

Redes de Computadores II

Universidade do Algarve

Semana 3

https://github.com/ncatanoc/redes_algarve

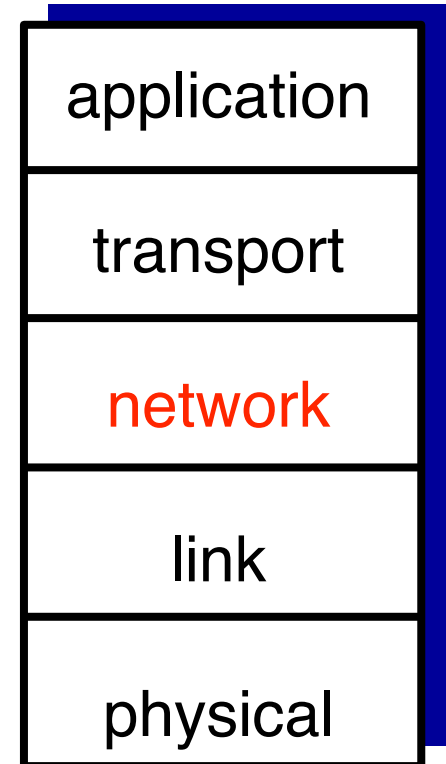
Néstor Cataño

nestor.catano@gmail.com

The network layer

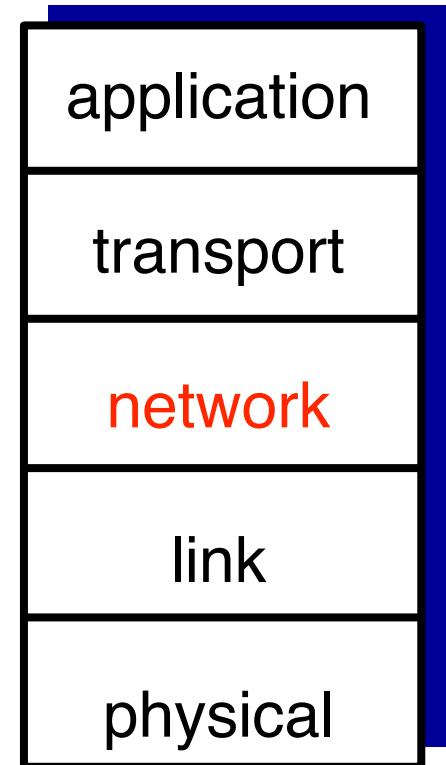
Goal:

To understand the principles behind the network layer.



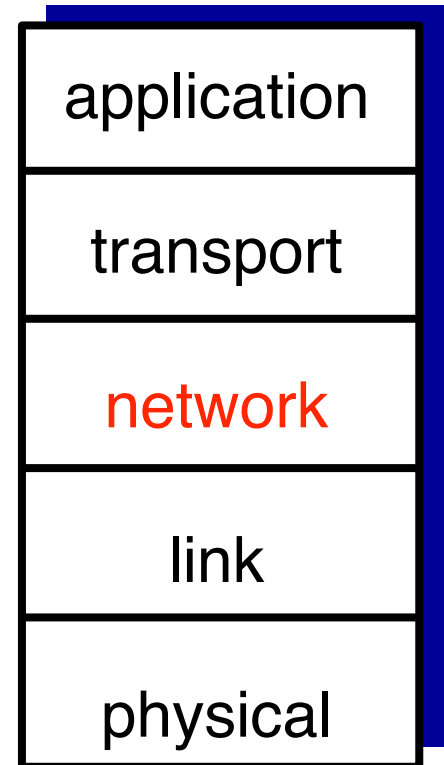
Roadmap

1. the network layer
2. IP addresses
3. IP packet structure
4. Routing basics



the network layer

- The **network layer** is responsible for connecting multiple local networks.
- It makes it possible for my friend and myself to **exchange messages**.
- It is implemented using the **IP** (**Internet Protocol**).
- The **IP** layer sits on the ethernet layer, but does not depend on it.



why a new protocol?

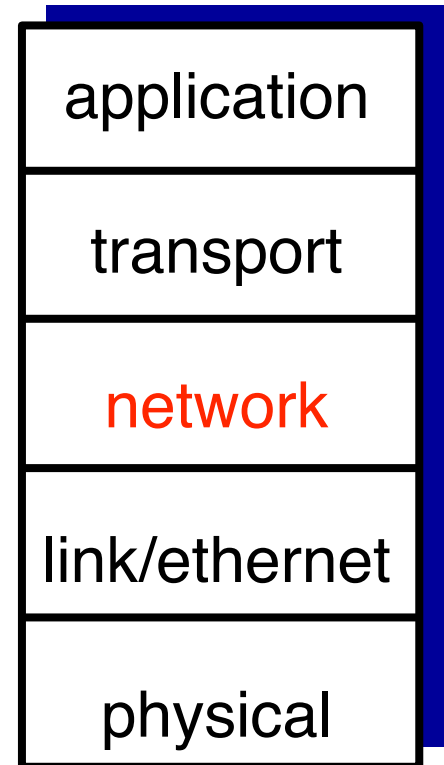
why don't we use ethernet for everything?

- Ethernet MAC addresses only contain information on the manufacturer; you have an idea of where the devices are in the network.
- To be able to send packets to the correct destination, **every switch** would need to manage a list of **all connected devices**.
- It would be like delivering a Mail only using a person's name.

Application HTTP, DNS, ...
Transport TCP, UDP
Internetwork IP
Link Ethernet

Why a new protocol?

- **Solution:** addresses should be organised hierarchically like we already do with postcards: country, state, city, etc.
- How does the Internet Protocol (IP) fix this?
 - IP Addressing + routing



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IP addresses

- IP addresses are dynamically assigned to devices.
- The first parts of IP addresses are equal for all the devices in the local network.
 - The first part of an IP is called a “locator”.
- One is assigned a new IP address with every new Wi-Fi connection.

Quiz - <http://menti.com> 3666 7199

Question

Check all statements that are true:

- ☐ Every router keeps track of all devices connected to the entire internet to route packets.
- ☐ A device will usually keep the same IP address over its lifetime.
- ☐ A device will usually keep the same MAC address over its lifetime.
- ☐ A routed network must not have any loops or circles.
- ☐ IP addresses can be used to implement “geo-blocking,” a technique where access to content is restricted based on the user’s geographical location.

Answers

Question

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what do IP addresses look like?

IPv4 addresses.

4 groups of bytes
 $32 = 8 \times 4$ bits in total
Insufficient!

IPv4 (1981)

192 . 0 . 2 . 254
↓ ↓ ↓ ↓
11000000 00000000 00000010 11111110
32 bits

$2^{32} \approx 4$ billion addresses

IPv6 addresses

8 groups of 4 hexadecimals
 $128 = 8 * 4 * 4$
Sufficient!

IPv6 (1998)

2001:0DB8:0015:FE01:0000:0000:0000:0000
=
2001:0DB8: 15:FE01::
↓↓↓
00100000 00000001 00001101 10111000
00000000 00010101 11111110 00000001
00000000 00000000 00000000 00000000
00000000 00000000 00000000 00000000
128 bits

$2^{128} \approx 3.4 * 10^{38}$ addresses

IPv6 - reduced versions

IPv6 (1998)

- Replace **0000** or groups of **0000:** **...:0000** with **::**
- remove leading **0**s
 - **0015** becomes **15**

2001:0DB8:0015:FE01:0000:0000:0000:0000

=

2001:0DB8: 15:FE01::

↓↓↓

00100000 00000001 00001101 10111000
00000000 00010101 11111110 00000001
00000000 00000000 00000000 00000000
00000000 00000000 00000000 00000000

128 bits

$2^{128} \approx 3.4 * 10^{38}$ addresses

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Select all correct statements:

- ☐ 192.168.0.256 is a valid IPv4 address.
- ☐ 8.8.4.4 is a valid IPv4 address.
- ☐ affe:: is a valid IPv6 address.
- ☐ 1.2.3.4 is a valid IPv6 address.
- ☐ There are strings that are both valid IPv4 and IPv6 addresses.

Questions

Reduce the following IP addresses to their shortest form:

1. 2001:0db8:0000:0000:0000:0000:0002:0001
2. 0000:0000:0000:0000:0000:0000:0000:0001
3. 192.168.0.1

Answers

Reduce the following IP addresses to their shortest form:

1. 2001:0db8:0000:0000:0000:0000:0002:0001

2001:db8::2:1

2. 0000:0000:0000:0000:0000:0000:0000:0001

::1

3. 192.168.0.1



IPv4 vs. IPv6

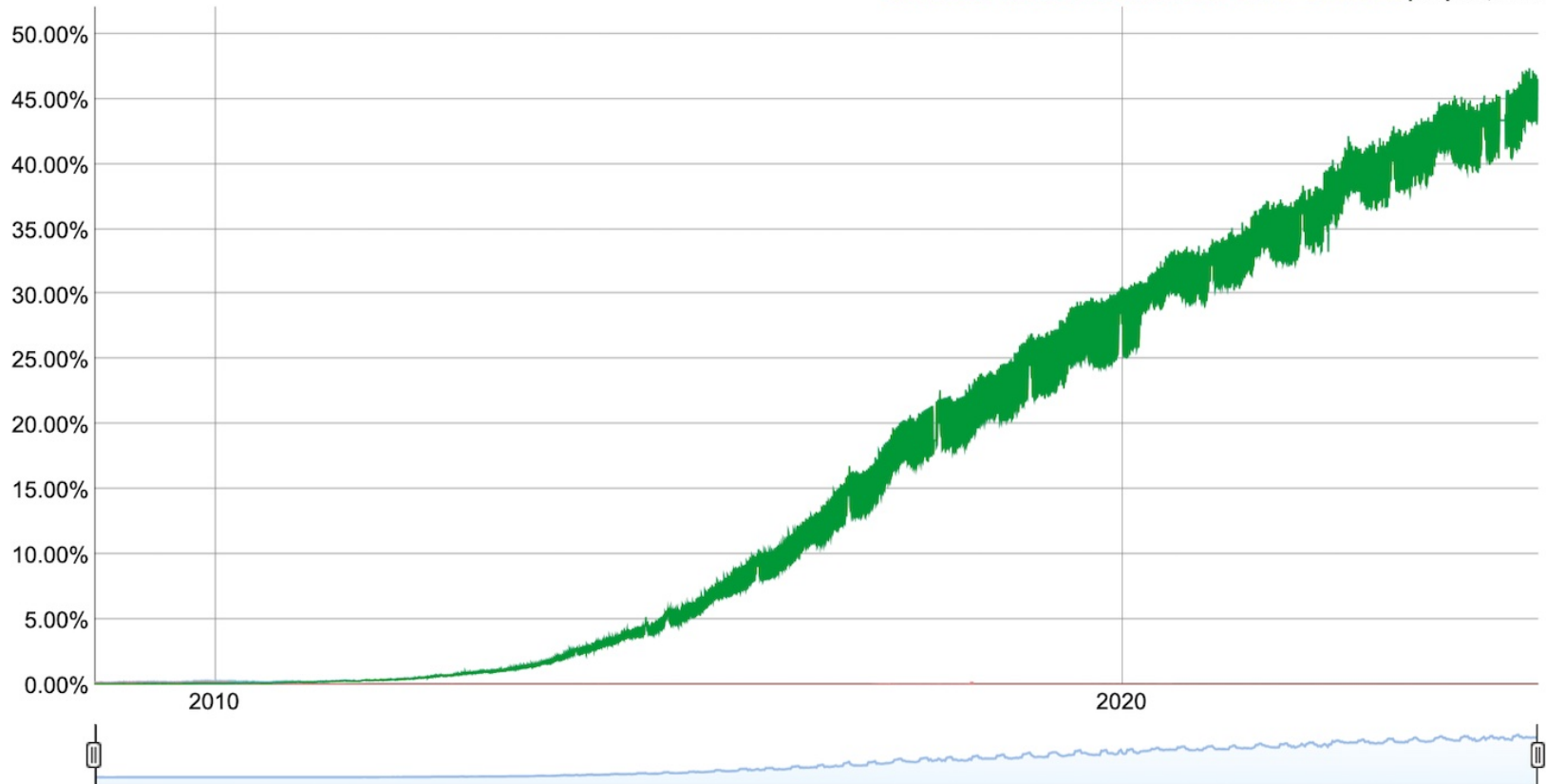
Currently, most connections are still **IPv4**

<https://www.google.com/ipv6/statistics.html>

IPv6 Adoption

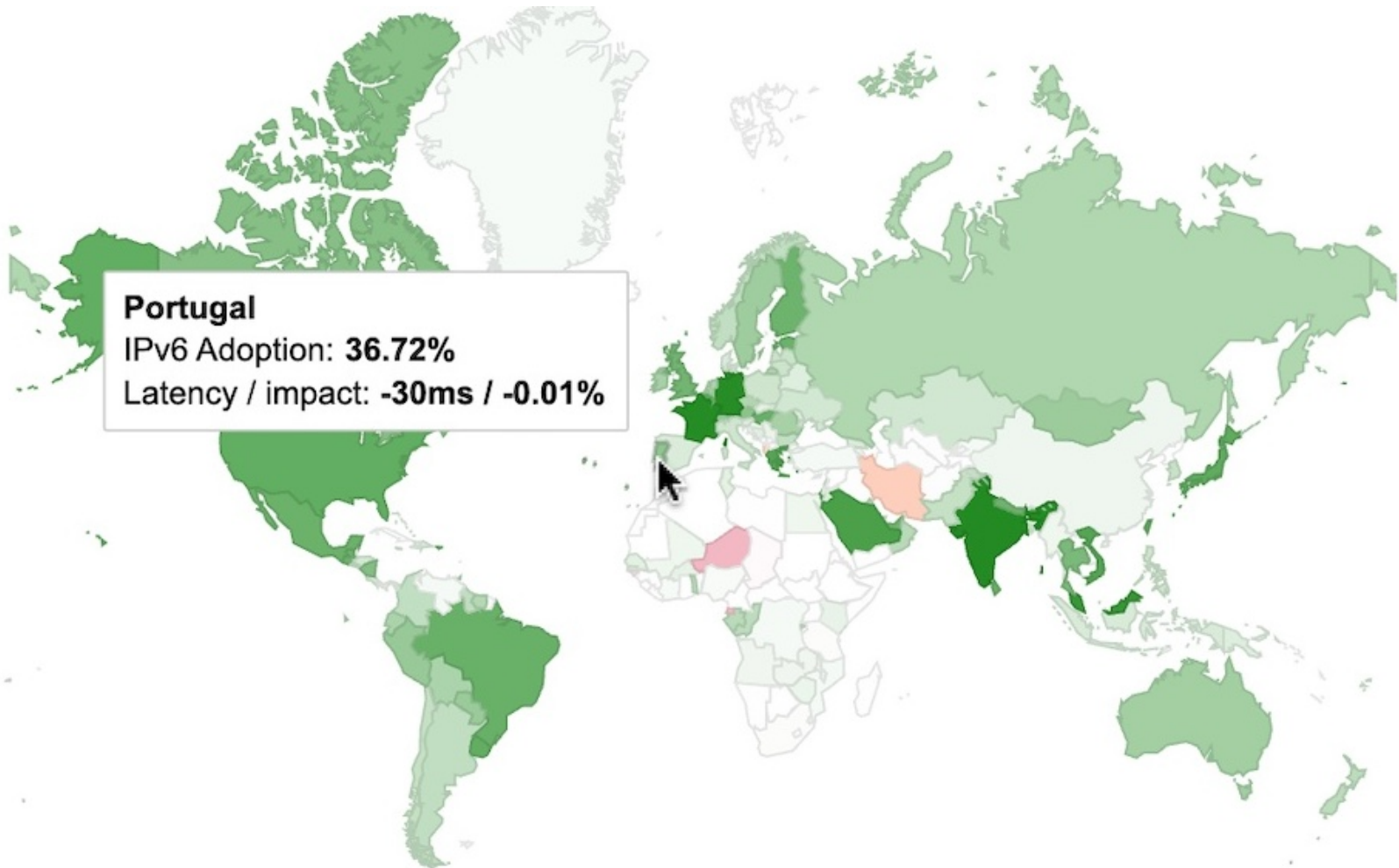
We are continuously measuring the availability of IPv6 connectivity among Google users. The graph shows the percentage of users that access Google over IPv6.

Native: 1.74% 6to4/Teredo: 0.01% Total IPv6: 1.75% | Sep 20, 2013



IPv6 adoption per country

<https://www.google.com/ipv6/statistics.html>



Reserved IP addresses

- **Loopback address** (it means 'this computer')
 - 127.0.0.1 (IPv4)
 - ::1 (IPv6)
- **Local/private addresses (IPv4)**: reserved for local communications between the local network only
 - 10.0.0.0 - 10.255.255.255
 - 172.16.0.0 - 172.16.255.255
 - 192.168.0.0 - 192.168.255.255

Reserved IP addresses - CIDR

- **Loopback address** (it means 'this computer')
 - 127.0.0.1 (IPv4)
 - ::1 (IPv6)
- **Local/private addresses (IPv4)**: reserved for local communications between the local network only
 - 10.0.0.0 - 10.255.255.255 ~ 10.0.0.0/24
 - 172.16.0.0 - 172.16.255.255 ~ 172.16.0.0/16
 - 192.168.0.0 - 192.168.255.255 ~ 192.168.0.0/16

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Question

Check all correct statements:

- ☐ `affe::/16` contains as many IP addresses as `beef::/16`.
- ☐ A `/8` network contains twice as many addresses as a `/9` network.
- ☐ `192.168.0.4/32` contains exactly one IP address.
- ☐ Hacking `127.0.0.1` and deleting all data on the machine is a bad idea.
- ☐ There are $256 * 256 = 65,536$ unique IPv4 addresses that start with `192.168`.

Answers

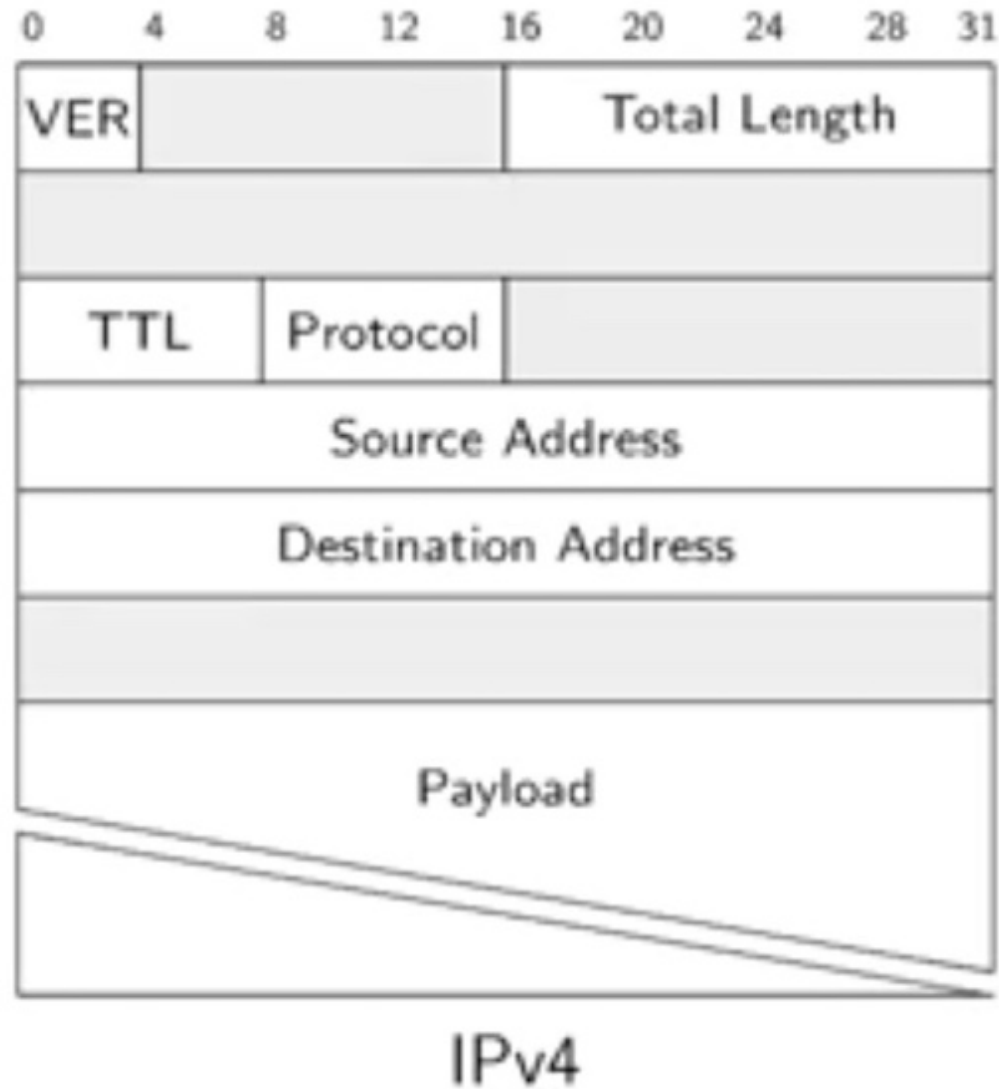
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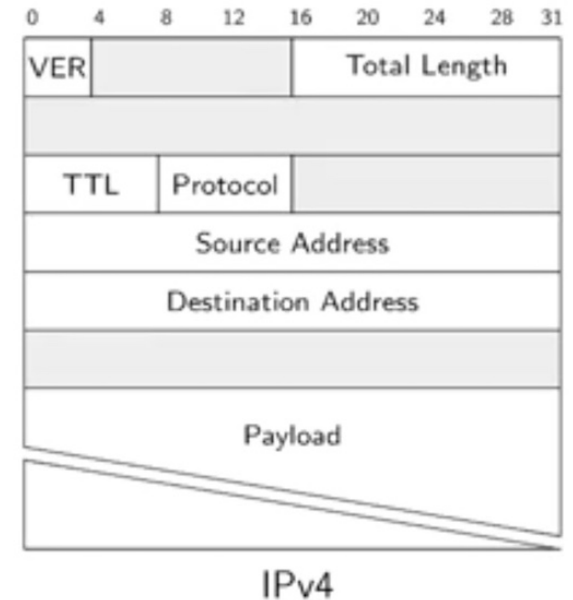
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IPv4 packet structure



IPv4 packet structure

- **VER**: 4 bits, protocol version, 0100
- **Total length**: 2 bytes, total length of the packet (which sometimes is fragmented)
- **TTL (Time To Live)**: **hop limit**, the maximum number of hops the package can traverse.



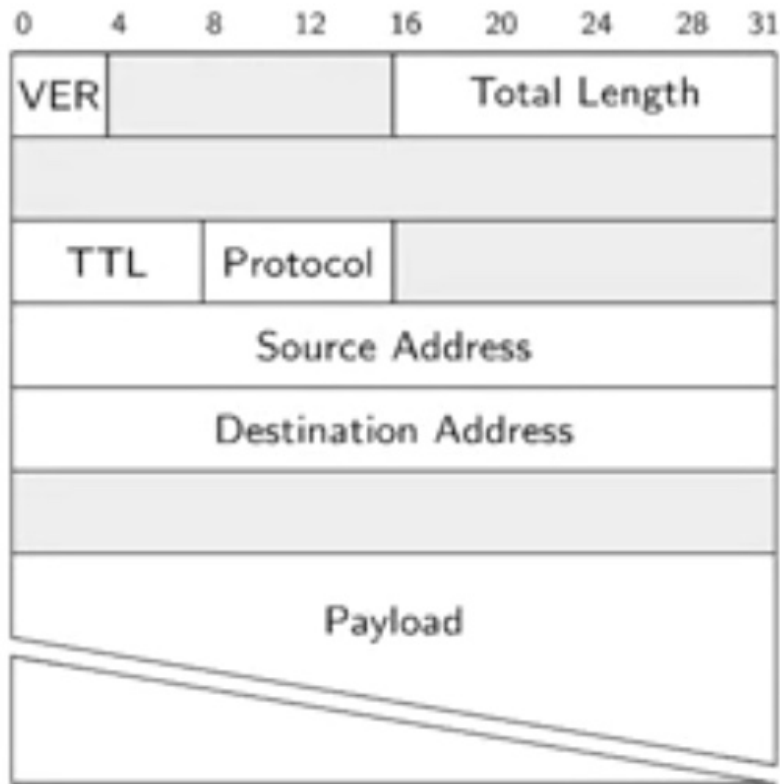
Protocol: protocol used in the **Transport Layer**

Source address: where the packet is coming from

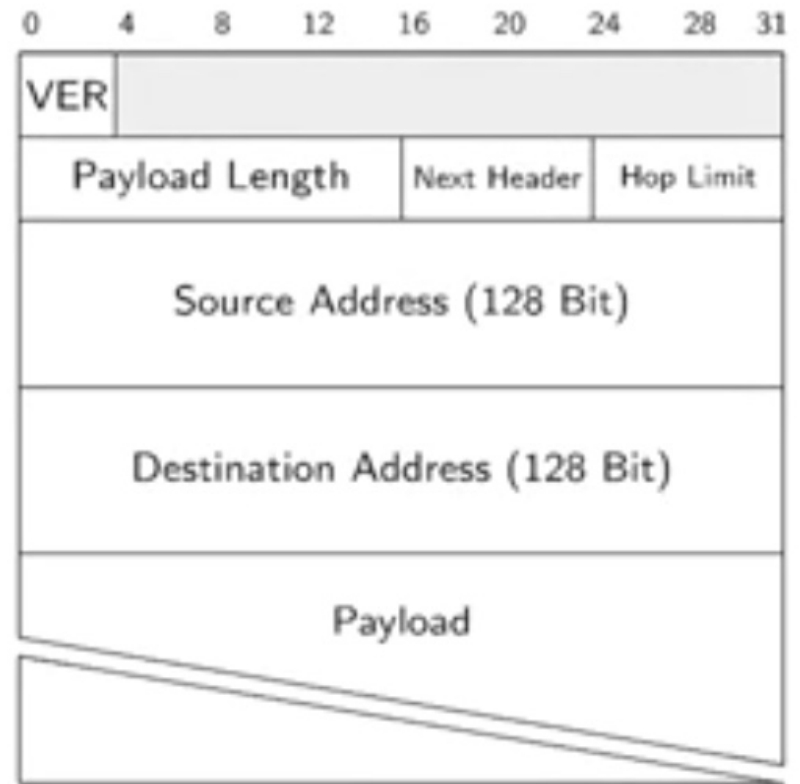
Destination address: where the packet is going to

Payload - the **Transport** protocol packet (remember the matryoshka image)

IPv4 vs IPv6 packet structure

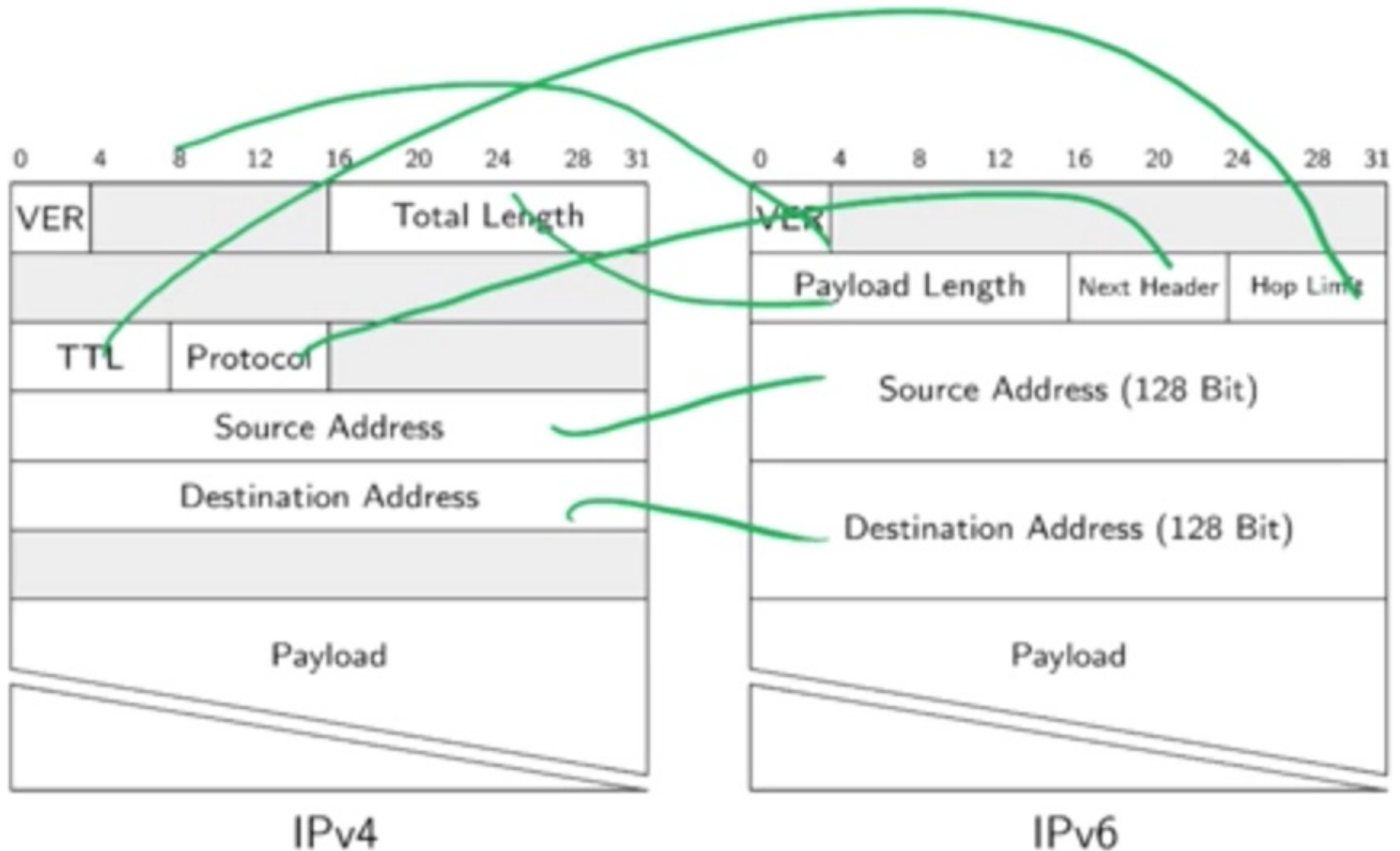


IPv4



IPv6

IPv4 vs IPv6 packet structure



The difference is **Source** and **Destination** addresses are **128 bits**

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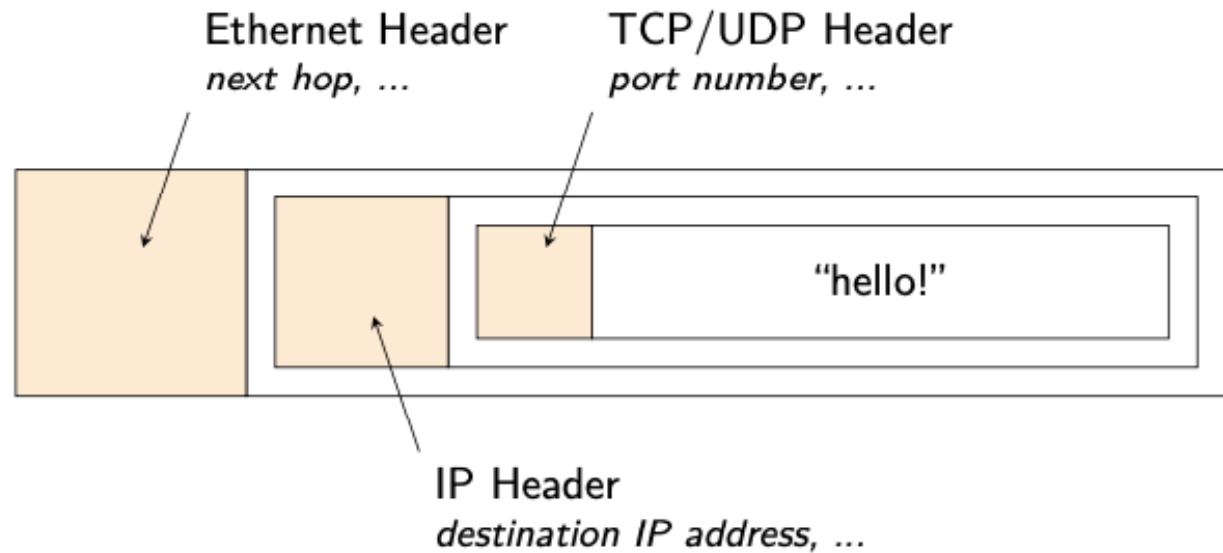
Question

Select all correct statements:

- ☐ IP packets have a fixed length.
- ☐ The IP packet header is "sandwiched" between the link and transport layers.
- ☐ IPv6 packets contain the destination's MAC address as the destination address.
- ☐ IP packets define the transport layer protocol used in the payload.

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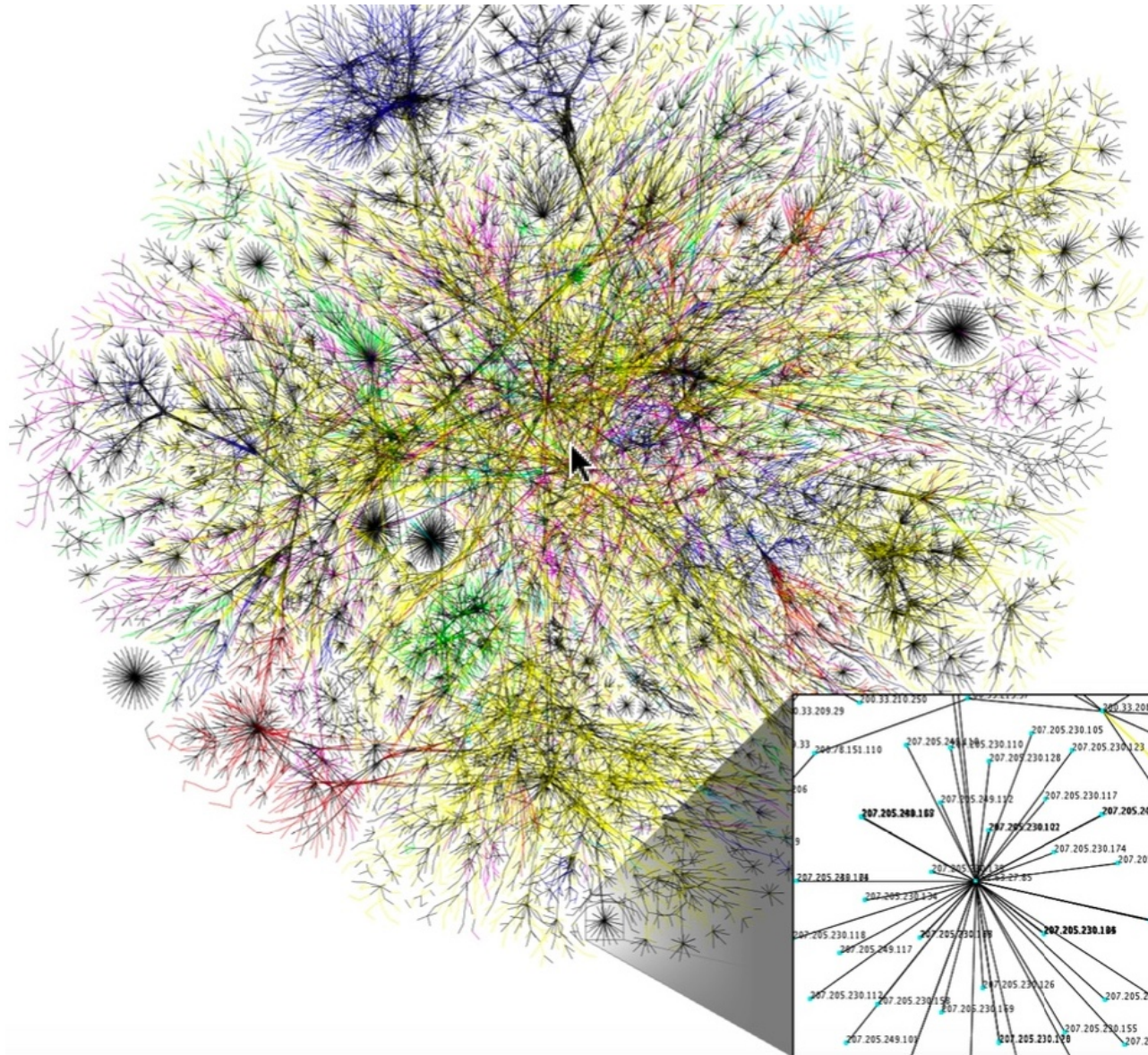
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Arpanet - 1974

ARPANET (1974)



30% of Internet in 2005



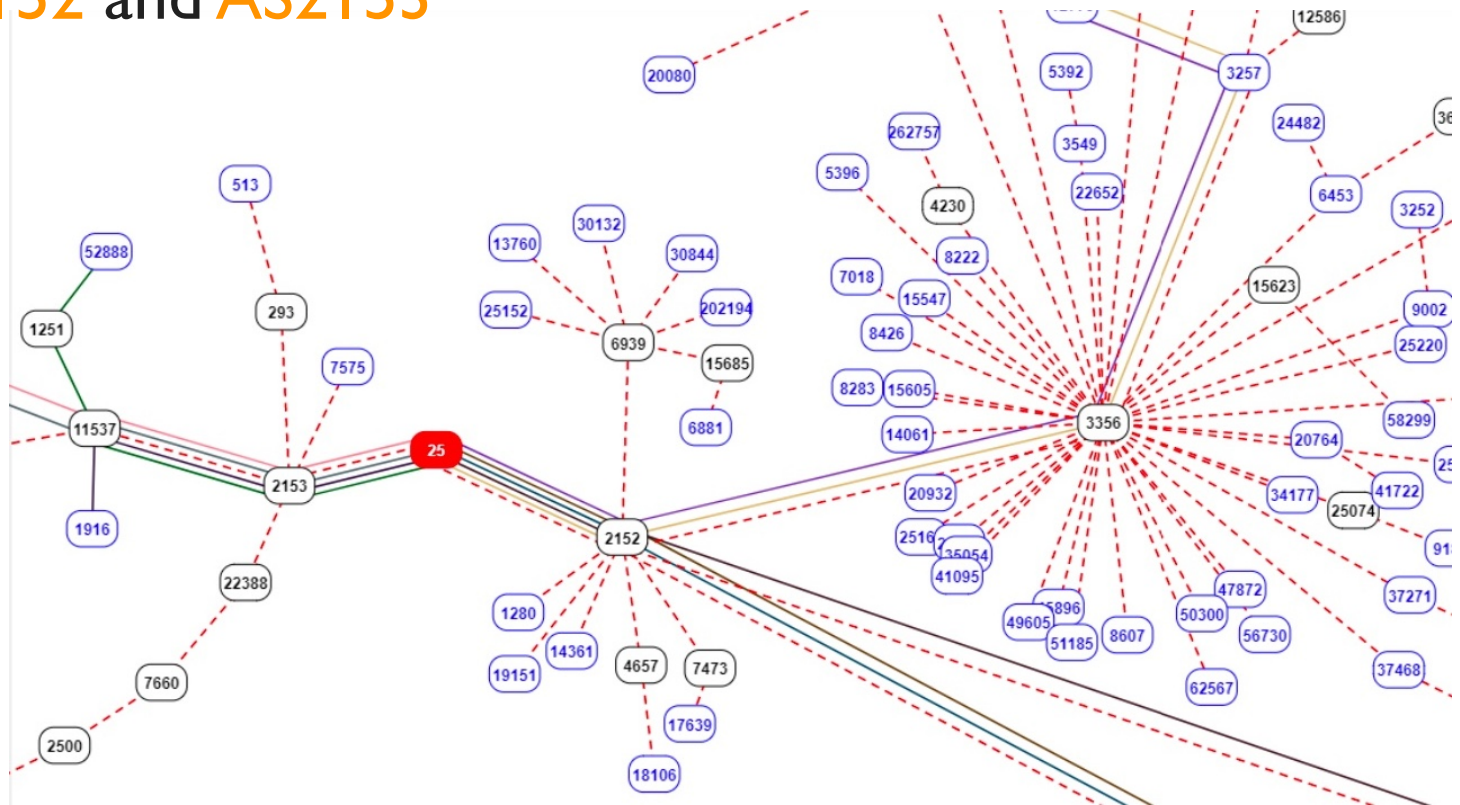
Internet

How do you maintain a routing table?

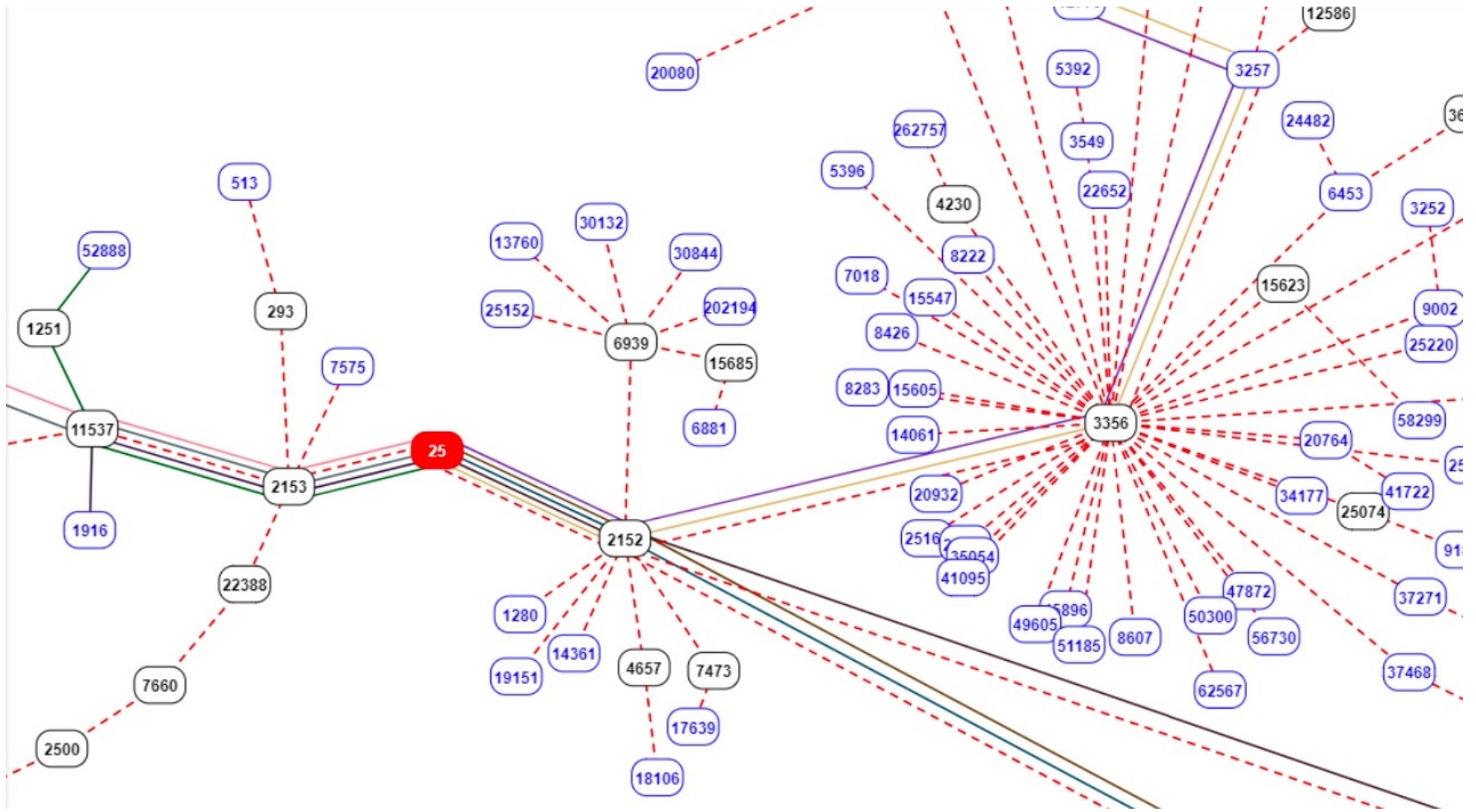
- the Internet is divided into **ASs** (**Autonomous Systems**).
 - each **AS** has a unique number and multiple IP ranges.
 - **IGP** (**Interior Gateway Protocols**) used for routing within **ASs**
- **Routing**: you need to take your packet to the right **AS** which will take care of its delivery
- **BGP** (**Border Gateway Protocol**): routing between **ASs**
 - **BGP**s are **Internet Providers**
- AS25 (UC Berkeley)

BGP routes for AS25

- **AS25** - UC Berkeley
- Each AS owns multiple IP address ranges
 - 128.32.0.0/**16** — UC Berkeley
- UC Berkeley is directly connected to 2 other systems:
 - **AS2152** and **AS2153**



BGP routes for AS25



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Check all statements that are true:

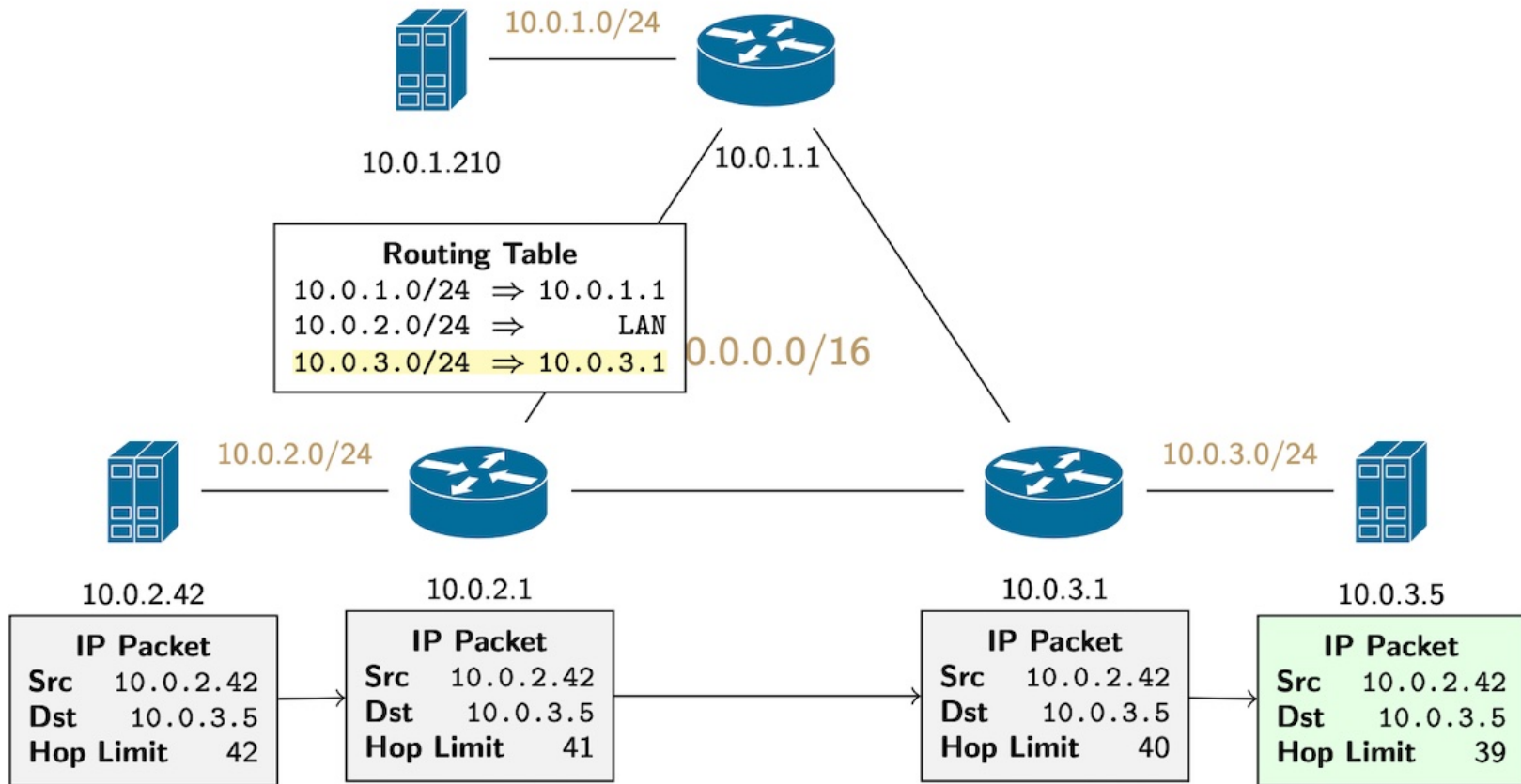
- ☐ To maximize the chances of reaching its destination, a packet should set the lowest possible hop limit.
- ☐ The destination IP address in an IP packet always points to the next router on the path.
- ☐ Having multiple submarine cables is primarily a safety measure, not a security measure.
- ☐ Many of today's internet protocols were developed for an internet with very different threat models.

Answers

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routing - basics



Routing Tables contain ranges of IP addresses

10.0.1.0/24 => 10.0.1

10.0.2.0/24 => LAN

10.0.3.0/24 => 10.0.3.1

Summary

IPv4 and IPv6

- ▶ Addressing
- ▶ Routing
- ▶ Addresses & Packets

Security

- ▶ Eavesdropping
- ▶ BGP Hijacking

Central Properties

- ▶ best effort
- ▶ connection-less
- ▶ unauthenticated plaintext

ICMP

- ▶ ping
- ▶ traceroute