Redes de Computadores II

Universidade do Algarve

Semana 3

https://github.com/ncatanoc/redes_algarve

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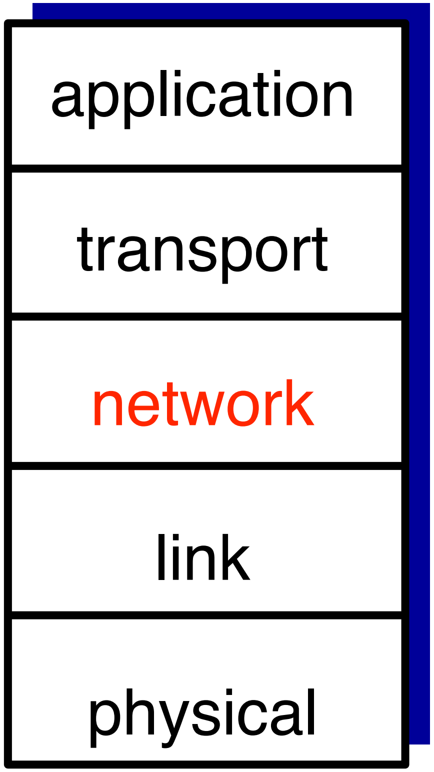
The network layer

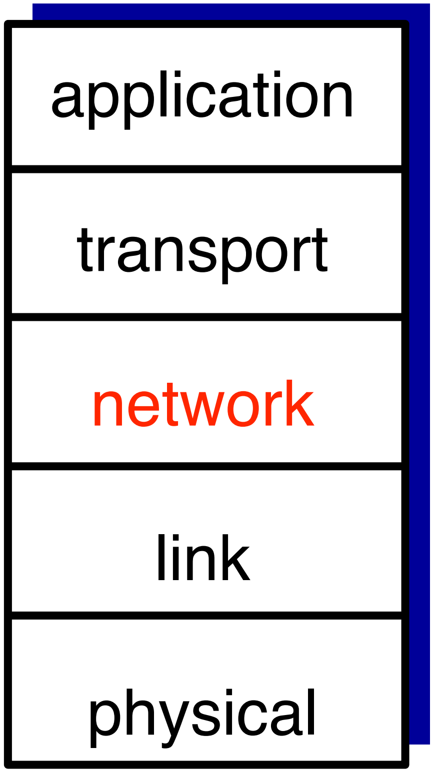
Goal:

To understand the principles behind the network layer.



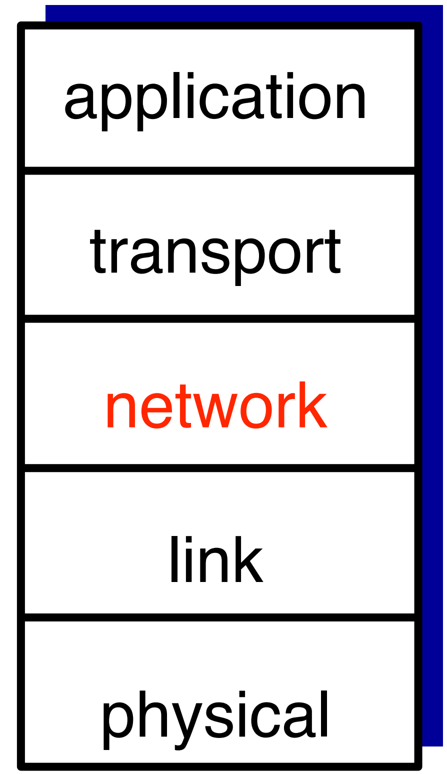
Roadmap

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?

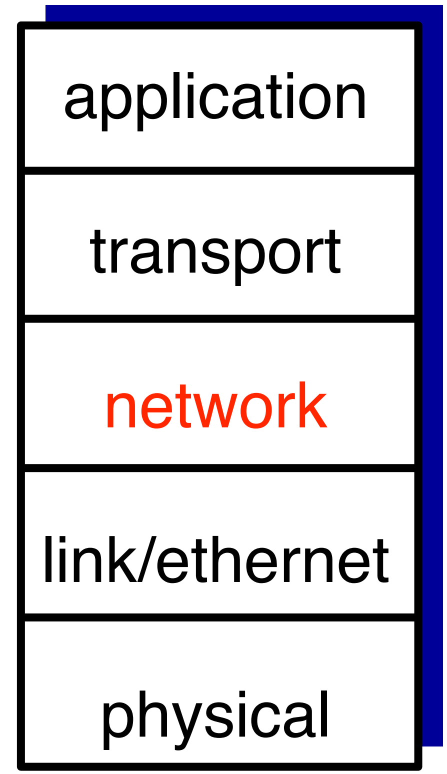
why don't we use ethernet for everything?

- 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.

what do IP addresses look like?

IPv4 addresses.
4 groups of bytes
32= 8x4 bits in total
Insufficient!

IPv6 addresses
8 groups of 4 hexadecimals
128 = 8 * 4 * 4
Sufficient!

IPv4 (1981)

$$\underbrace{\begin{array}{cccc} 192\,. & 0\;\;. & 2\;\;. & 254 \\ \downarrow & \downarrow & \downarrow & \downarrow \\ 11000000 & 00000000 & 00000010 & 11111110 \end{array}}_{32 \text{ bits}}$$

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

IPv6 (1998)

2001:0DB8:0015:FE01:0000:0000:0000:0000
=
2001:0DB8: 15:FE01::
↓↓↓

$$\underbrace{\begin{array}{cccc} 00100000 & 00000001 & 00001101 & 10111000 \\ 00000000 & 00010101 & 11111110 & 00000001 \\ 00000000 & 00000000 & 00000000 & 00000000 \\ 00000000 & 00000000 & 00000000 & 00000000 \end{array}}_{128 \text{ bits}}$$

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

IPv6 - reduced versions

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

IPv6 (1998)

2001:0DB8:0015:FE01:0000:0000:0000:0000
=
2001:0DB8:   15:FE01::
↓↓↓

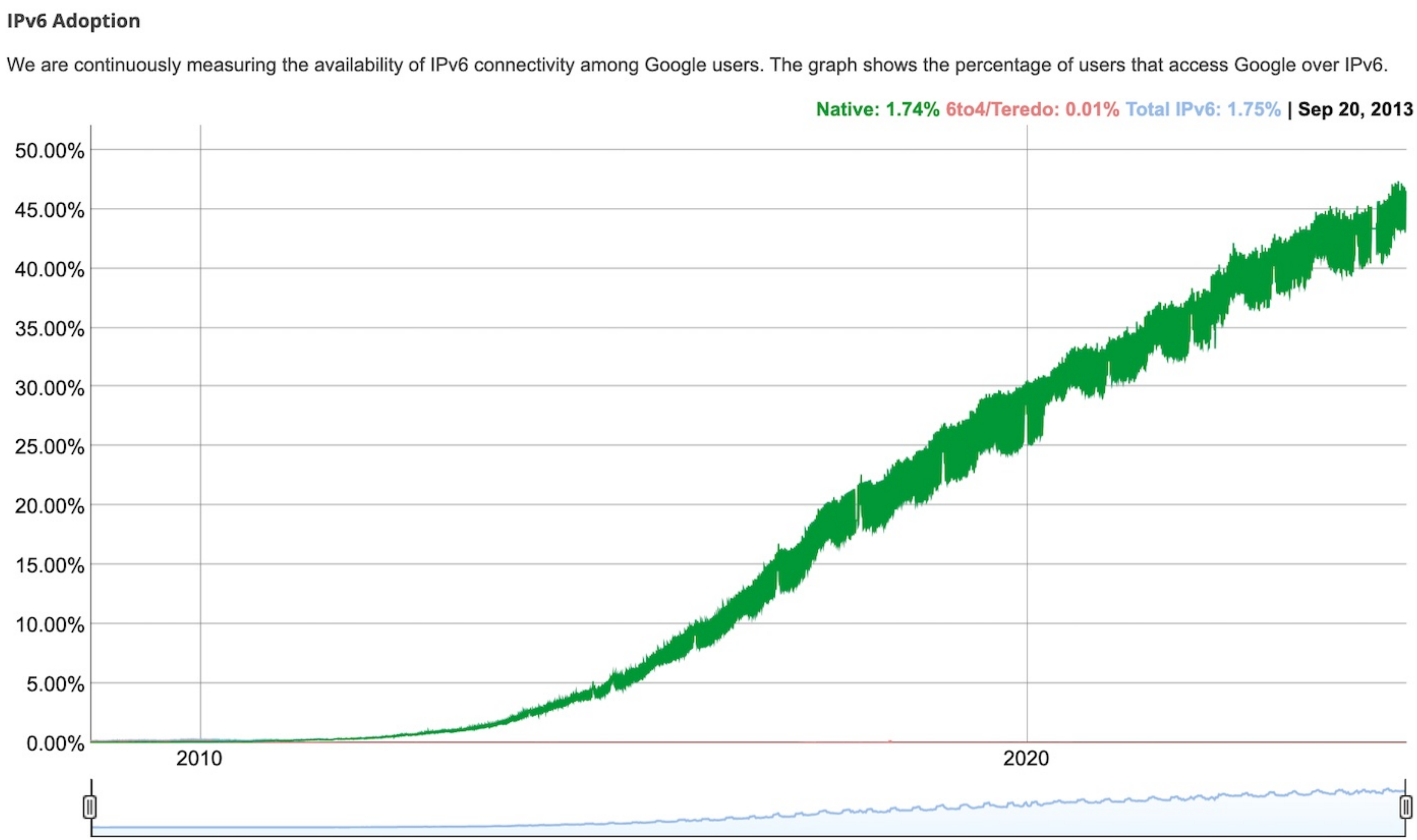
$$\underbrace{\begin{matrix} 00100000 & 00000001 & 00001101 & 10111000 \\ 00000000 & 00010101 & 11111110 & 00000001 \\ 00000000 & 00000000 & 00000000 & 00000000 \\ 00000000 & 00000000 & 00000000 & 00000000 \end{matrix}}_{\texttt{128 bits}}$$

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

IPv4 vs. IPv6

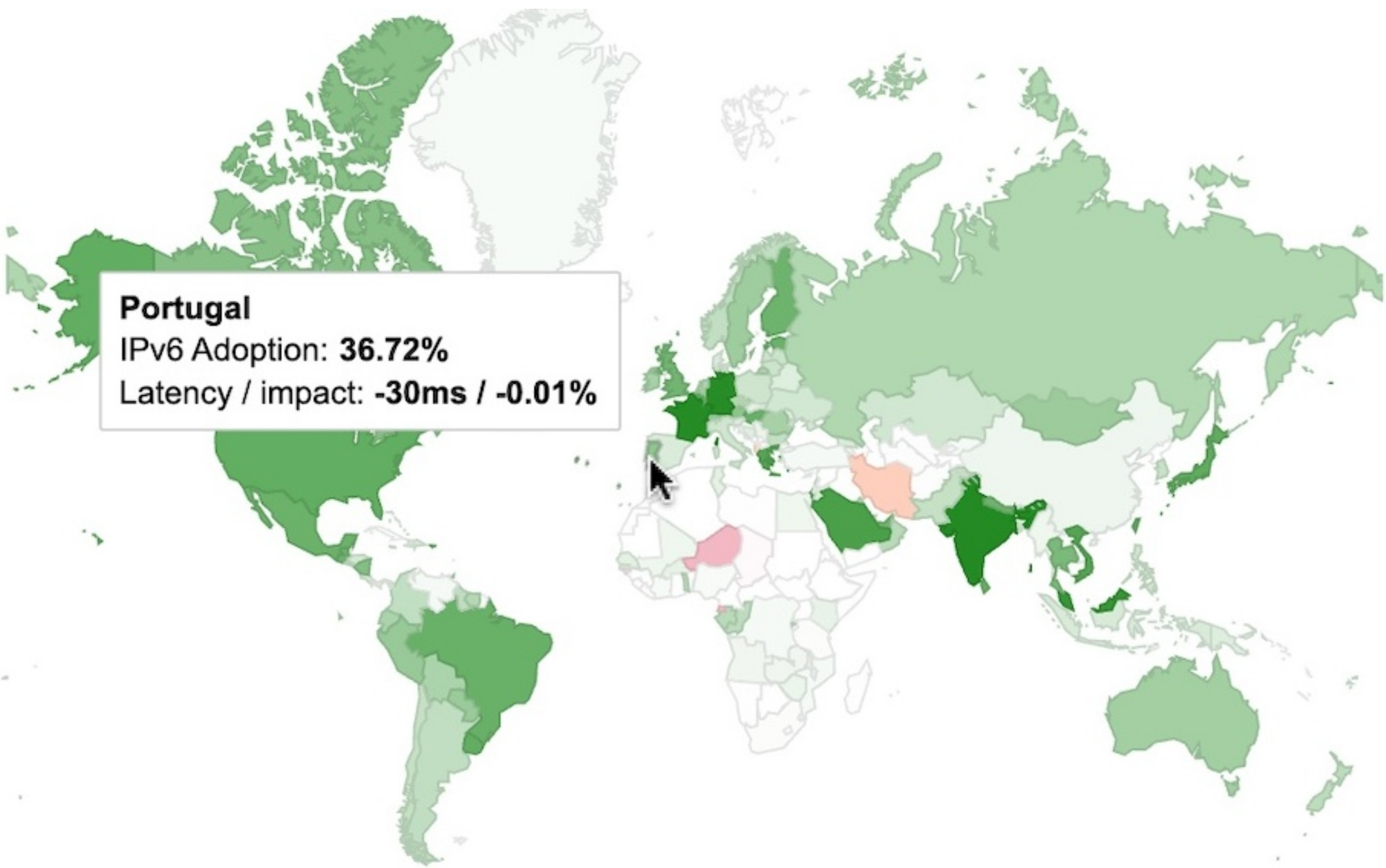
Currently, most connections are still IPv4

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



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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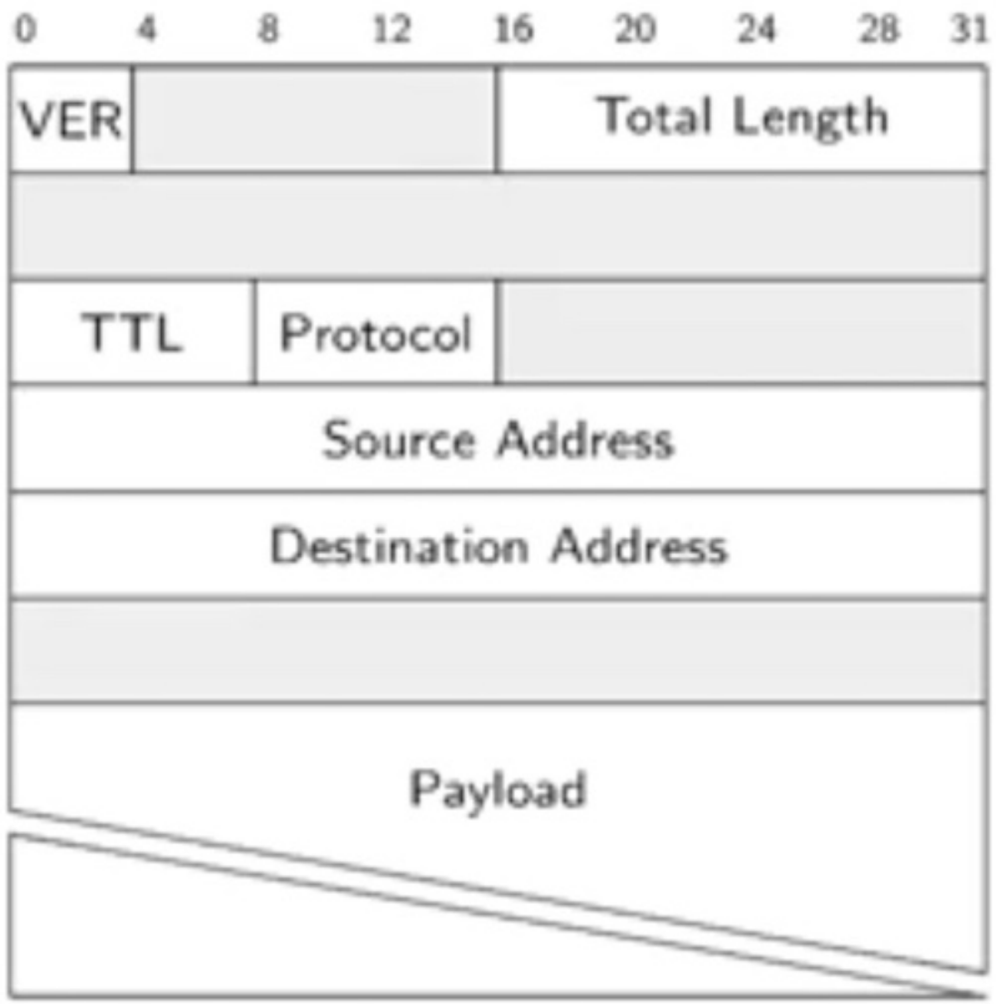
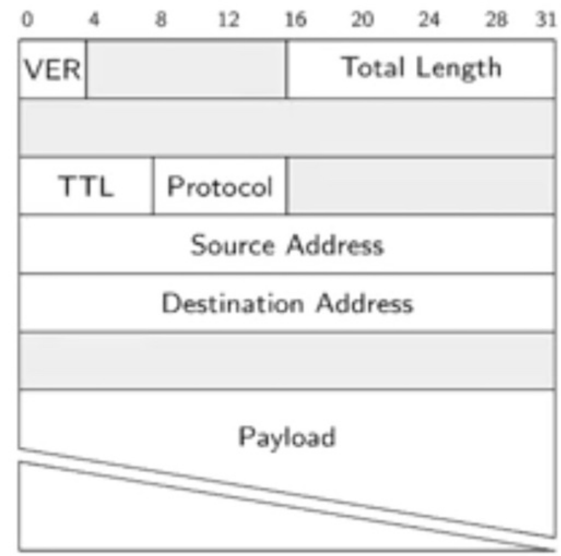
IPv4 packet structure



IPv4

IPv4 packet structure

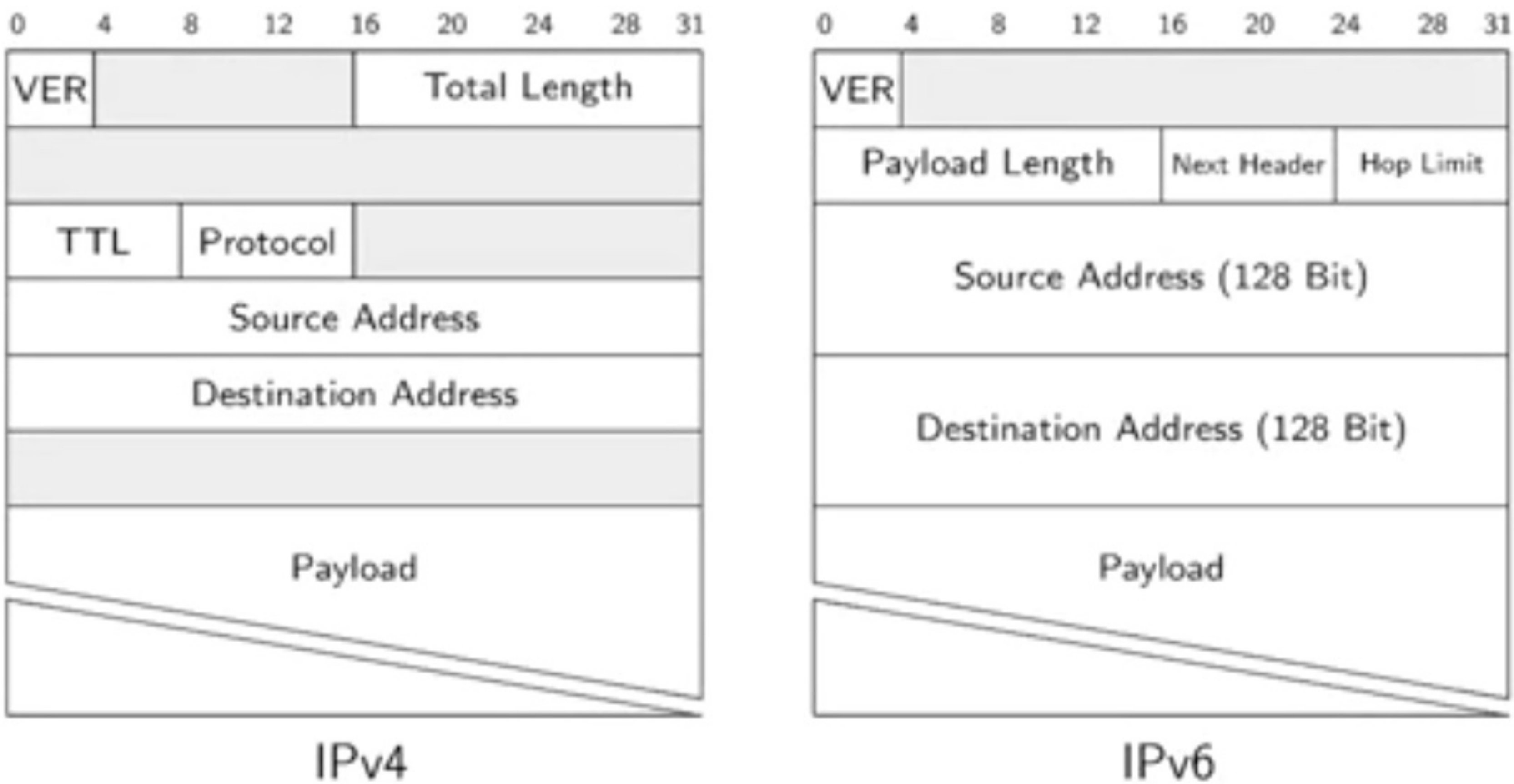
- VER: 4 bits, protocol version, 0100
- Total length: 2 bytes, total length of the packet (which sometimes is fragmented)
- TTL (Time To Live): **hop limit**, the maximum number of hops the package can traverse.



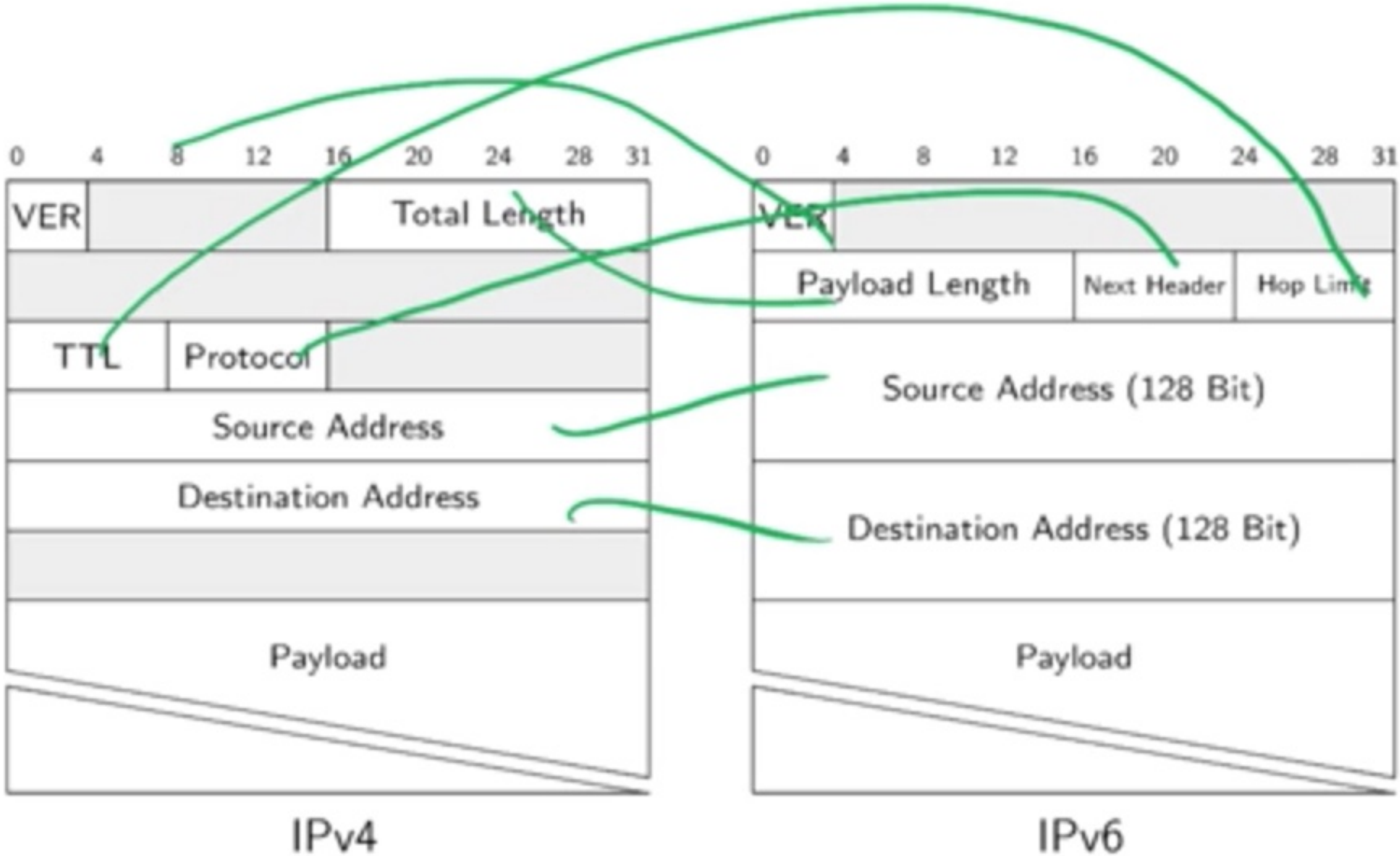
IPv4

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 vs IPv6 packet structure



The difference is Source and Destination addresses are 128 bits

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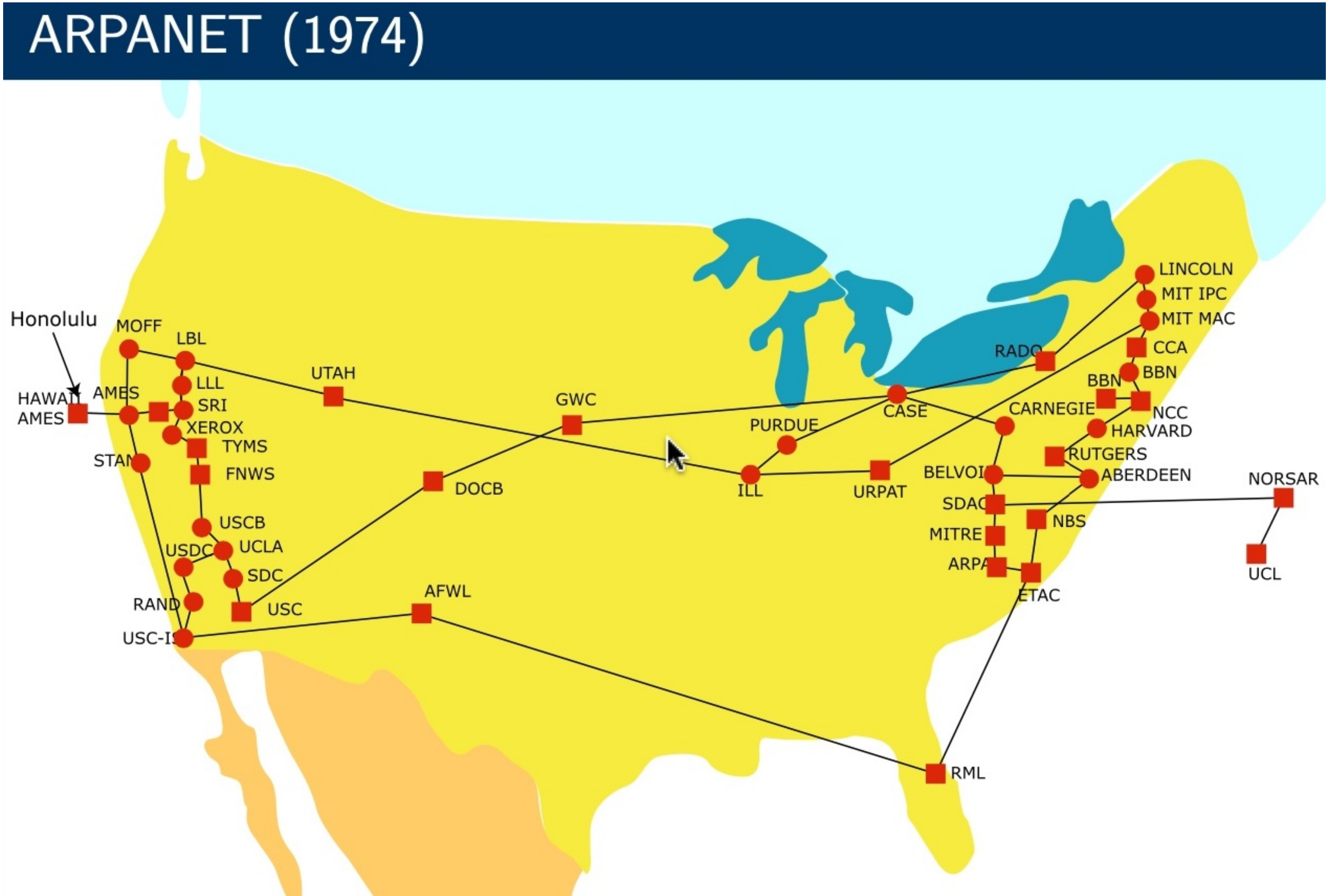
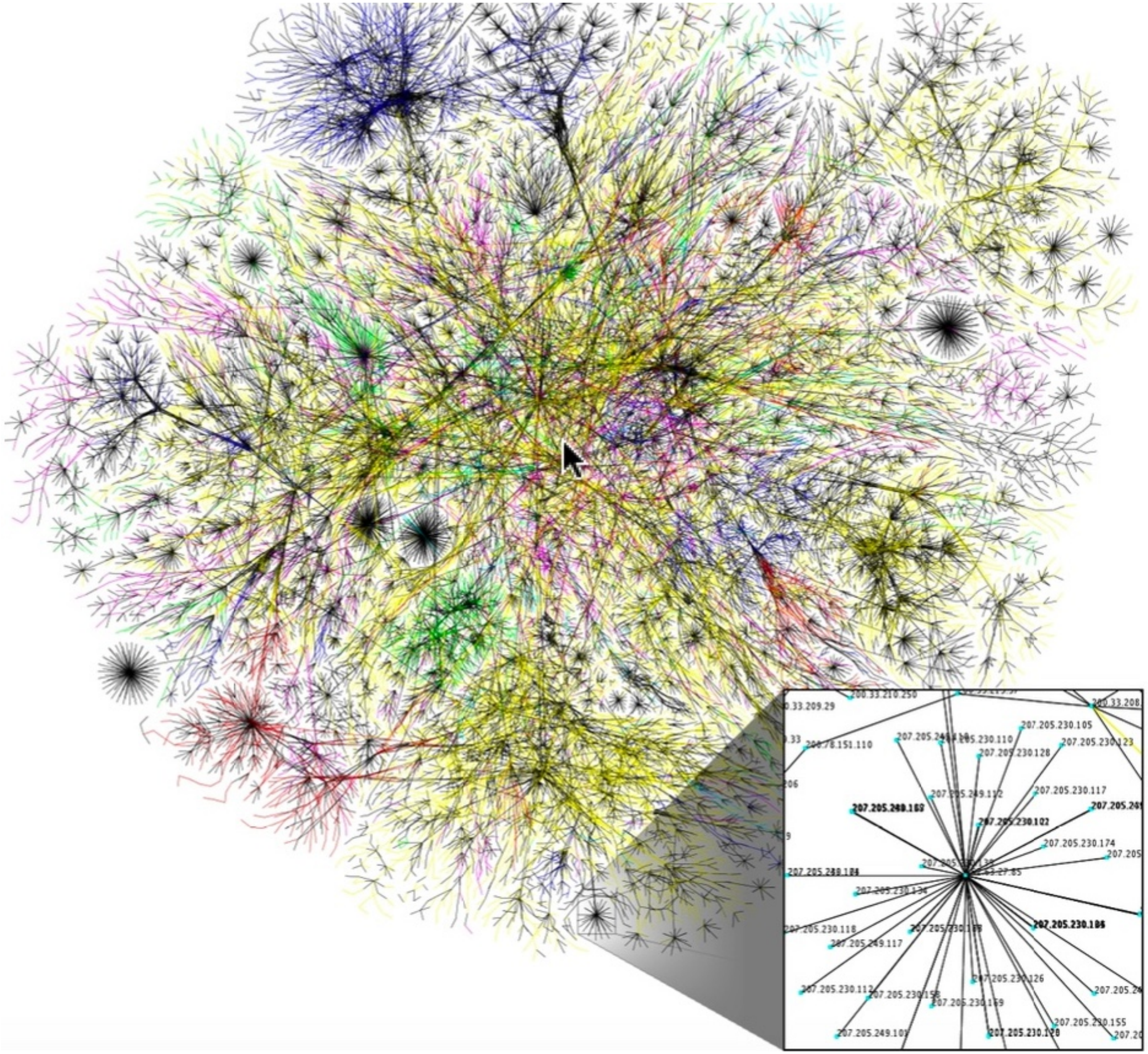
Arpanet - 1974



30% of Internet in 2005



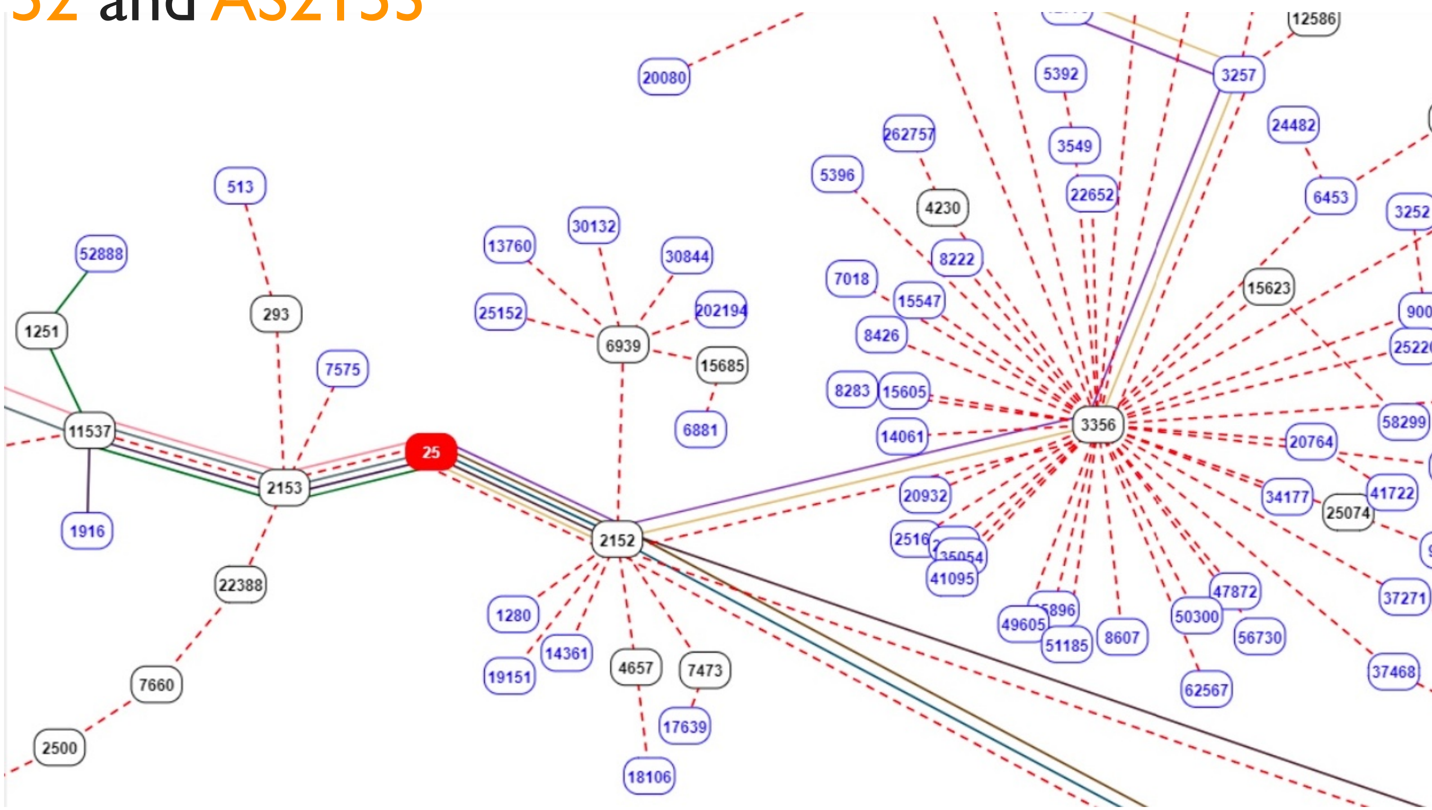
Internet

How do you maintain a routing table?

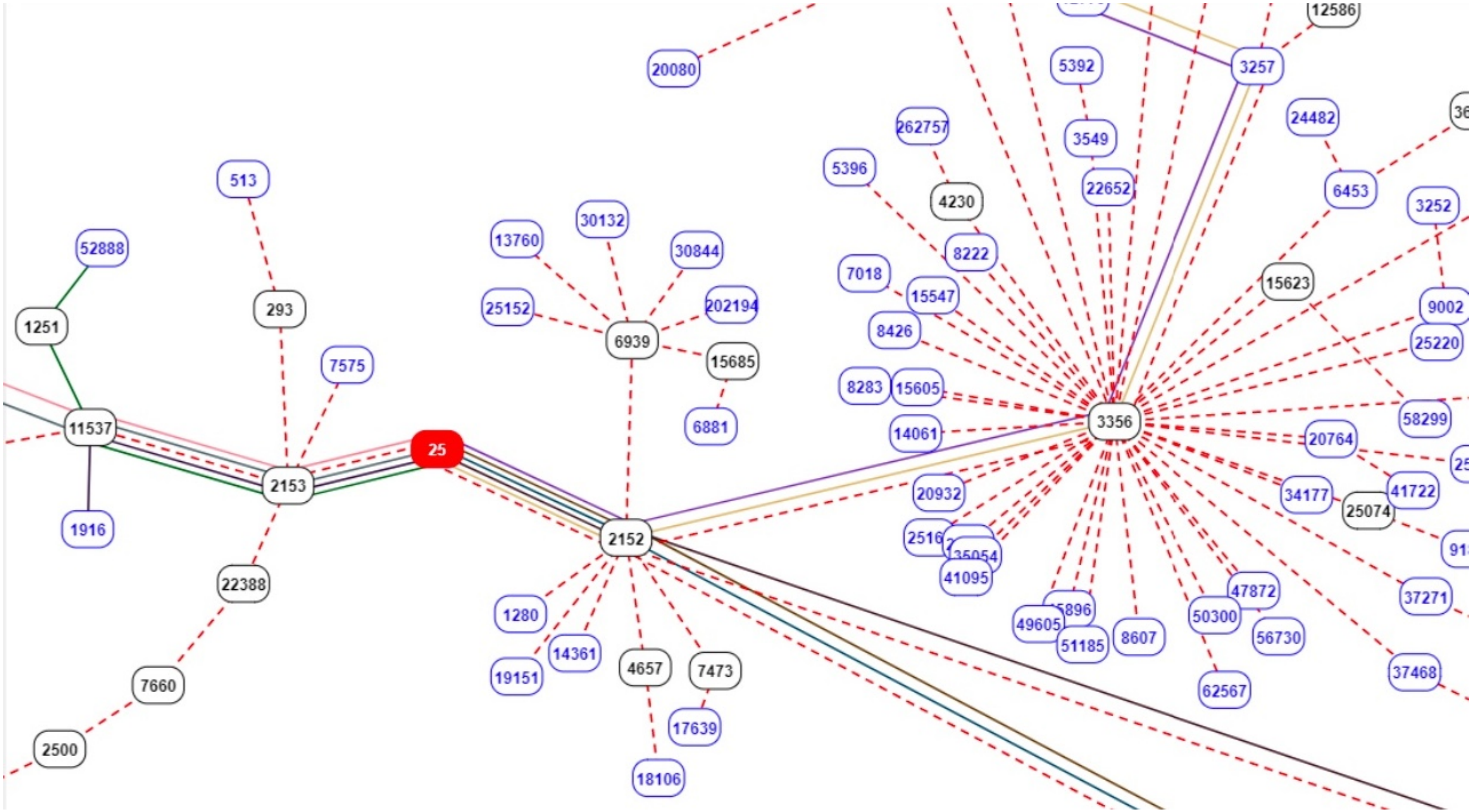
- the Internet is divided into ASs (Autonomous Systems).
  - each AS has a unique number and multiple IP ranges.
  - IGP (Interior Gateway Protocols) used for routing within ASs
- **Routing**: you need to take your packet to the right AS which will take care of its delivery
- BGP (Border Gateway Protocol):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

BGP routes for AS25

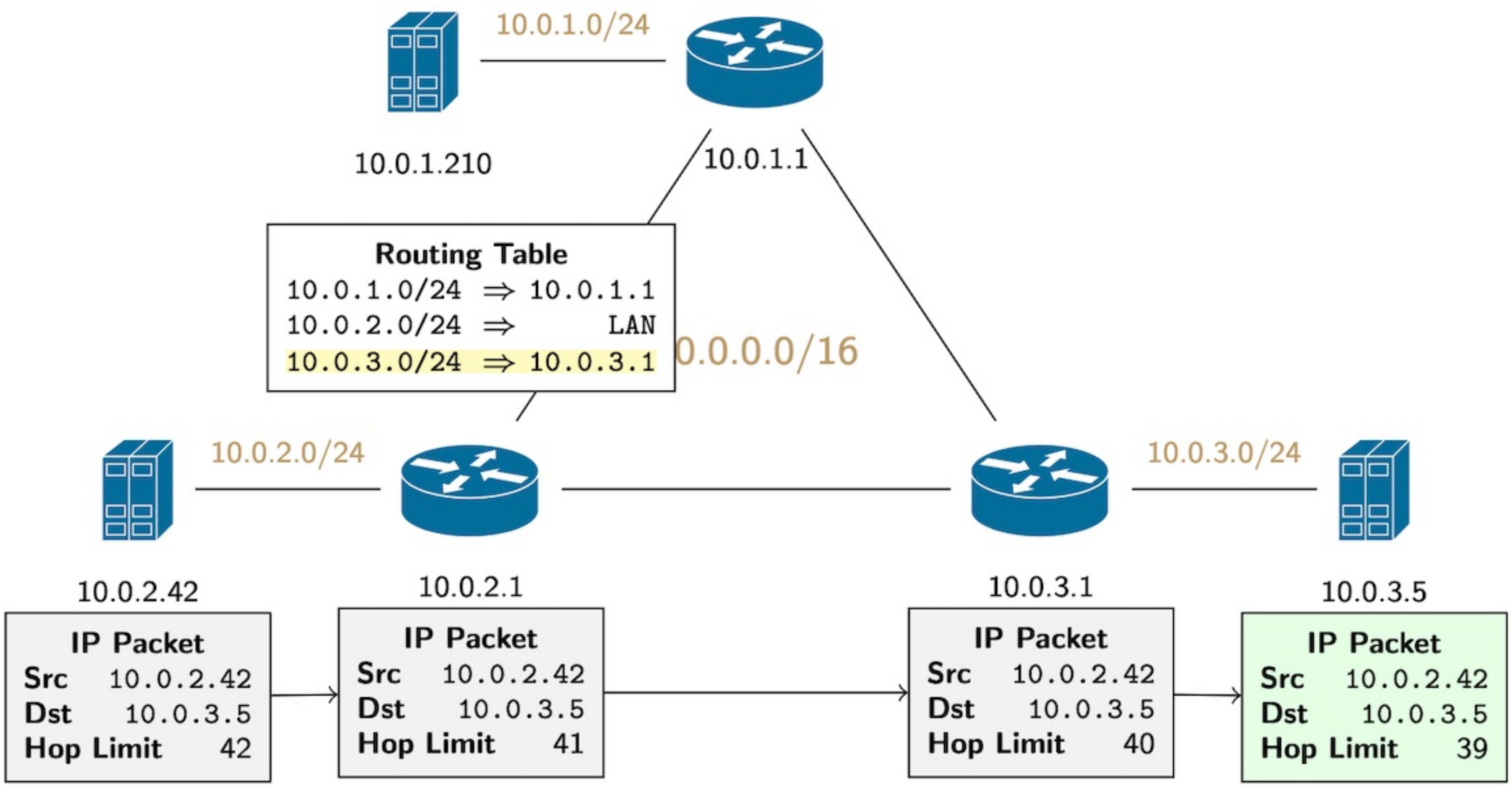
- AS25 - UC Berkeley
- Each AS owns multiple IP address ranges
  - 128.32.0.0/16 — UC Berkeley
- UC Berkeley is directly connected to 2 other systems:
  - AS2152 and AS2153



BGP routes for AS25



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

Central Properties

- best effort
- connection-less
- unauthenticated plaintext

Security

- Eavesdropping
- BGP Hijacking

ICMP

- ping
- traceroute