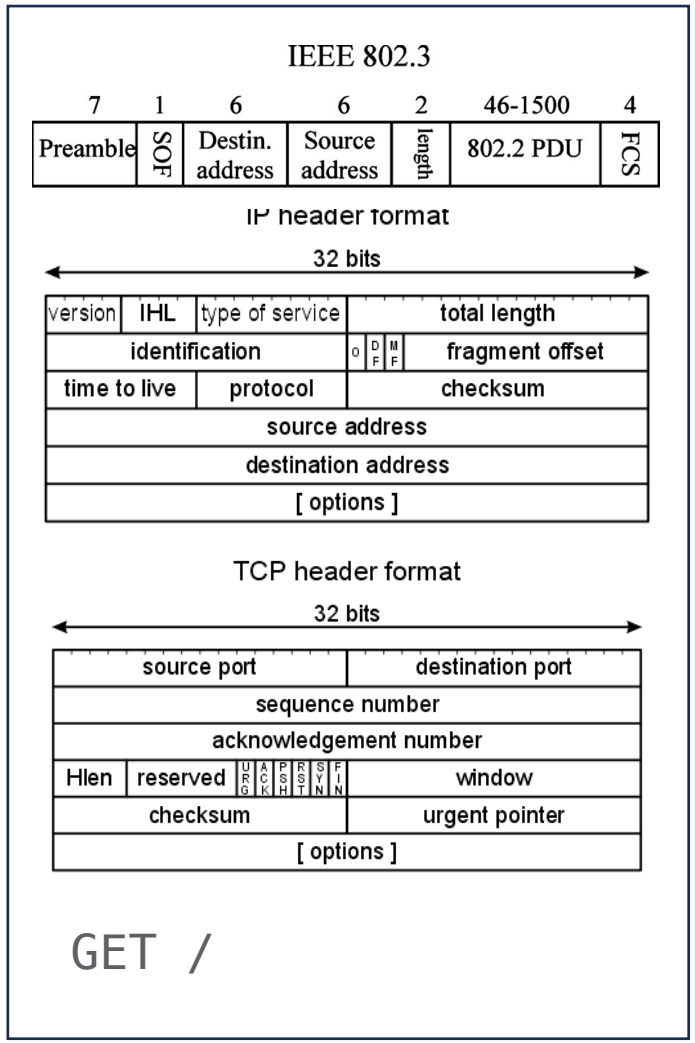
IP Addresses

Port

Let's go through the layers to construct a packet



# Example – Reading http://fricke.co.uk web page.

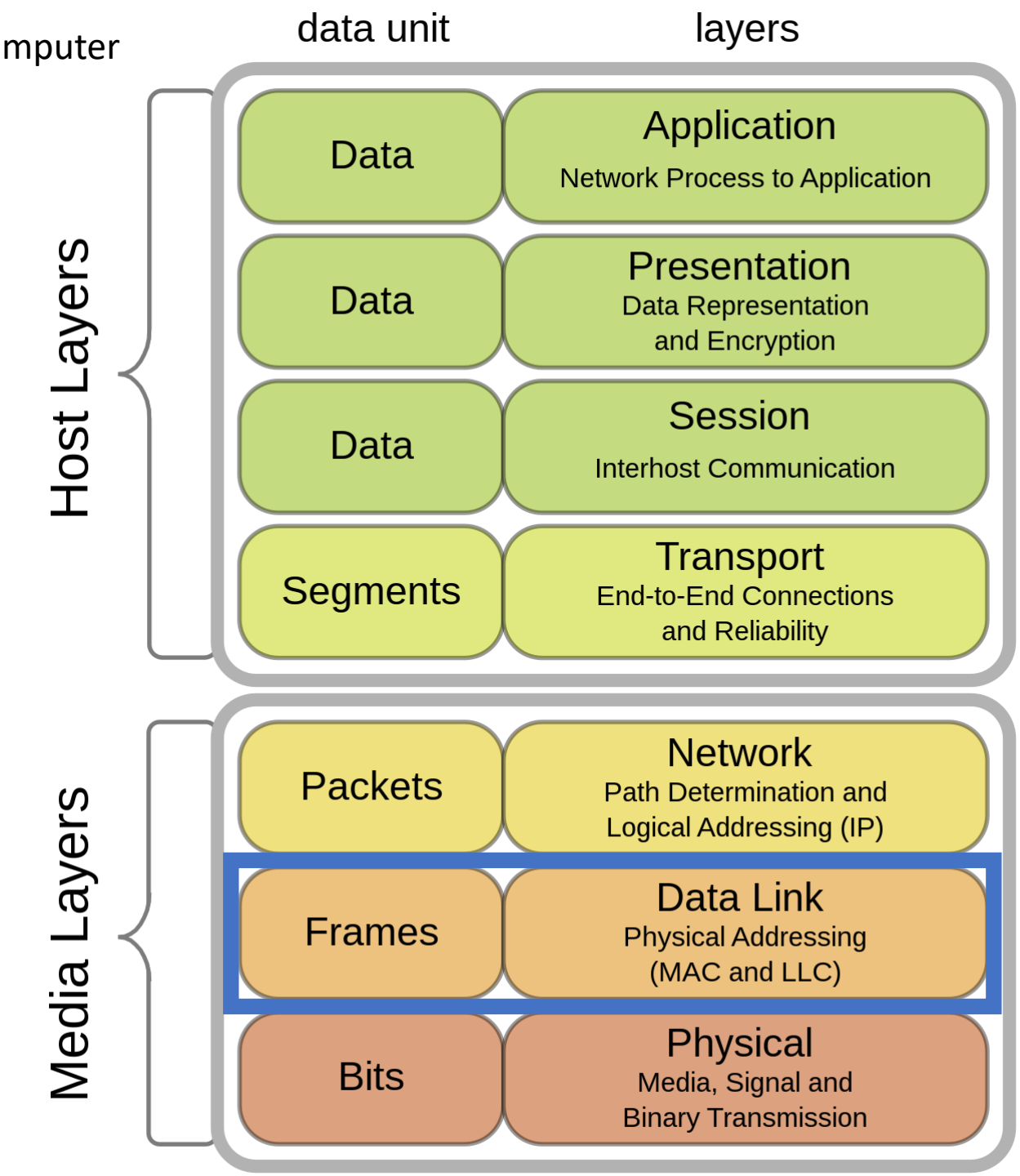



MAC Addresses

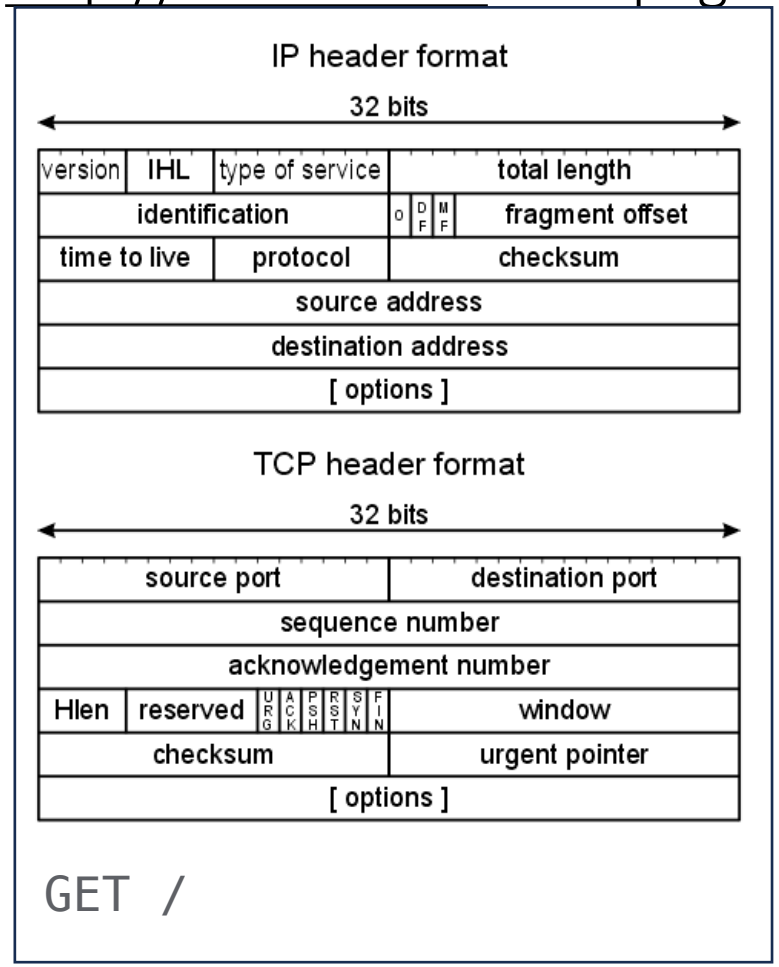
IP Addresses

Port

Let's go through the layers to construct a packet

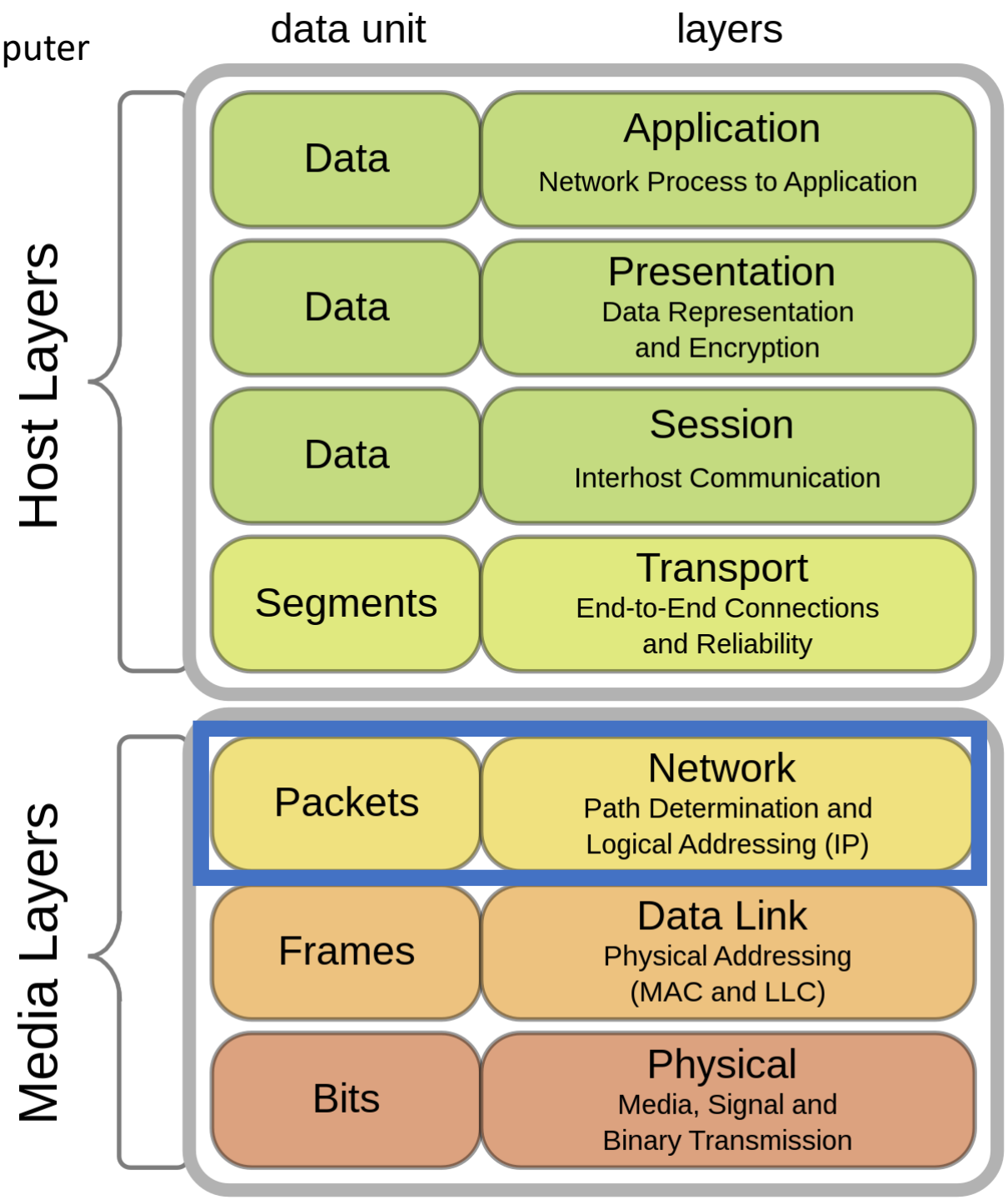


# Example – Reading http://fricke.co.uk web page.

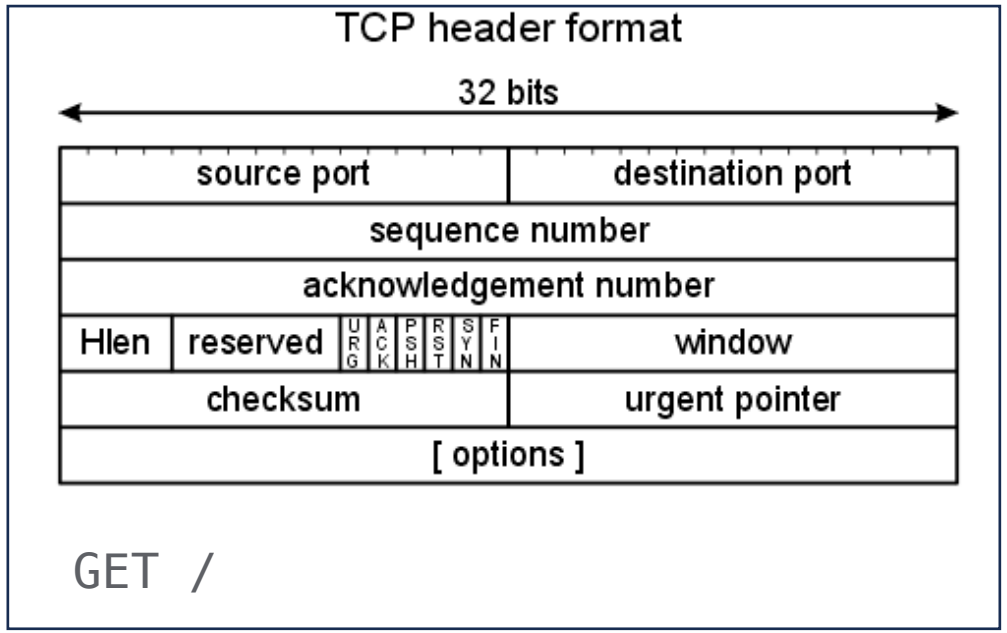



Let's go through the layers to construct a packet

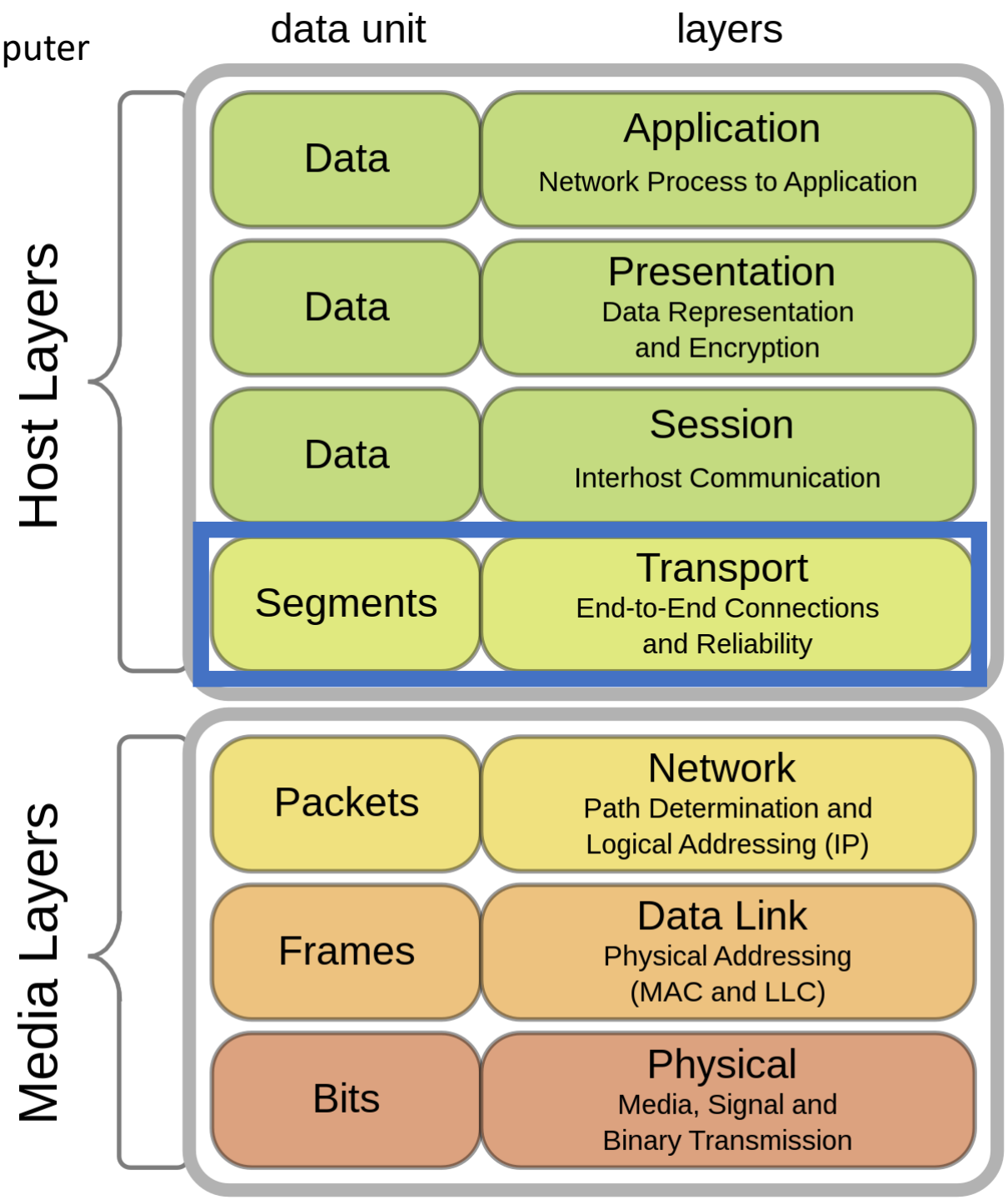
Receiving Computer



# Example – Reading http://fricke.co.uk web page.



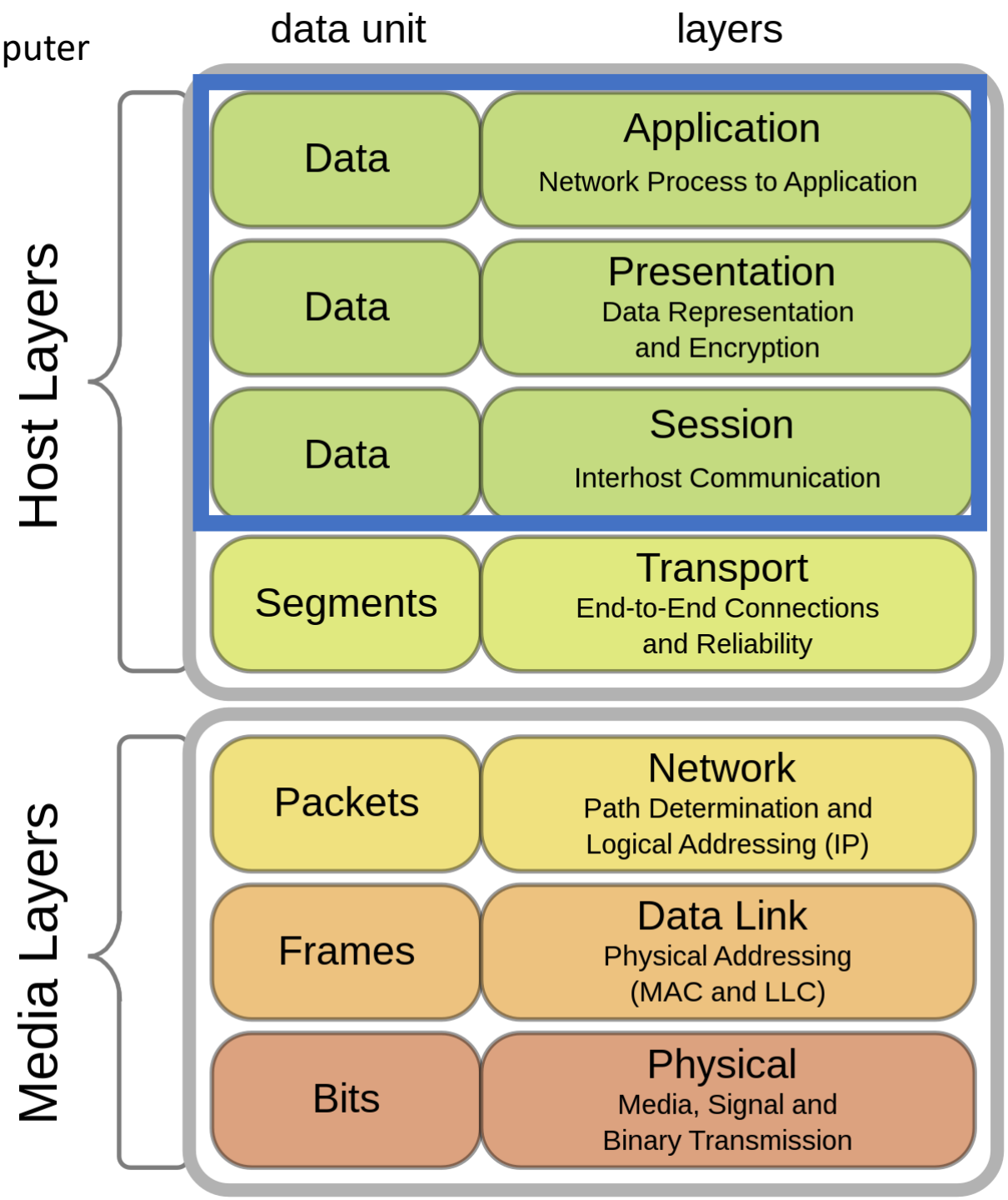

Let's go through the layers to construct a packet



# Example – Reading http://fricke.co.uk web page.

```
GET /
```

Let's go through the layers to construct a packet

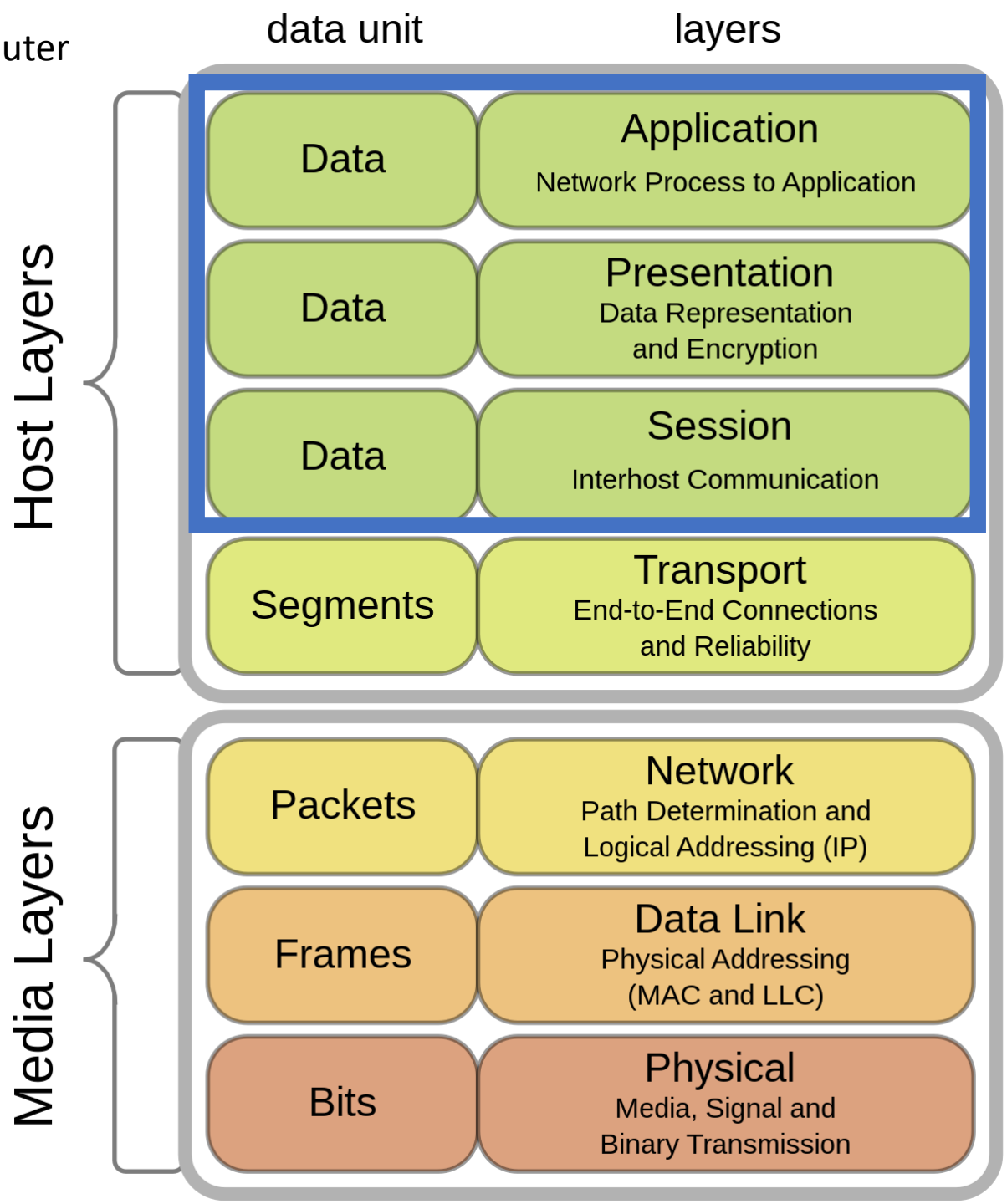


# Example – Reading http://fricke.co.uk web page.

```
<!DOCTYPE html>
<html>
<head>
<style>office
body {
    font-family: Arial;
    font-size: 16px;
    margin: 0;
}
```

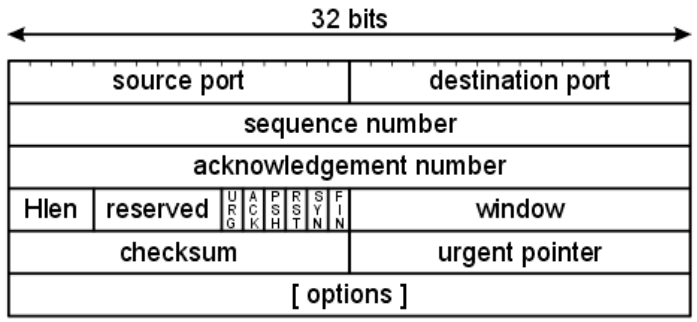
Let's go through the layers to construct a packet

Replying Computer



# Example – Reading http://fricke.co.uk web page.

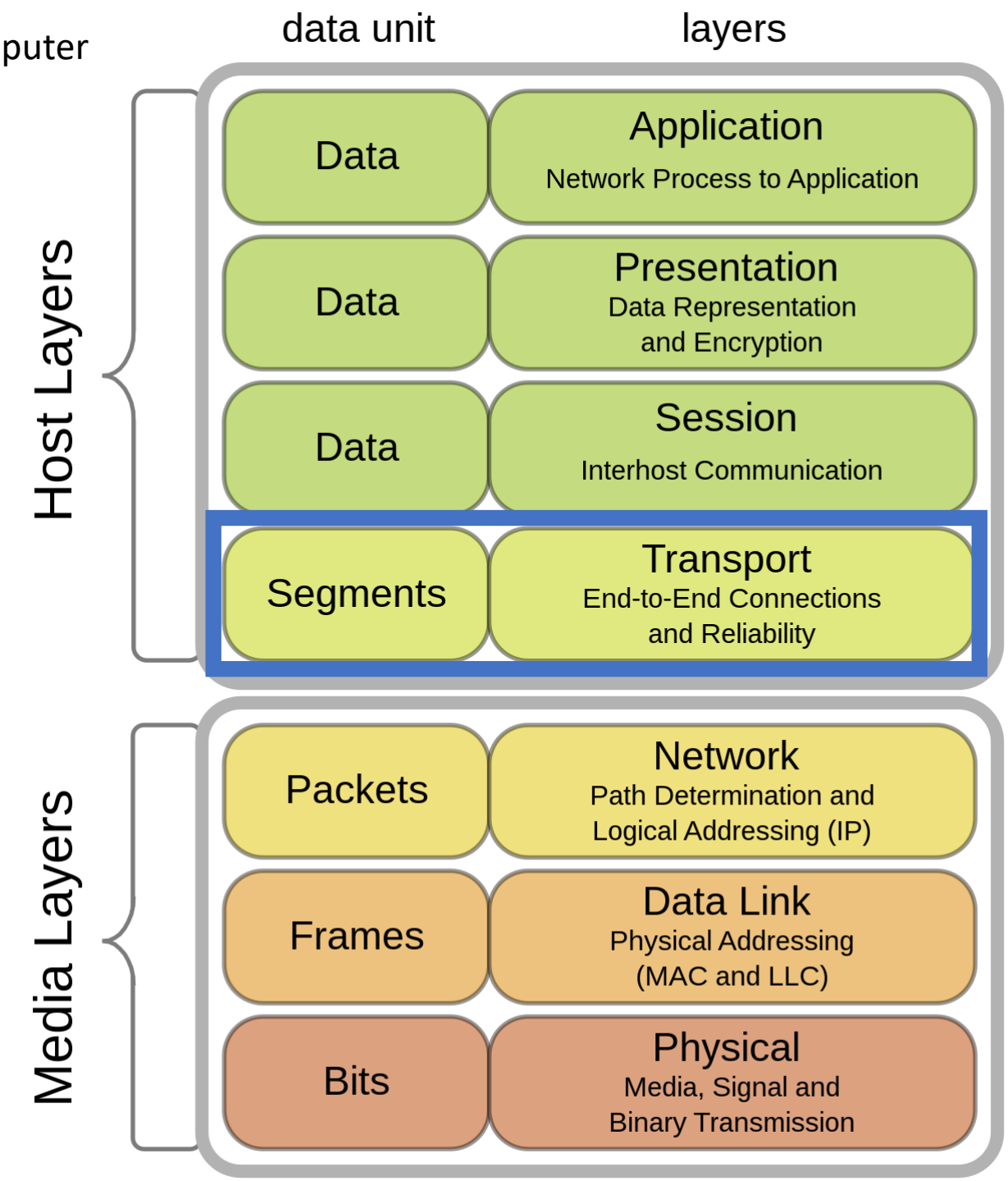
TCP header format




```
<!DOCTYPE html>
<html>
<head>
<style>office
body {
    font-family: Arial;
    font-size: 16px;
    margin: 0;
}
```

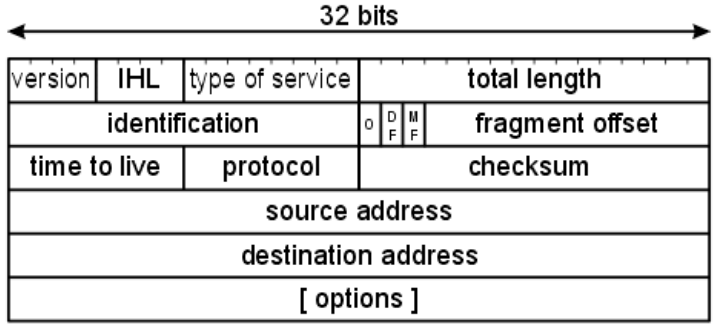
Let's go through the layers to construct a packet

Replying Computer

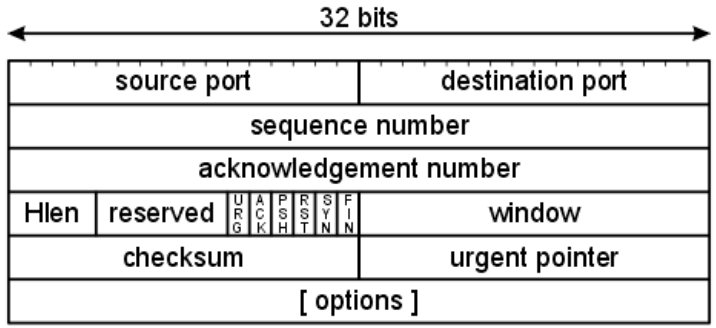


# Example – Reading http://fricke.co.uk web page.

IP header format

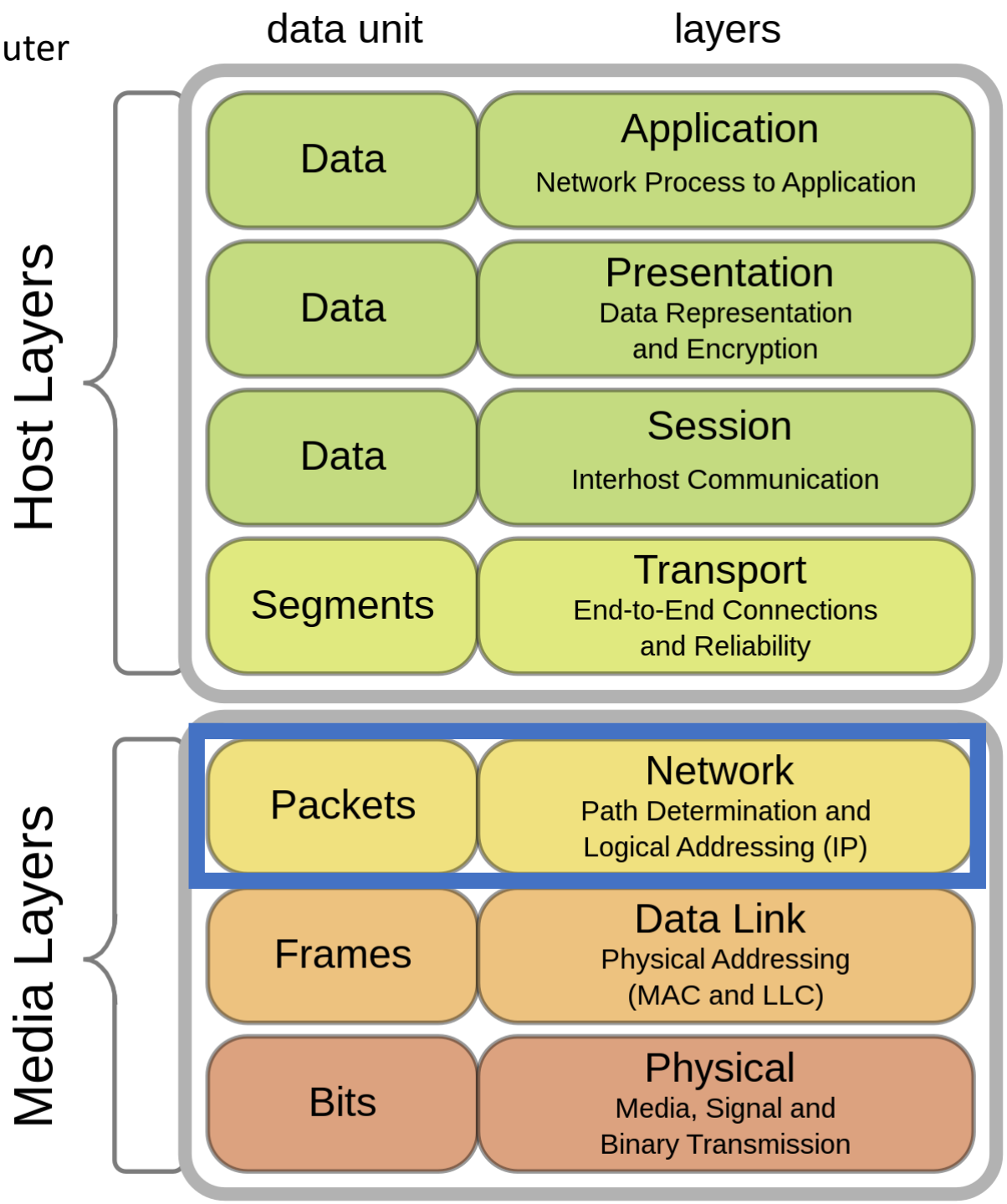



TCP header format

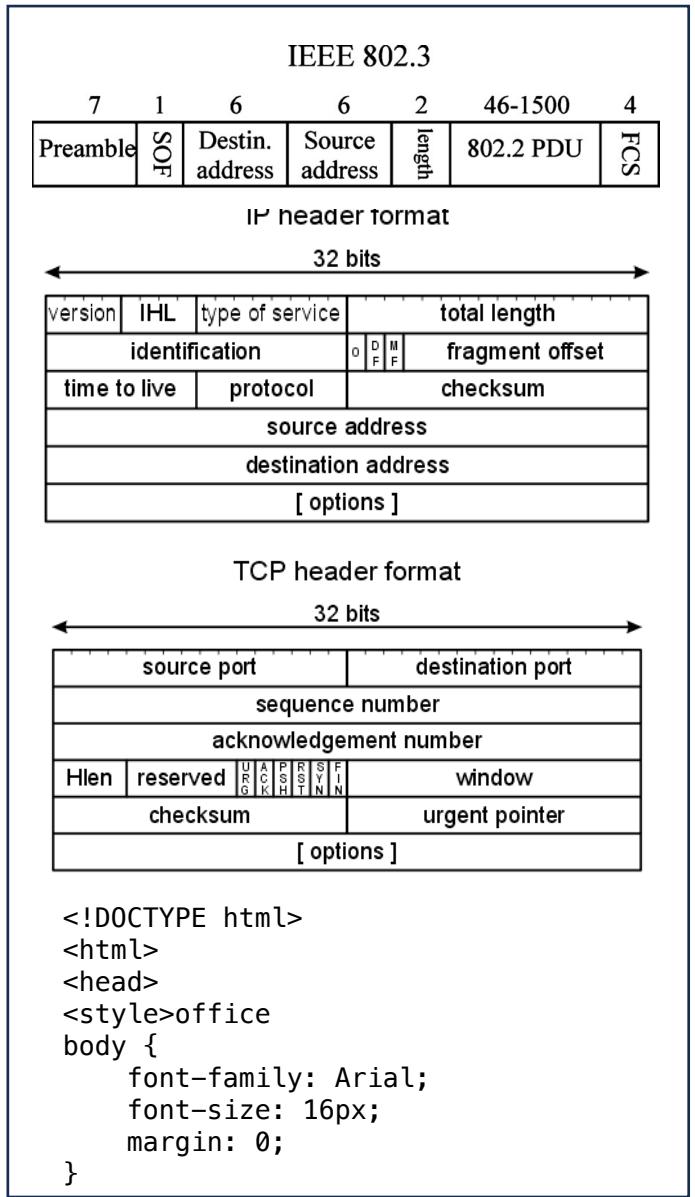



```
<!DOCTYPE html>
<html>
<head>
<style>office
body {
    font-family: Arial;
    font-size: 16px;
    margin: 0;
}
```

Replying Computer



# Example – Reading http://fricke.co.uk web page.



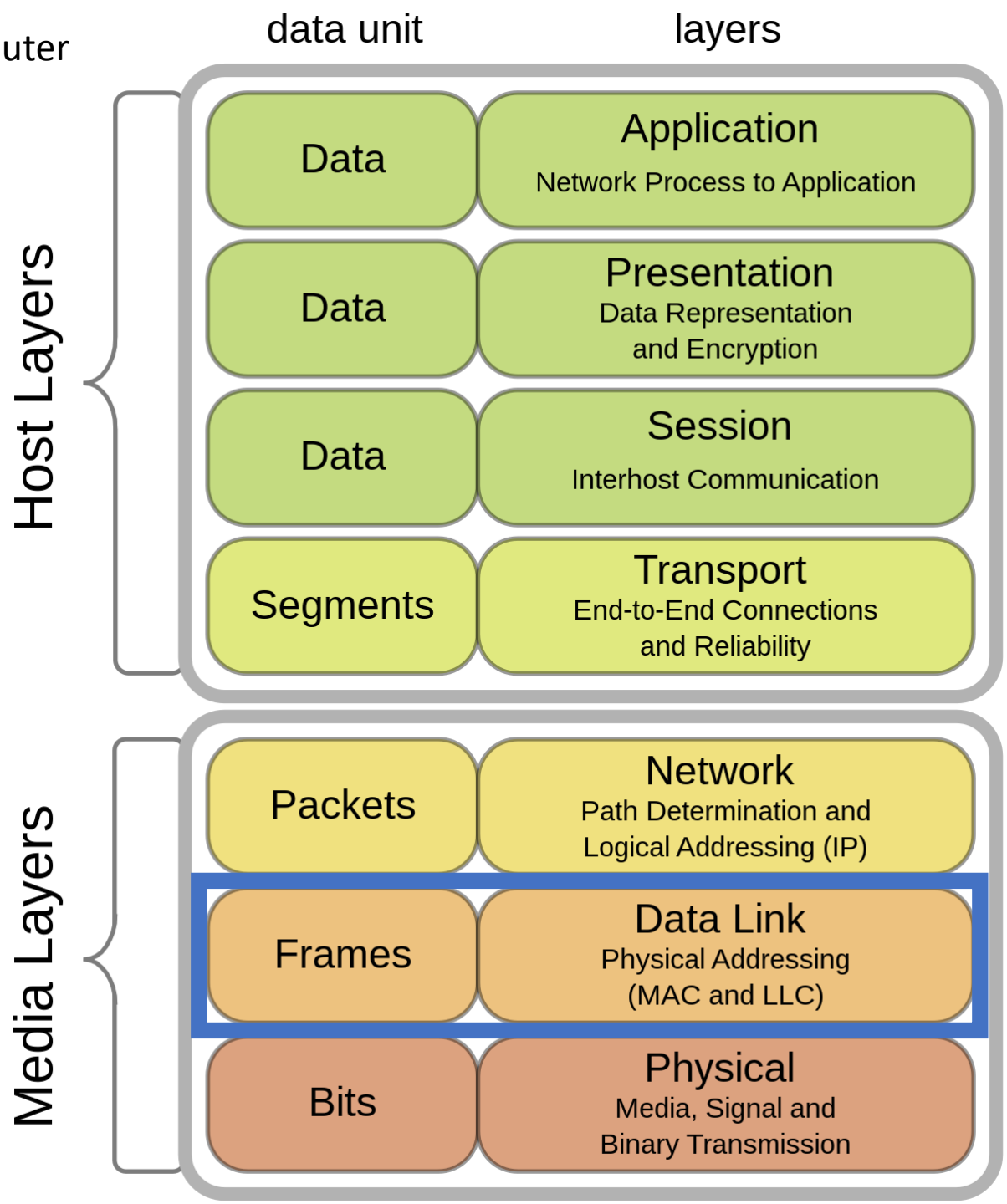

```
<!DOCTYPE html>
<html>
<head>
<style>office
body {
    font-family: Arial;
    font-size: 16px;
    margin: 0;
}
```

MAC Addresses

IP Addresses

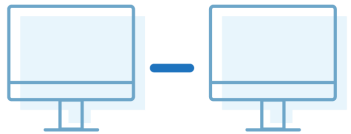
Port

Replying Computer

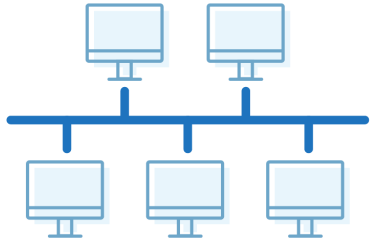


# Network Topology Types

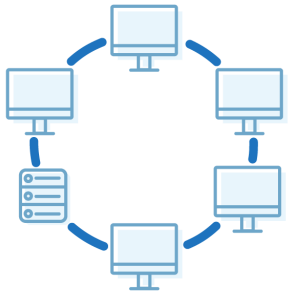
1 Point to point



2 Bus

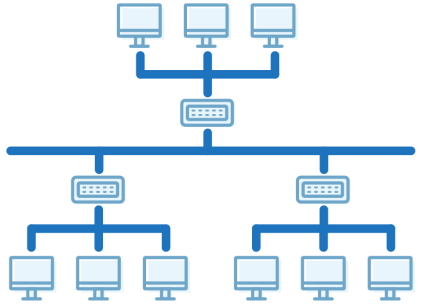


3 Ring

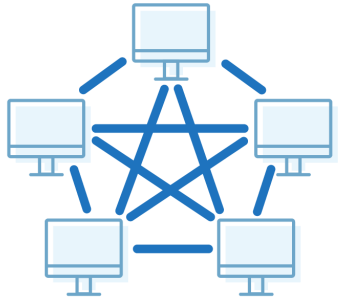


4 Star

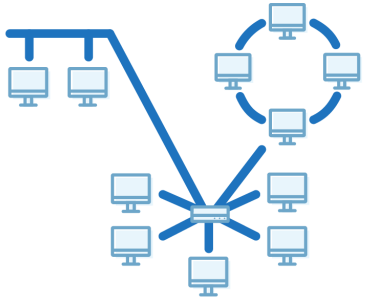
5 Tree

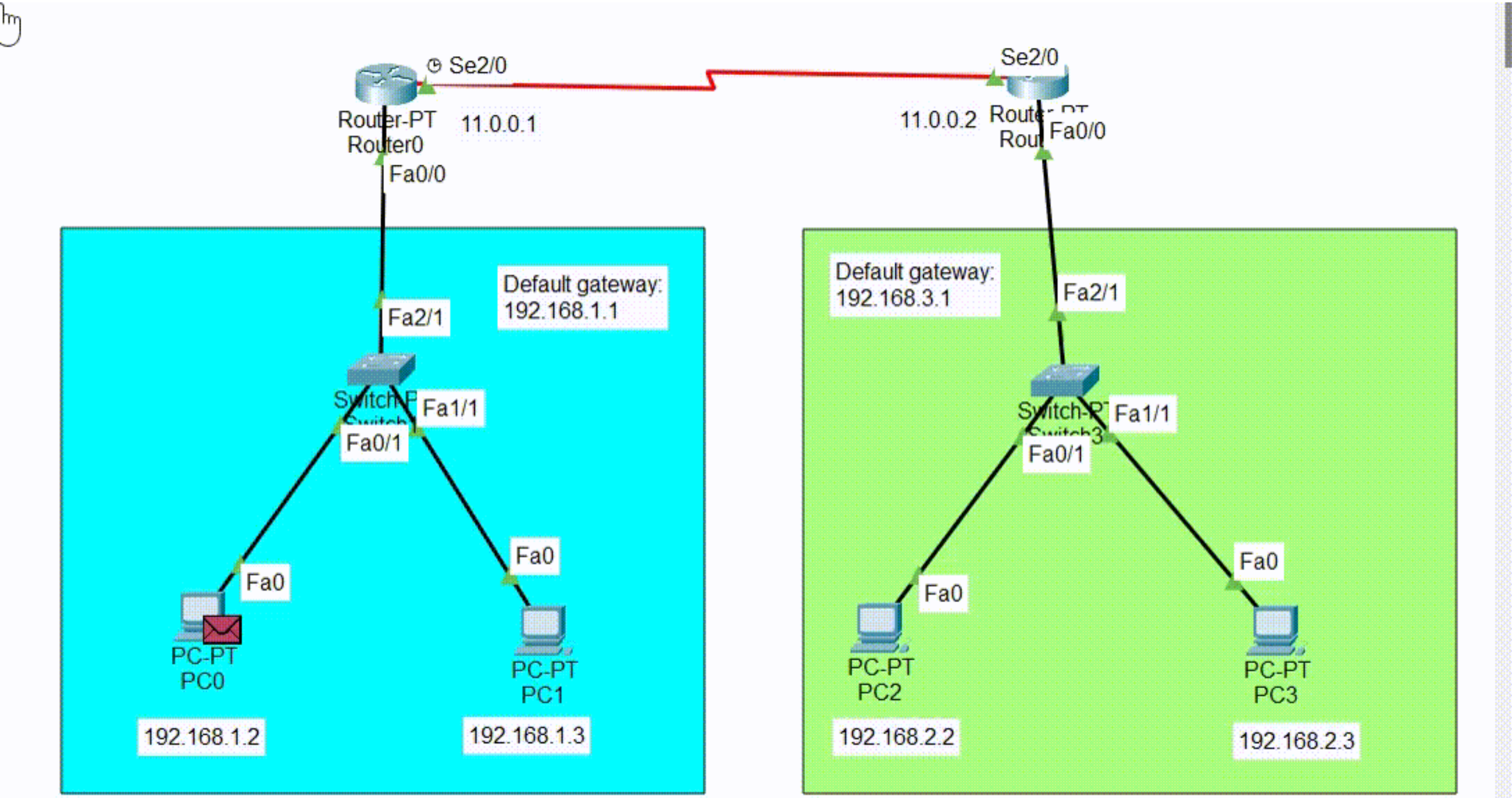


6 Mesh

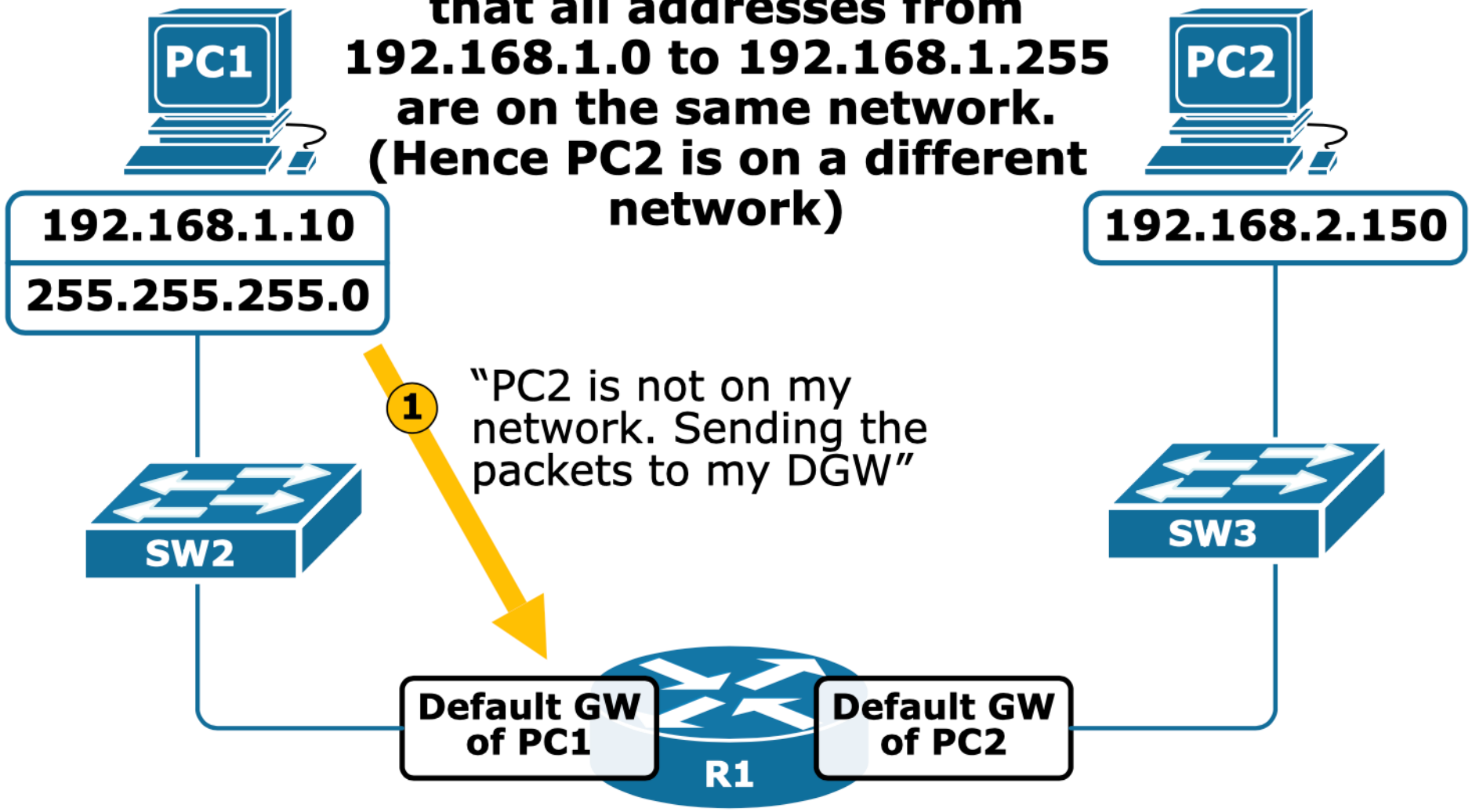


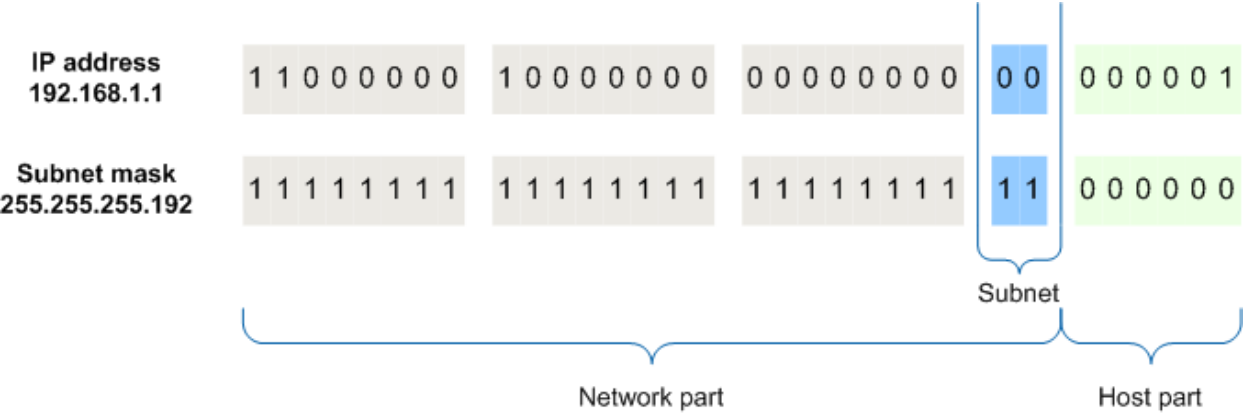
7 Hybrid




Se2/0
Router-PT
Router0
11.0.0.1
Fa0/0
Se2/0
11.0.0.2
Fa0/0
Default gateway:
192.168.1.1
Fa2/1
Fa1/1
Fa0/1
Fa0
Fa0
PC-PT
PC0
PC-PT
PC1
192.168.1.2
192.168.1.3
Default gateway:
192.168.3.1
Fa2/1
Fa1/1
Fa0/1
Fa0
Fa0
PC-PT
PC2
PC-PT
PC3
192.168.2.2
192.168.2.3

**The subnet mask tells PC1 that all addresses from 192.168.1.0 to 192.168.1.255 are on the same network. (Hence PC2 is on a different network)**

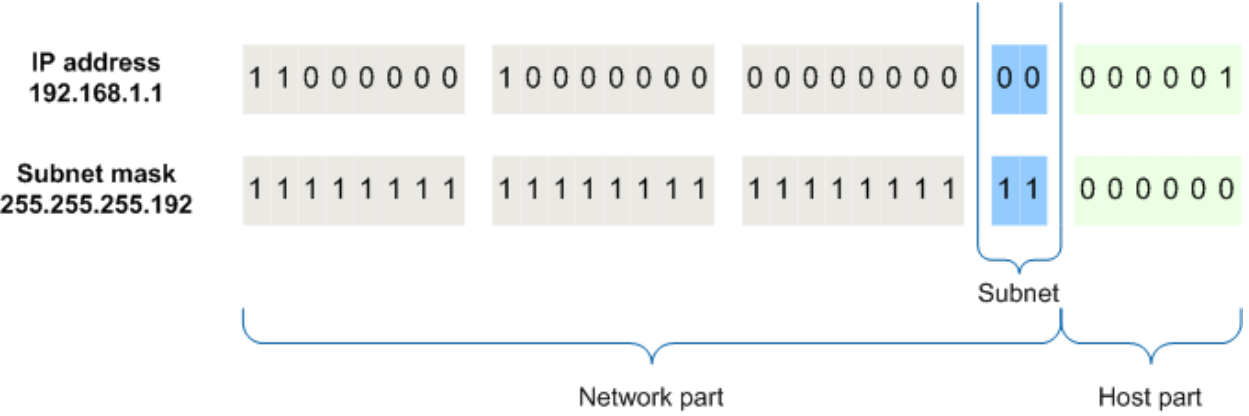





# IP Subnet Masks

The mask divides addresses into addresses that need to go through a router (network address) and those that don't (host address).

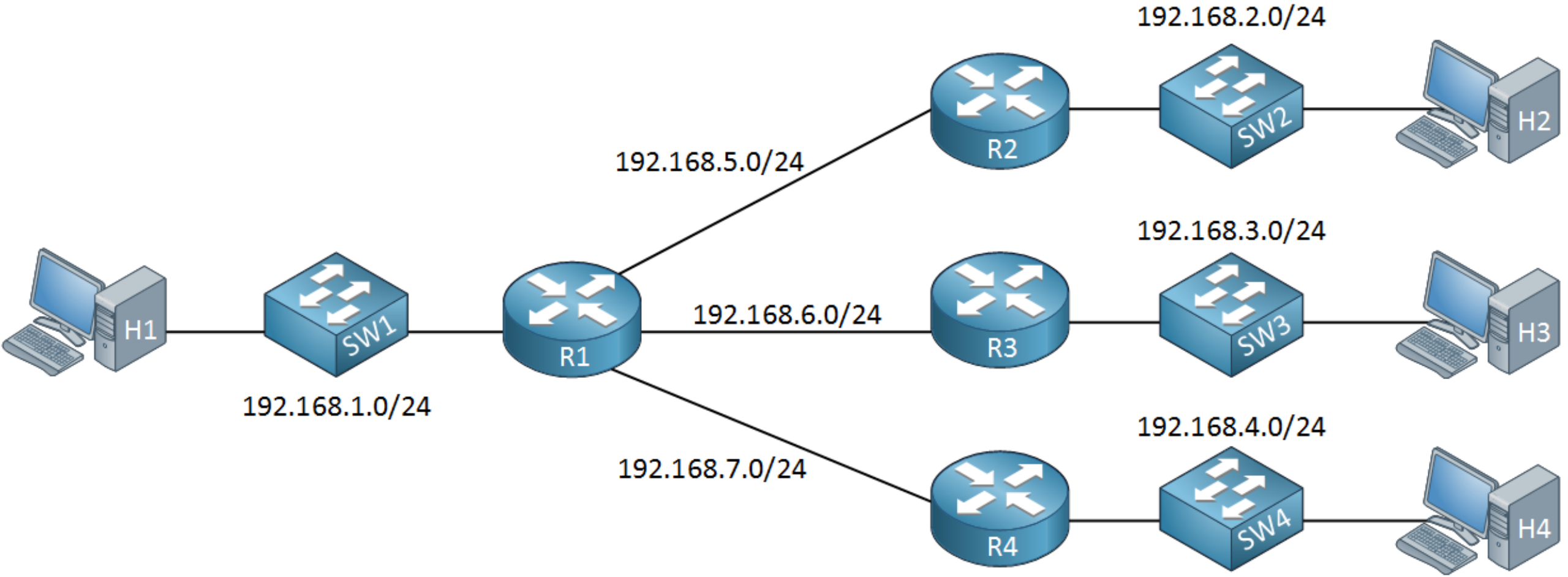
| Network Bits | Subnet Mask | Bits Borrowed | Subnets | Hosts/Subnet |
|---|---|---|---|---|
| 8 | 255.0.0.0 | 0 | 1 | 16777214 |
| 9 | 255.128.0.0 | 1 | 2 | 8388606 |
| 10 | 255.192.0.0 | 2 | 4 | 4194302 |
| 11 | 255.224.0.0 | 3 | 8 | 2097150 |
| 12 | 255.240.0.0 | 4 | 16 | 1048574 |
| 13 | 255.248.0.0 | 5 | 32 | 524286 |
| 14 | 255.252.0.0 | 6 | 64 | 262142 |
| 15 | 255.254.0.0 | 7 | 128 | 131070 |
| 16 | 255.255.0.0 | 8 | 256 | 65534 |
| 17 | 255.255.128.0 | 9 | 512 | 32766 |
| 18 | 255.255.192.0 | 10 | 1024 | 16382 |
| 19 | 255.255.224.0 | 11 | 2048 | 8190 |
| 20 | 255.255.240.0 | 12 | 4096 | 4094 |
| 21 | 255.255.248.0 | 13 | 8192 | 2046 |
| 22 | 255.255.252.0 | 14 | 16384 | 1022 |
| 23 | 255.255.254.0 | 15 | 32768 | 510 |
| 24 | 255.255.255.0 | 16 | 65536 | 254 |
| 25 | 255.255.255.128 | 17 | 131072 | 126 |
| 26 | 255.255.255.192 | 18 | 262144 | 62 |
| 27 | 255.255.255.224 | 19 | 524288 | 30 |
| 28 | 255.255.255.240 | 20 | 1048576 | 14 |
| 29 | 255.255.255.248 | 21 | 2097152 | 6 |
| 30 | 255.255.255.252 | 22 | 4194304 | 2 |




# IP Subnet Masks

The mask divides addresses into addresses that need to go through a router (network address) and those that don't (host address).

| BINARY REPRESENTATION | DECIMAL REPRESENTATION |
|---|---|
| 00000000.00000000.00000000.00000000 | 0.0.0.0 |
| 10000000.00000000.00000000.00000000 | 128.0.0.0 |
| 11000000.00000000.00000000.00000000 | 192.0.0.0 |
| 11100000.00000000.00000000.00000000 | 224.0.0.0 |
| 11110000.00000000.00000000.00000000 | 240.0.0.0 |
| 11111000.00000000.00000000.00000000 | 248.0.0.0 |
| 11111100.00000000.00000000.00000000 | 252.0.0.0 |
| 11111110.00000000.00000000.00000000 | 254.0.0.0 |
| 11111111.00000000.00000000.00000000 | 255.0.0.0 (Class A) |
| 11111111.10000000.00000000.00000000 | 255.128.0.0 |
| 11111111.11000000.00000000.00000000 | 255.192.0.0 |
| 11111111.11100000.00000000.00000000 | 255.224.0.0 |
| 11111111.11110000.00000000.00000000 | 255.240.0.0 |
| 11111111.11111000.00000000.00000000 | 255.248.0.0 |
| 11111111.11111100.00000000.00000000 | 255.252.0.0 |
| 11111111.11111110.00000000.00000000 | 255.254.0.0 |
| 11111111.11111111.00000000.00000000 | 255.255.0.0 (Class B) |
| 11111111.11111111.10000000.00000000 | 255.255.128.0 |
| 11111111.11111111.11000000.00000000 | 255.255.192.0 |
| 11111111.11111111.11100000.00000000 | 255.255.224.0 |
| 11111111.11111111.11110000.00000000 | 255.255.240.0 |
| 11111111.11111111.11111000.00000000 | 255.255.248.0 |
| 11111111.11111111.11111100.00000000 | 255.255.252.0 |
| 11111111.11111111.11111110.00000000 | 255.255.254.0 |
| 11111111.11111111.11111111.00000000 | 255.255.255.0 (Class C) |
| 11111111.11111111.11111111.10000000 | 255.255.255.128 |
| 11111111.11111111.11111111.11000000 | 255.255.255.192 |
| 11111111.11111111.11111111.11100000 | 255.255.255.224 |
| 11111111.11111111.11111111.11110000 | 255.255.255.240 |
| 11111111.11111111.11111111.11111000 | 255.255.255.248 |
| 11111111.11111111.11111111.11111100 | 255.255.255.252 |
| 11111111.11111111.11111111.11111110 | 255.255.255.254 |
| 11111111.11111111.11111111.11111111 | 255.255.255.255 |




# Networks have a hierarchical structure

# Special Addresses

A subnetwork consists of three types of addresses:

The network address (first address in the subnet)

The host addresses – can be assigned to hosts

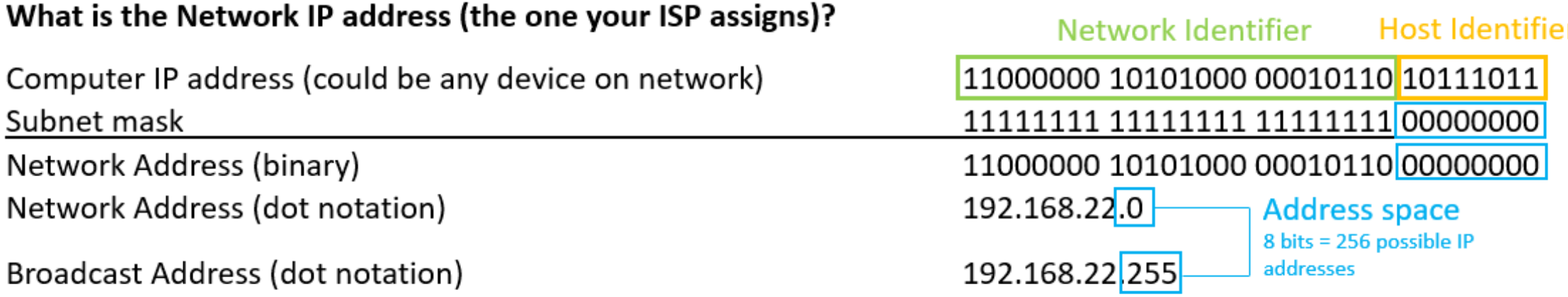
The broadcast address – last address in the range.

Packets sent to the broadcast address go to all devices in the subnet.

The network address is the address of the network itself and is used for routing.

| | |
|---|---|
| **IP Address of your Computer (base 8 or "dot" notation):** | 192.168.22.187 |
| **IP Address of your Computer (base 2 or "binary" notation):** | 11000000 10101000 00010110 10111011 |
| **Subnet Mask (base 8 or "dot" notation):** | 255.255.255.0 |
| **Subnet Mask (base 2 or "binary" notation):** | 11111111 11111111 11111111 00000000 |

**What is the Network IP address (the one your ISP assigns)?**



```
[matthew@localhost ~]$ sudo yum install traceroute
[sudo] password for matthew:
Sorry, try again.
[sudo] password for matthew:
Last metadata expiration check: 0:46:44 ago on Wed 07 Feb 2024 12:12:07 PM CST.
Dependencies resolved.
================================================================================
 Package                 Architecture           Version                 Reposi
tory               Size
================================================================================
Installing:
 traceroute              x86_64                 3:2.1.0-
16.el9                  baseos                57 k


Transaction Summary
================================================================================
Install  1 Package


Total download size: 57 k
Installed size: 108 k
Is this ok [y/N]: y
Downloading Packages:
```

```
[matthew@localhost ~]$ traceroute google.com
traceroute to google.com (172.253.115.101), 30 hops max, 60 byte packets
 1  * * *
 2  198.83.93.10 (198.83.93.10)  0.378 ms  0.358 ms  0.372 ms
 3  10.2.18.65 (10.2.18.65)  0.489 ms  0.469 ms  0.449 ms
 4  10.2.18.85 (10.2.18.85)  0.893 ms  0.873 ms  0.855 ms
 5  10-1-3-3472.ear3.Denver1.Level3.net (4.14.121.49)  8.568 ms  8.587 ms  8.568 ms
 6  Google-level3-Denver1.Level3.net (4.68.110.218)  8.580 ms  8.554 ms  8.515 ms
 7  * * *
 8  142.251.51.154 (142.251.51.154)  9.602 ms 142.251.51.220 (142.251.51.220)  8.535 ms
142.251.61.182 (142.251.61.182)  9.106 ms
 9  142.251.49.92 (142.251.49.92)  9.026 ms 209.85.143.66 (209.85.143.66)  9.686 ms  9.652 ms
10  172.253.51.78 (172.253.51.78)  9.335 ms 172.253.51.82 (172.253.51.82)  9.611 ms
172.253.51.78 (172.253.51.78)  9.359 ms
11  172.253.74.22 (172.253.74.22)  19.065 ms  19.116 ms  18.770 ms
12  142.251.250.180 (142.251.250.180)  20.471 ms  18.762 ms 172.253.77.126
(172.253.77.126)  19.793 ms
13  192.178.72.203 (192.178.72.203)  31.754 ms  31.576 ms 192.178.72.195
(192.178.72.195)  31.549 ms
14  * 192.178.81.230 (192.178.81.230)  49.200 ms 192.178.81.232 (192.178.81.232)  50.735 ms
15  172.253.67.52 (172.253.67.52)  49.206 ms 172.253.67.50 (172.253.67.50)  48.991 ms
172.253.67.0 (172.253.67.0)  48.884 ms
16  172.253.66.159 (172.253.66.159)  43.625 ms 172.253.66.155 (172.253.66.155)  49.569 ms
172.253.66.149 (172.253.66.149)  48.383 ms^
17  * * *
18  * * *…
23  * bg-in-f101.1e100.net (172.253.115.101)  48.658 ms *
```

```
[matthew@localhost ~]$ traceroute fricke.co.uk
traceroute to fricke.co.uk (50.193.238.94), 30 hops max, 60 byte packets
 1  * * *
 2  198.83.93.10 (198.83.93.10)  0.336 ms  0.359 ms  0.339 ms
 3  10.2.18.65 (10.2.18.65)  0.409 ms  0.429 ms  0.410 ms
 4  te-0-0-0-15-3972-ssag04.albuquerque.nm.albuq.comcast.net (50.226.196.225)  2.218 ms  2.313
ms *
 5  * * *
 6  be-288-ar02.albuquerque.nm.albuq.comcast.net (96.108.43.153)  3.045 ms  2.794 ms  2.765 ms
 7  be-501-arsc2.albuquerque.nm.albuq.comcast.net (96.108.67.233)  2.772 ms  2.842 ms *
 8  po-1-xar02.albuquerque.nm.albuq.comcast.net (96.108.43.106)  1.868 ms  1.855 ms  1.854 ms
 9  po-1-rur202.albuquerque.nm.albuq.comcast.net (68.85.65.122)  1.811 ms  1.696 ms  1.734 ms
10  96.216.21.222 (96.216.21.222)  1.797 ms  1.821 ms  1.788 ms
11  * * *
12  * * *
13  * * *
```

```
[root@moonshine ~]# yum install net-tools

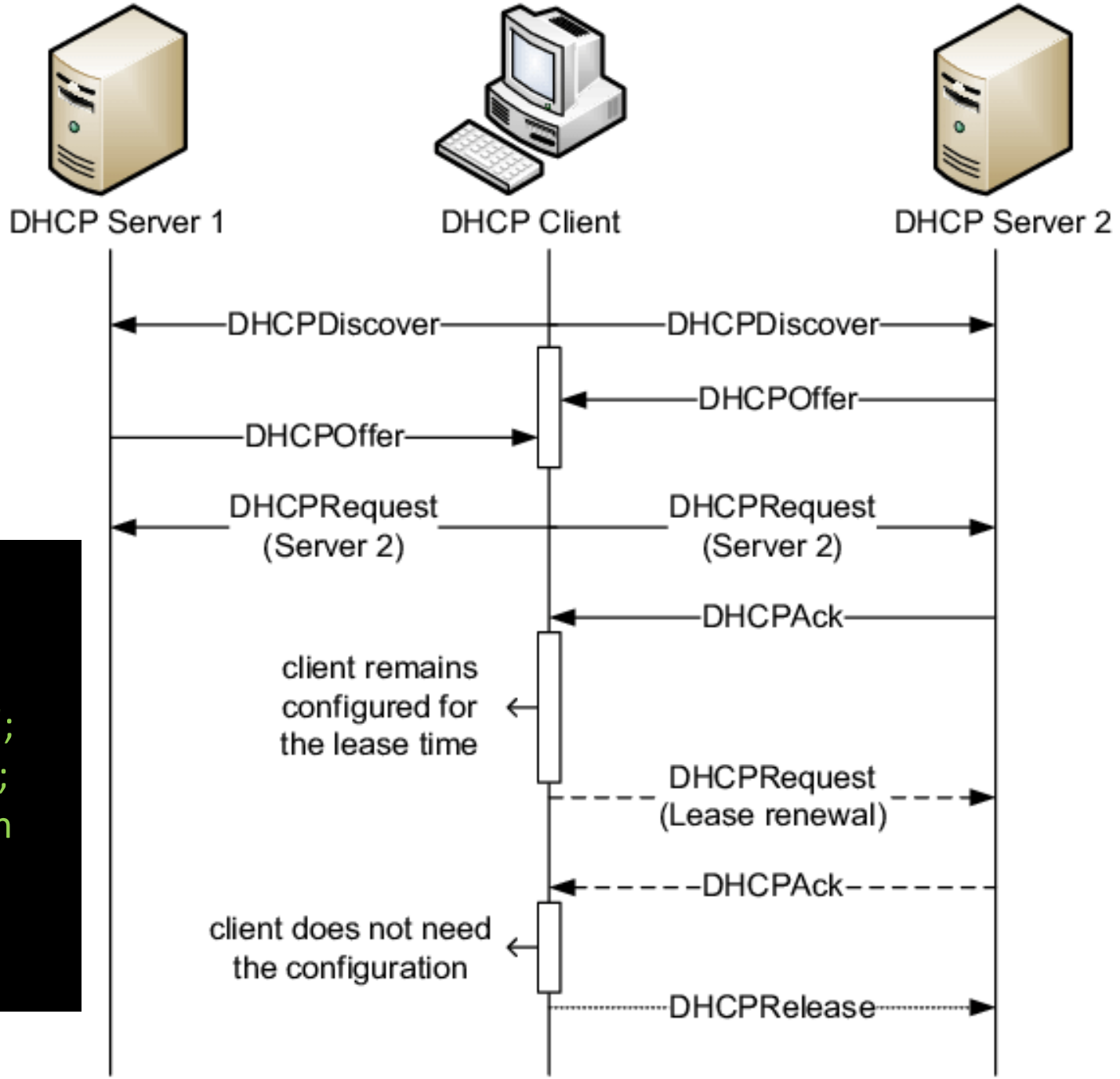
…

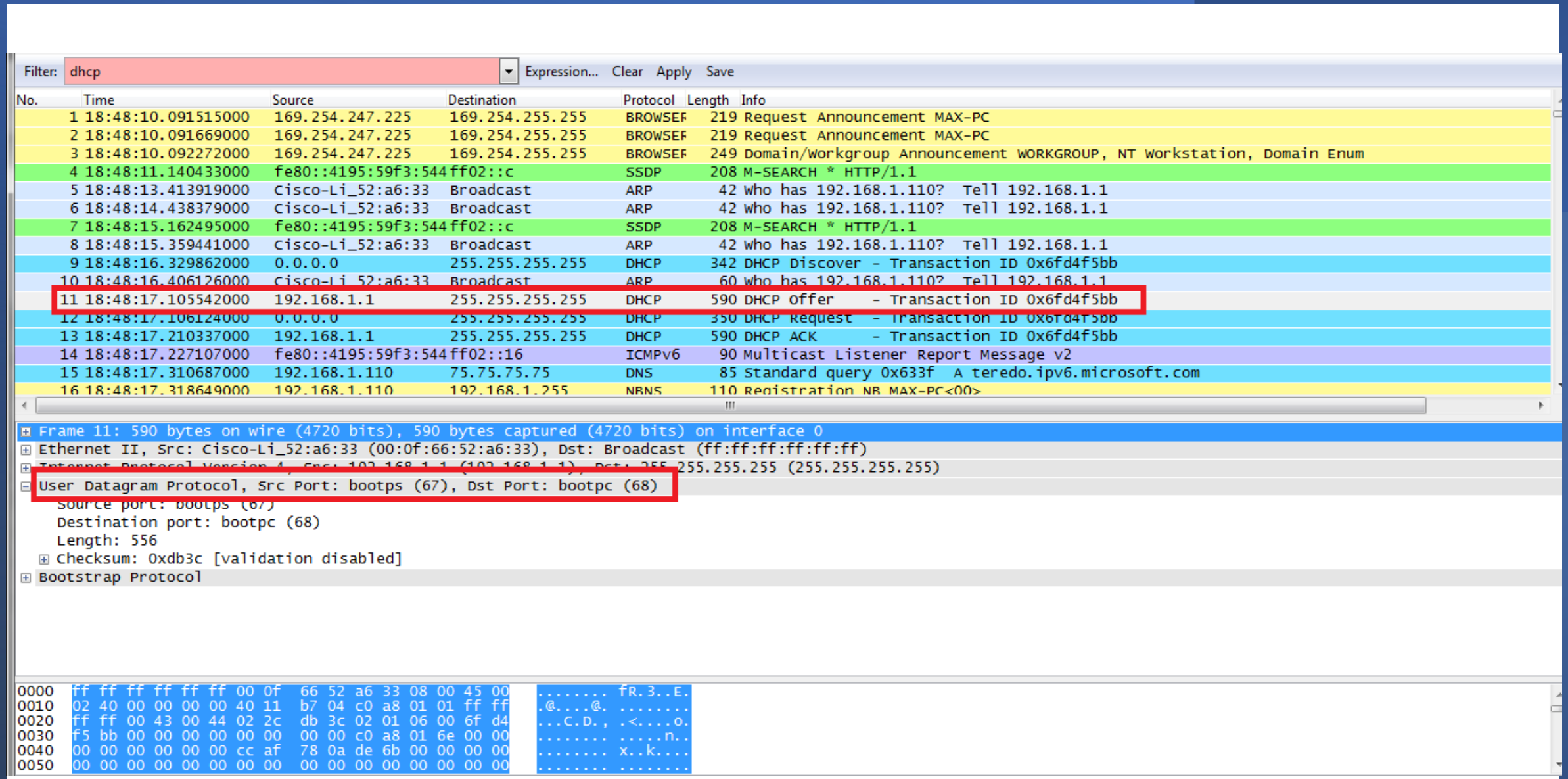
[root@localhost ~]# route
Kernel IP routing table
Destination     Gateway         Genmask         Flags Metric Ref    Use Iface
default         summit.carc.unm 0.0.0.0         UG    100    0        0 eno1
129.24.244.0    0.0.0.0         255.255.252.0   U     100    0        0 eno1
```

# Dynamic Host Configuration Protocol

When you have many hosts to configure it is useful to configure them all in one place.

```
subnet 192.168.1.0 netmask 255.255.255.0 {
      option routers                  192.168.1.254;
      option subnet-mask              255.255.255.0;
      option domain-search            "example.com";
      option domain-name-servers      192.168.1.1;
      option time-offset              -18000;     # Eastern
Standard Time
            range 192.168.1.10 192.168.1.100;
}
```




Filter: dhcp
Expression... Clear Apply Save
No. Time Source Destination Protocol Length Info
1 18:48:10.091515000 169.254.247.225 169.254.255.255 BROWSER 219 Request Announcement MAX-PC
2 18:48:10.091669000 169.254.247.225 169.254.255.255 BROWSER 219 Request Announcement MAX-PC
3 18:48:10.092272000 169.254.247.225 169.254.255.255 BROWSER 249 Domain/Workgroup Announcement WORKGROUP, NT Workstation, Domain Enum
4 18:48:11.140433000 fe80::4195:59f3:544 ff02::c SSDP 208 M-SEARCH * HTTP/1.1
5 18:48:13.413919000 Cisco-Li_52:a6:33 Broadcast ARP 42 Who has 192.168.1.110? Tell 192.168.1.1
6 18:48:14.438379000 Cisco-Li_52:a6:33 Broadcast ARP 42 Who has 192.168.1.110? Tell 192.168.1.1
7 18:48:15.162495000 fe80::4195:59f3:544 ff02::c SSDP 208 M-SEARCH * HTTP/1.1
8 18:48:15.359441000 Cisco-Li_52:a6:33 Broadcast ARP 42 Who has 192.168.1.110? Tell 192.168.1.1
9 18:48:16.329862000 0.0.0.0 255.255.255.255 DHCP 342 DHCP Discover - Transaction ID 0x6fd4f5bb
10 18:48:16.406126000 Cisco-Li_52:a6:33 Broadcast ARP 60 Who has 192.168.1.110? Tell 192.168.1.1
11 18:48:17.105542000 192.168.1.1 255.255.255.255 DHCP 590 DHCP Offer - Transaction ID 0x6fd4f5bb
12 18:48:17.106124000 0.0.0.0 255.255.255.255 DHCP 350 DHCP Request - Transaction ID 0x6fd4f5bb
13 18:48:17.210337000 192.168.1.1 255.255.255.255 DHCP 590 DHCP ACK - Transaction ID 0x6fd4f5bb
14 18:48:17.227107000 fe80::4195:59f3:544 ff02::16 ICMPv6 90 Multicast Listener Report Message v2
15 18:48:17.310687000 192.168.1.110 75.75.75.75 DNS 85 Standard query 0x633f A teredo.ipv6.microsoft.com
16 18:48:17.318649000 192.168.1.110 192.168.1.255 NBNS 110 Registration NB MAX-PC<00>
Frame 11: 590 bytes on wire (4720 bits), 590 bytes captured (4720 bits) on interface 0
Ethernet II, Src: Cisco-Li_52:a6:33 (00:0f:66:52:a6:33), Dst: Broadcast (ff:ff:ff:ff:ff:ff)
255.255.255.255 (255.255.255.255)
User Datagram Protocol, Src Port: bootps (67), Dst Port: bootpc (68)
Source port: bootps (67)
Destination port: bootpc (68)
Length: 556
Checksum: 0xdb3c [validation disabled]
Bootstrap Protocol
0000 ff ff ff ff ff ff 00 0f 66 52 a6 33 08 00 45 00 ........ fR.3..E.
0010 02 40 00 00 00 00 40 11 b7 04 c0 a8 01 01 ff ff .@....@. ........
0020 ff ff 00 43 00 44 02 2c db 3c 02 01 06 00 6f d4 ...C.D., .<....o.
0030 f5 bb 00 00 00 00 00 00 00 00 c0 a8 01 6e 00 00 ........ .....n..
0040 00 00 00 00 00 00 cc af 78 0a de 6b 00 00 00 00 ........ x..k....
0050 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 ........ ........

# Packet Sniffing

In one terminal connected to your cluster run

sudo yum install wireshark-cli

watch wget http://fricke.co.uk

In another we will look at ARP traffic

sudo tshark -i <network interface> -f "arp”

What’s this?

sudo tshark –i <network interface> -f "port 22"

# Packet Sniffing

In one terminal connected to your cluster run

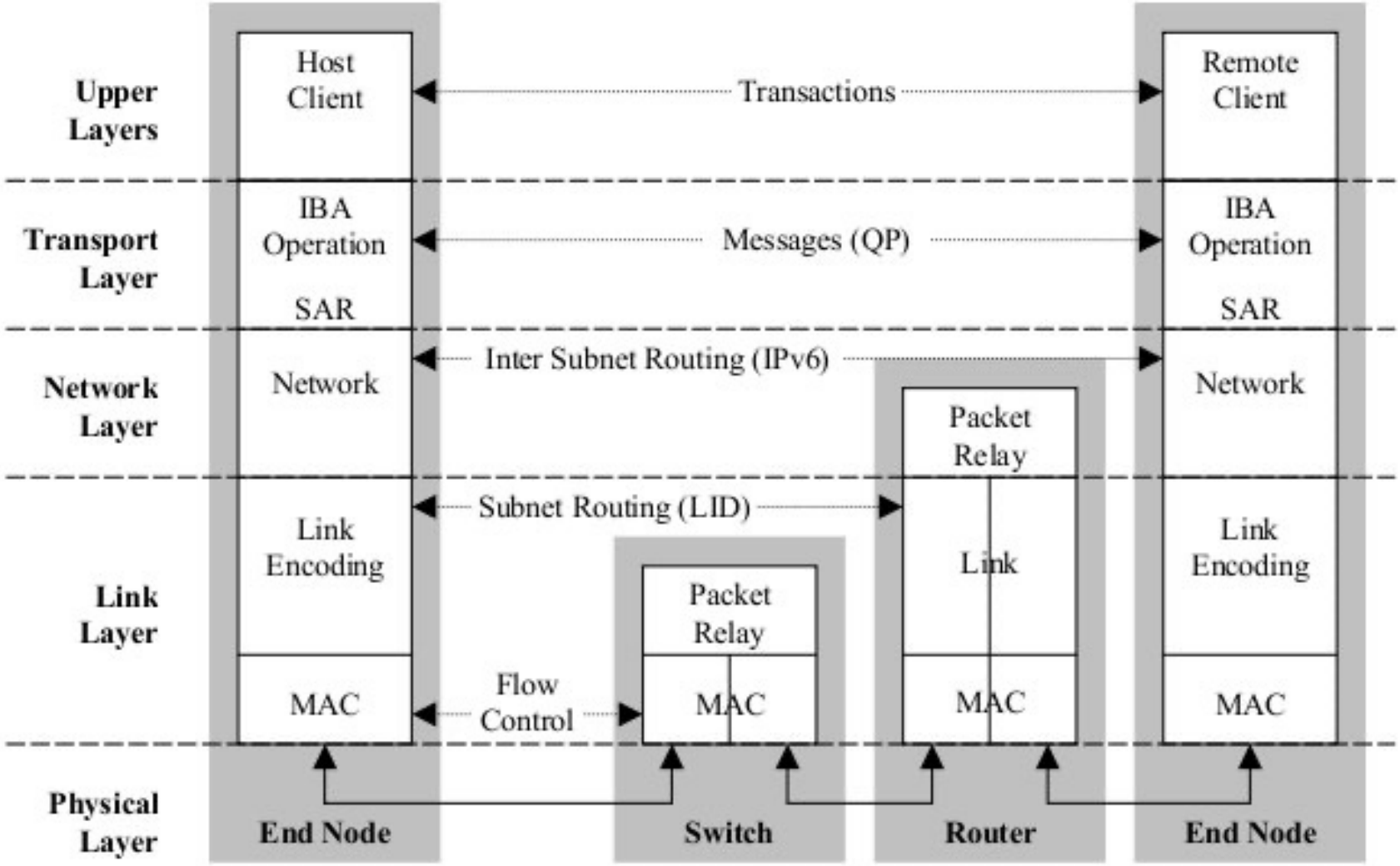
watch wget http://fricke.co.uk

In another

sudo tshark -V --color -i <interface name> -f "host fricke.co.uk" -f "port 80" -x

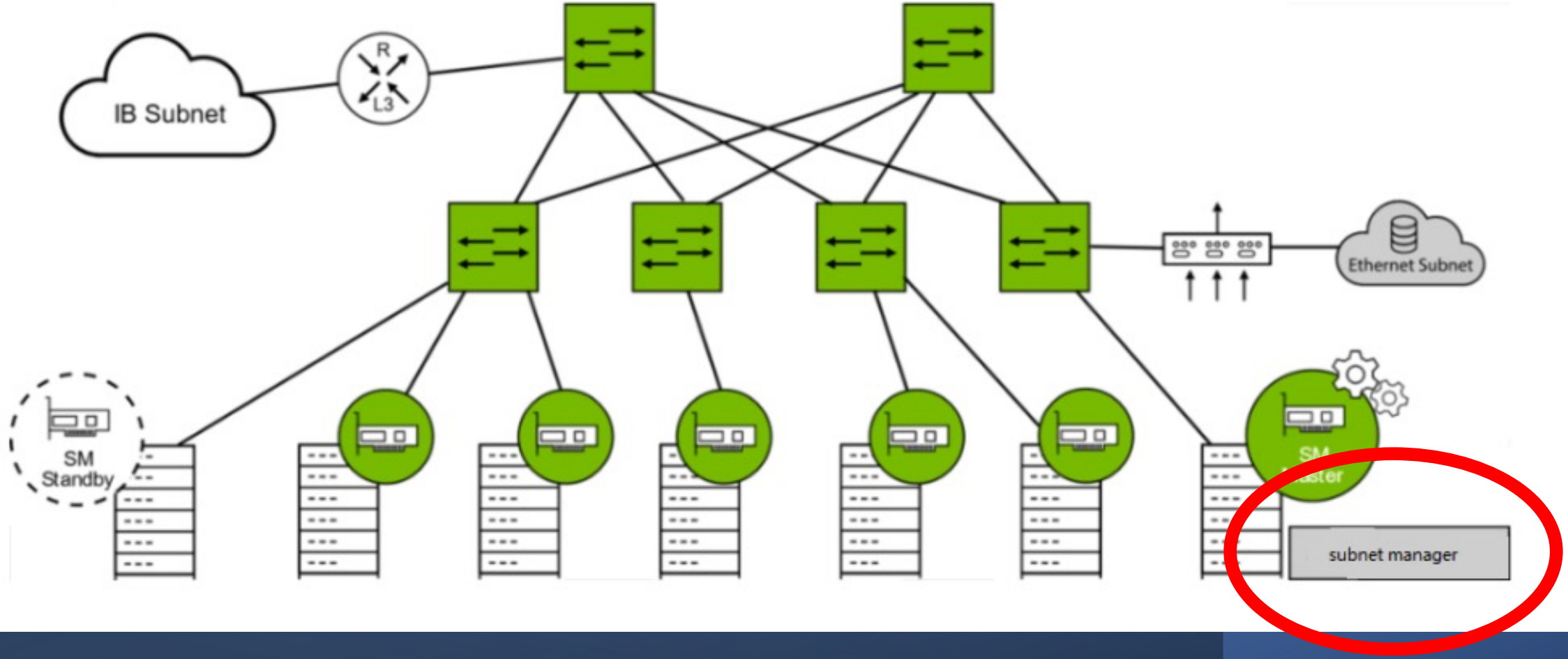
# Infiniband uses RDMA based Communication

1999




Everything in the OSI model is handled by the kernel.
Infiniband tries to bypass the Kernel and even the CPU to increase performance.
DMA is Direct Memory Access. (Bypass CPU and kernel, Remote Direct Memory Access)

Ethernet broadcasts data and switches learn routes.
Infiniband uses a centralized subnet manager (opensm for example) that learns the routes and tells all the clients.



```
mfricke@hopper:~ $ systemctl status opensm
● opensm.service - Starts the OpenSM InfiniBand fabric Subnet
Manager
   Loaded: loaded (/usr/lib/systemd/system/opensm.service;
enabled; vendor pres
   Active: active (running) since Wed 2023-12-20 09:07:30 MST;
1 months 20 days
     Docs: man:opensm
 Main PID: 1373 (opensm-launch)
    Tasks: 72 (limit: 605216)
   Memory: 11.9M
   CGroup: /system.slice/opensm.service
           ├─ 1373 /bin/bash /usr/libexec/opensm-launch
           └─10819 /usr/sbin/opensm
```

# Comparison of latency

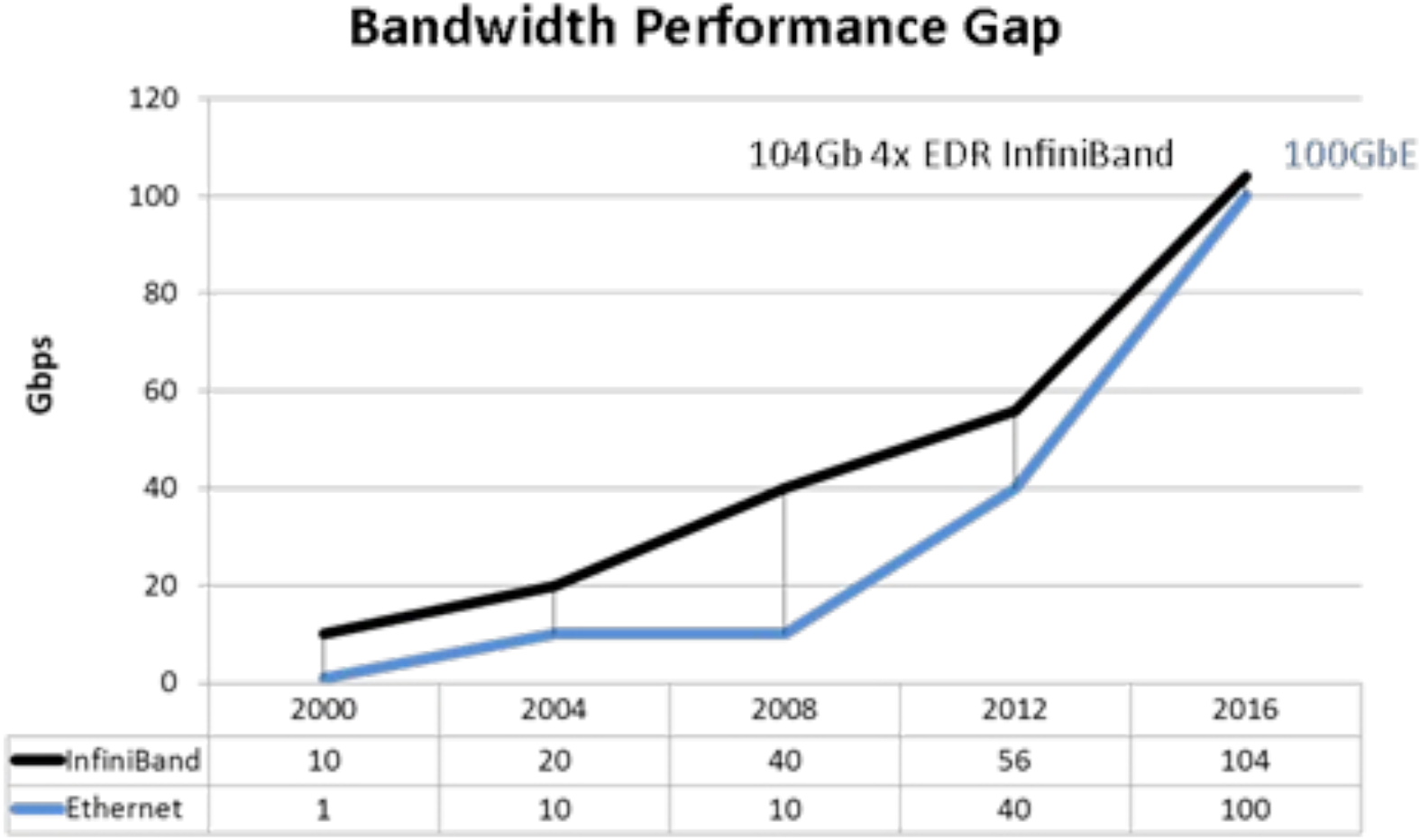
Infiniband uses a credit strategy instead of CDMA/CD.

Each receivers “credit” is the amount of buffer space they have to receive data.

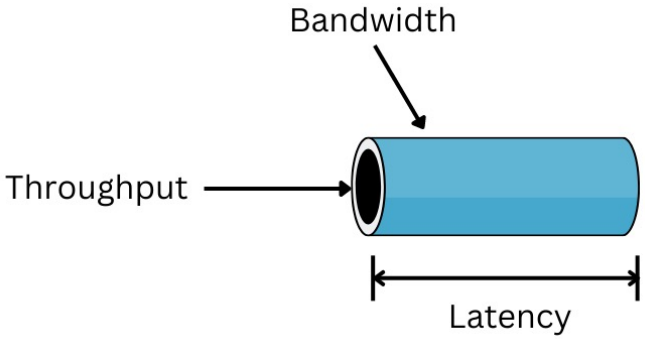
Only receivers who can actually receive all the data to be transmitted are allowed to receive.

With ethernet a switch stores the whole message incase it needs to retransmit.

Infiniband switches don’t need to receive the whole message before sending it on to the destination host.




| | 2000 | 2004 | 2008 | 2012 | 2016 |
|---|---|---|---|---|---|
| InfiniBand | 10 | 20 | 40 | 56 | 104 |
| Ethernet | 1 | 10 | 10 | 40 | 100 |




Latency is the delay between sending and receiving.

Throughput is how much data gets transmitted in a time period

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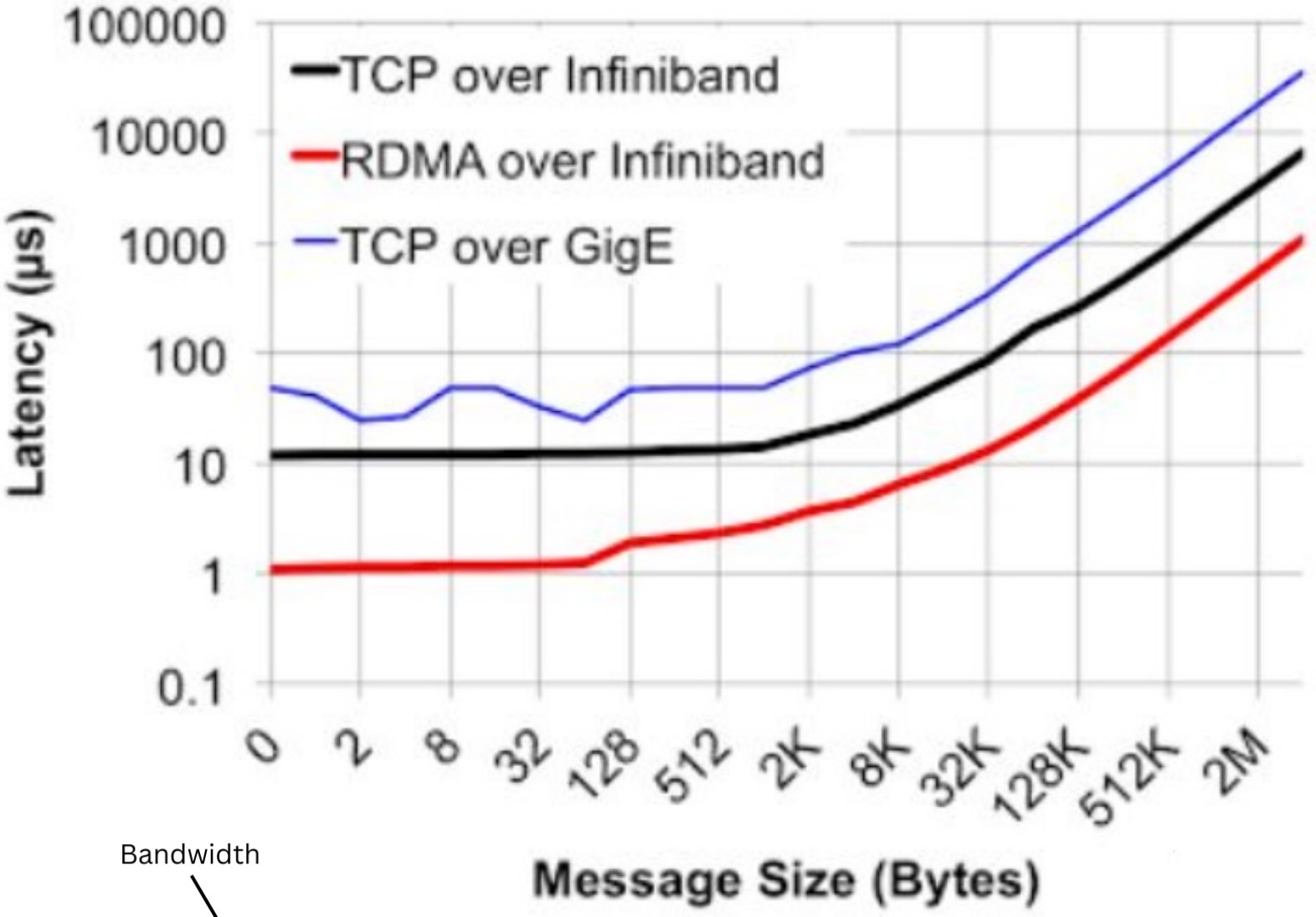


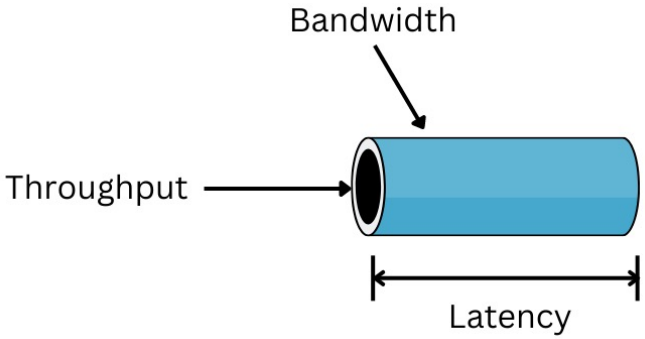


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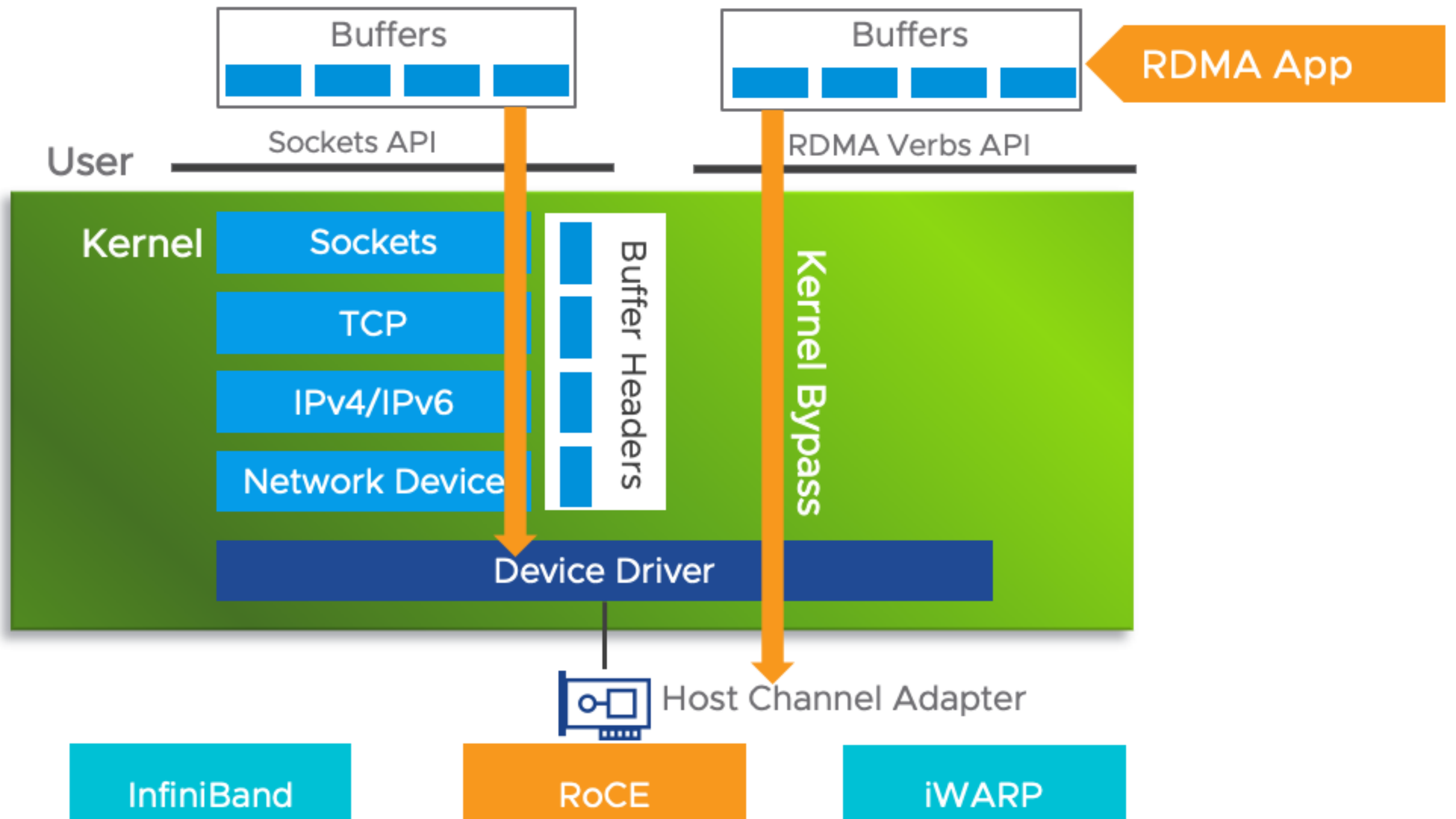
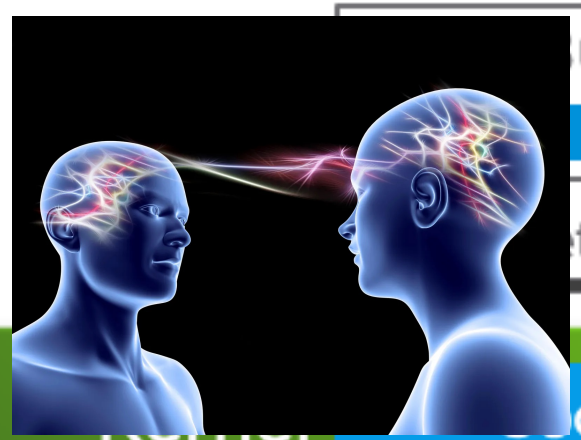

Buffers
Buffers
RDMA App
User
Sockets API
RDMA Verbs API
Kernel
Sockets
TCP
IPv4/IPv6
Network Device
Buffer Headers
Kernel Bypass
Device Driver
Host Channel Adapter
InfiniBand
RoCE
iWARP



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InfiniBand

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App

# With Rocky 9.3 Connect-X 3 Inifniband Cards need the driver to be installed after install

```
[matthew@moonshine ~]# sudo yum install rdma-core libibverbs-utils librdmacm
librdmacm-utils ibacm infiniband-diags opensm

Dependencies resolved.
================================================================================
 Package                 Architecture Version                 Repository      Size
================================================================================
Installing:
 ibacm                   x86_64       46.0-1.el9              baseos          88 k
 infiniband-diags        x86_64       46.0-1.el9              appstream      310 k
 libibverbs-utils        x86_64       46.0-1.el9              baseos          67 k
 librdmacm               x86_64       46.0-1.el9              baseos          70 k
 librdmacm-utils         x86_64       46.0-1.el9              baseos          90 k
 opensm                  x86_64       3.3.24-2.el9            baseos         503 k
 rdma-core               x86_64       46.0-1.el9              baseos          51 k
Installing dependencies:
 libibumad               x86_64       46.0-1.el9              baseos          26 k
 opensm-libs             x86_64       3.3.24-2.el9            baseos          75 k
 pciutils                x86_64       3.7.0-5.el9             baseos          92 k
```

```
[matthew@moonshine ~]$ sudo reboot now
Connection to 129.24.245.16 closed by remote host.
```

```
matthew@lycaon ~ % ssh matthew@129.24.245.16
matthew@129.24.245.16's password:
Last login: Tue Feb  6 20:07:00 2024 from 50.193.238.94
[matthew@localhost ~]$ ibstat
CA 'mlx4_0'
CA type: MT4099
Number of ports: 1
Firmware version: 2.10.700
Hardware version: 0
Node GUID: 0x0002c90300f67b70
System image GUID: 0x0002c90300f67b73
Port 1:
State: Initializing
Physical state: LinkUp
Rate: 40
Base lid: 0
LMC: 0
SM lid: 0
Capability mask: 0x02594868
```

```
[matthew@localhost ~]$ ip a
1: lo: <LOOPBACK,UP,LOWER_UP> mtu 65536 qdisc noqueue state UNKNOWN group default qlen 1000
    link/loopback 00:00:00:00:00:00 brd 00:00:00:00:00:00
    inet 127.0.0.1/8 scope host lo
       valid_lft forever preferred_lft forever
    inet6 ::1/128 scope host
       valid_lft forever preferred_lft forever
2: eno1: <BROADCAST,MULTICAST,UP,LOWER_UP> mtu 1500 qdisc mq state UP group default qlen 1000
    link/ether d4:ae:52:8b:72:8c brd ff:ff:ff:ff:ff:ff
    altname enp1s0f0
    inet 129.24.245.16/22 brd 129.24.247.255 scope global noprefixroute eno1
       valid_lft forever preferred_lft forever
    inet6 fe80::d6ae:52ff:fe8b:728c/64 scope link noprefixroute
       valid_lft forever preferred_lft forever
3: eno2: <NO-CARRIER,BROADCAST,MULTICAST,UP> mtu 1500 qdisc mq state DOWN group default qlen 1000
    link/ether d4:ae:52:8b:72:8d brd ff:ff:ff:ff:ff:ff
    altname enp1s0f1
4: eno3: <NO-CARRIER,BROADCAST,MULTICAST,UP> mtu 1500 qdisc mq state DOWN group default qlen 1000
    link/ether d4:ae:52:8b:72:8e brd ff:ff:ff:ff:ff:ff
    altname enp2s0f0
5: eno4: <NO-CARRIER,BROADCAST,MULTICAST,UP> mtu 1500 qdisc mq state DOWN group default qlen 1000
    link/ether d4:ae:52:8b:72:8f brd ff:ff:ff:ff:ff:ff
    altname enp2s0f1
6: ibp65s0: <NO-CARRIER,BROADCAST,MULTICAST,UP> mtu 4092 qdisc fq_codel state DOWN group default qlen
256
    link/infiniband 80:00:02:08:fe:80:00:00:00:00:00:00:00:02:c9:03:00:f6:7b:71 brd
00:ff:ff:ff:ff:12:40:1b:ff:ff:00:00:00:00:00:00:ff:ff:ff:ff
```