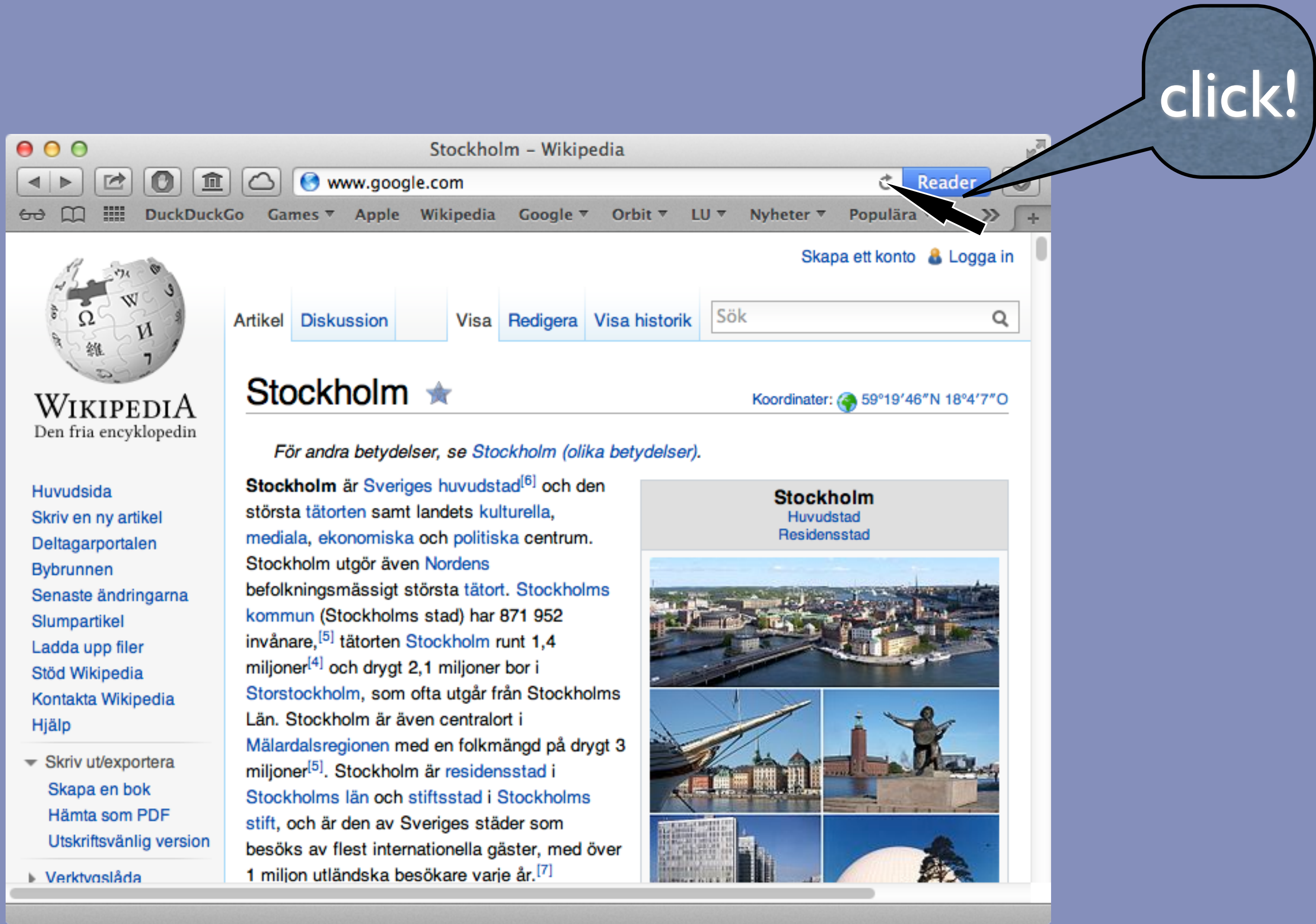
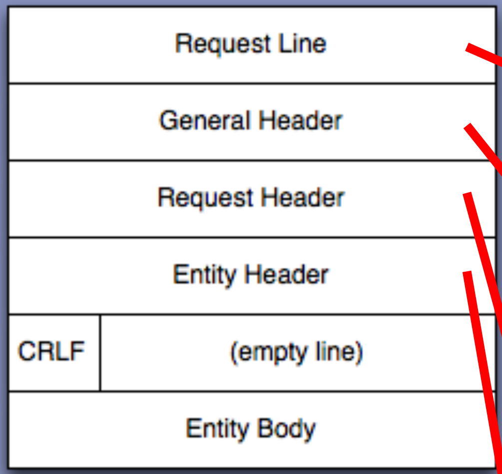
Everything summarised, what happens when you click the mouse / tap your finger?

PC/Laptop/Mobile Phone



Step 1

Generate a HTTP packet:



"GET http://www.google.com/ HTTP/1.1 CRLF"

General header. E.g.
MIME-Version: 1.0 CRLF
Date: Tue Apr 21 11:30:29 CEST 2009 CRLF

Request header. E.g.
Accept-Charset: utf-8 CRLF
From: harryw@liacs.nl CRLF

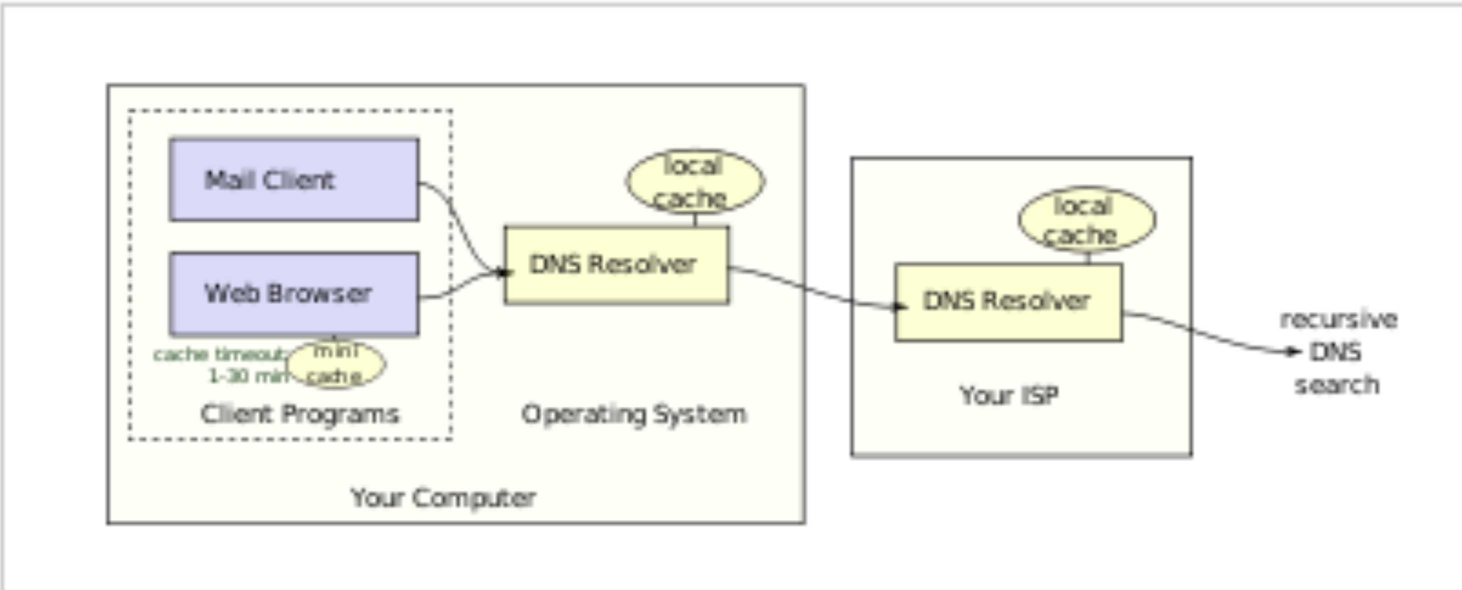
Entity header is in principle not used for GET. Used primarily for responses. E.g. Content-Encoding: gzip CRLF Title: Example CRLF

Step 2

- DNS (Domain Name System) is used to lookup the IP address of the URL we are requesting.
- www.google.com. 173.194.67.105

Domain Name System

DNS primarily uses User Datagram Protocol (UDP) on port 53.



DNS resolution sequence

Illustration

https://www.youtube.com/watch?v=72snZctFFtA

The Dot

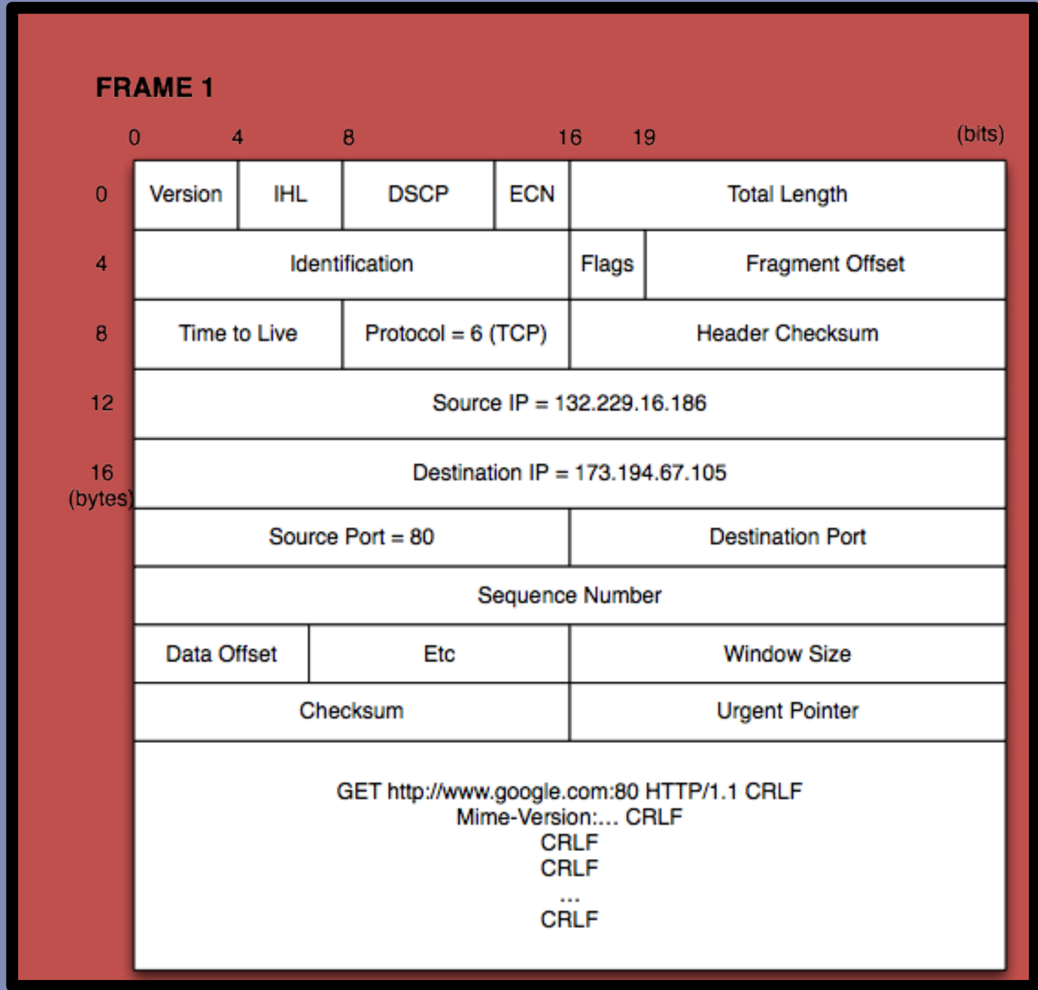
The “Dot” was documented in the DNS specification, RFC 1034, way back in 1987.
Since a complete domain name ends with the root label, this leads to a printed form which ends in a dot. We use this property to distinguish between:

•a character string which represents a complete domain name (often called "absolute"). For example, "poneria.ISI.EDU.”

•a character string that represents the starting labels of a domain name which is incomplete, and should be completed by local software using knowledge of the local domain (often called "relative"). For example, "poneria” used in the ISI.EDU domain.

Step 3

- HTTP packet is embedded in a TCP/IP packet.



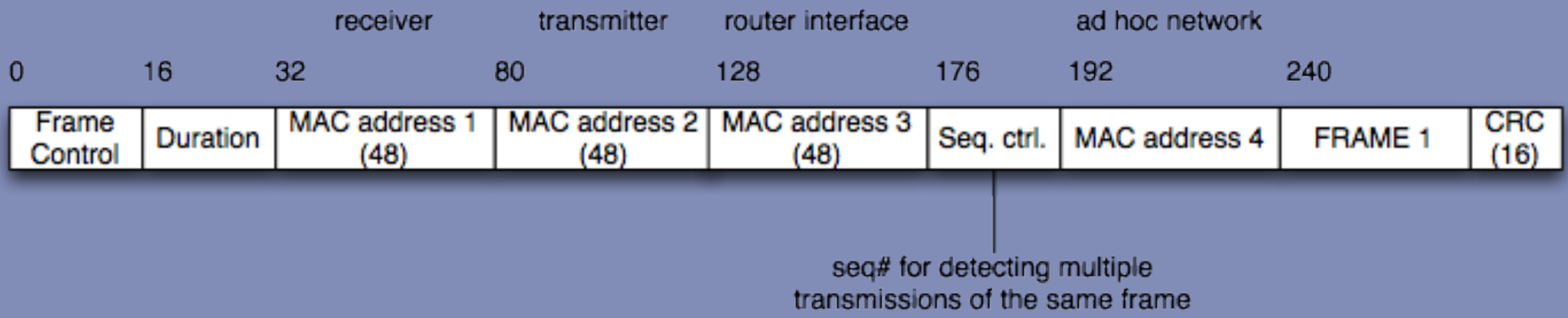
Naturally, all characters are translated using ASCII to 0 and 1

Scenario A

- PC/Laptop/Mobile Phone at home and connected over WiFi to a modem from a provider.

Step 4A

- FRAME 1 is embedded in a IEEE 802.11 WiFi frame.



Step 5A

- All the zeroes and ones are modulated and sent over the “ether” using 802.11b .
- 802.11b uses Direct Sequence Spread Spectrum (DSSS) at a frequency of 2.4 GHz and a data rate of 4.3 MB/s
- Carrier sine wave is phase modulated (PM), and each 1 and 0 (-1) is modulated using agreed random chip sequence.

Step 5A

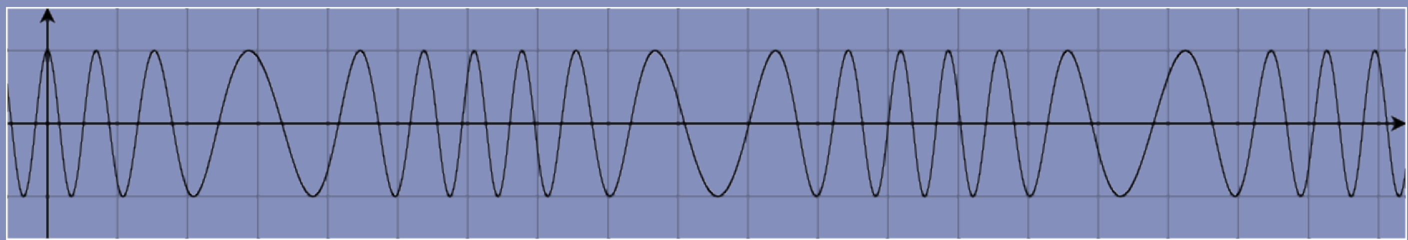
- For example, with chip sequence 1 1 1 -1 1 1 -1 -1
- 1 -1 1 is translated into:

1 1 1 -1 1 1 -1 -1   -1 -1 -1 1 -1 -1 1 1

1 1 1 -1 1 1 -1 -1

Step 5A

Resulting Signal:



etc.

Note that PM and FM are more or less the same.

Step 6A

- WiFi receiver demodulates the received signal using the same chip sequence.

Step 7A

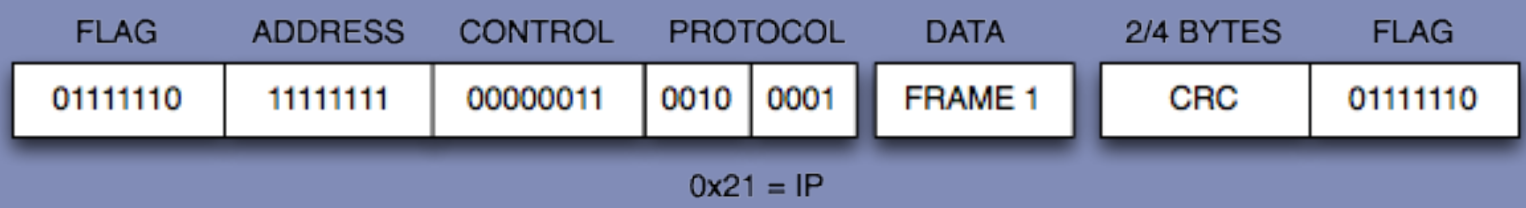
- WiFi receiver checks the sequence control field and the 16 bit CRC field (Cyclic Redundancy Check) in order to verify the validity of the WiFi frame.

Step 8A

- Receiver takes the payload (FRAME 1) out of the WiFi frame and hands the payload to the modem of the ISP.

Step 9A

- FRAME 1 is sent using the PPP protocol.



Step 10 A

- The PPP frame is modulated using for example 16-QAM.
- ADSL goes up to 32-QAM, but higher QAM degrees makes the signal more prone to errors.
- Signal sent using Frequency Division Multiplexing (FDM) using an upstream channel of 25-200 kHz

Step 11A

- The modem of the ISP demodulates the signal and does a CRC check on the received data. If OK, FRAME 1 will be extracted.

Step 12

Assuming that the ISP has a fiber leased line to another Internet node. Then, FRAME 1 will be embedded in an ATM cell.

0	4	12	28	31	32	40 (bits)
Generic Flow Control	Virtual Path Identifier	Virtual Channel Identifier	Payload Type	Cell Loss Priority	Header Error Control	FRAME 1 part
				0 don't discard 1 discard	$X^8 + X^2 + X + 1$	48 * 8 bits

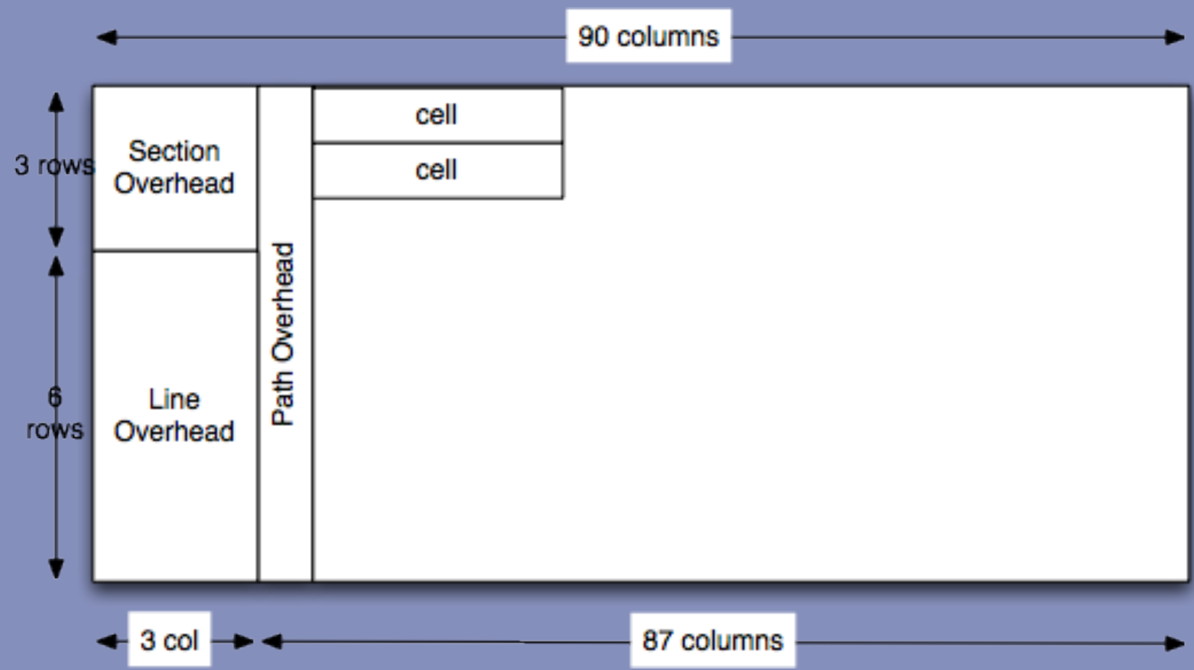
Total 53 octets = 424 bits.

<u>Virtual Circuit Switching!!!</u>

Step 12

- Several ATM cells are packed in one SONET / SDH frame.
  - SONET in the US + Canada
  - SDH in EU + rest of world
- Total payload (STS-1) = 810 octets

Step 12A



Several communication streams from different users may be sent: Time Division Multiplexing

Step 13

- Different light (electro magnetic radiation) modulation (PSK, ASK) in combination with wave length division multiplexing, encodes the 0 and 1 bits in a light bundle.

Step 14

- Using Time Division Switching, the ATM cells are sent (through different switches) to the next router.
- Light signals are transformed into electricity and the cells are unpacked and FRAME 1 reassembled.
- Based on the source and destination address, the router looks up the next router (packet switching).
- FRAME 1 is again embedded in ATM cells and sent to the next router.

Step 15

- If FRAME 1 reaches its destination it will be further routed depending on the local configuration at 173.194.67.105.

Step 16

- Assuming destination is in a multi switched network, this step is similar but reversed to 4B.

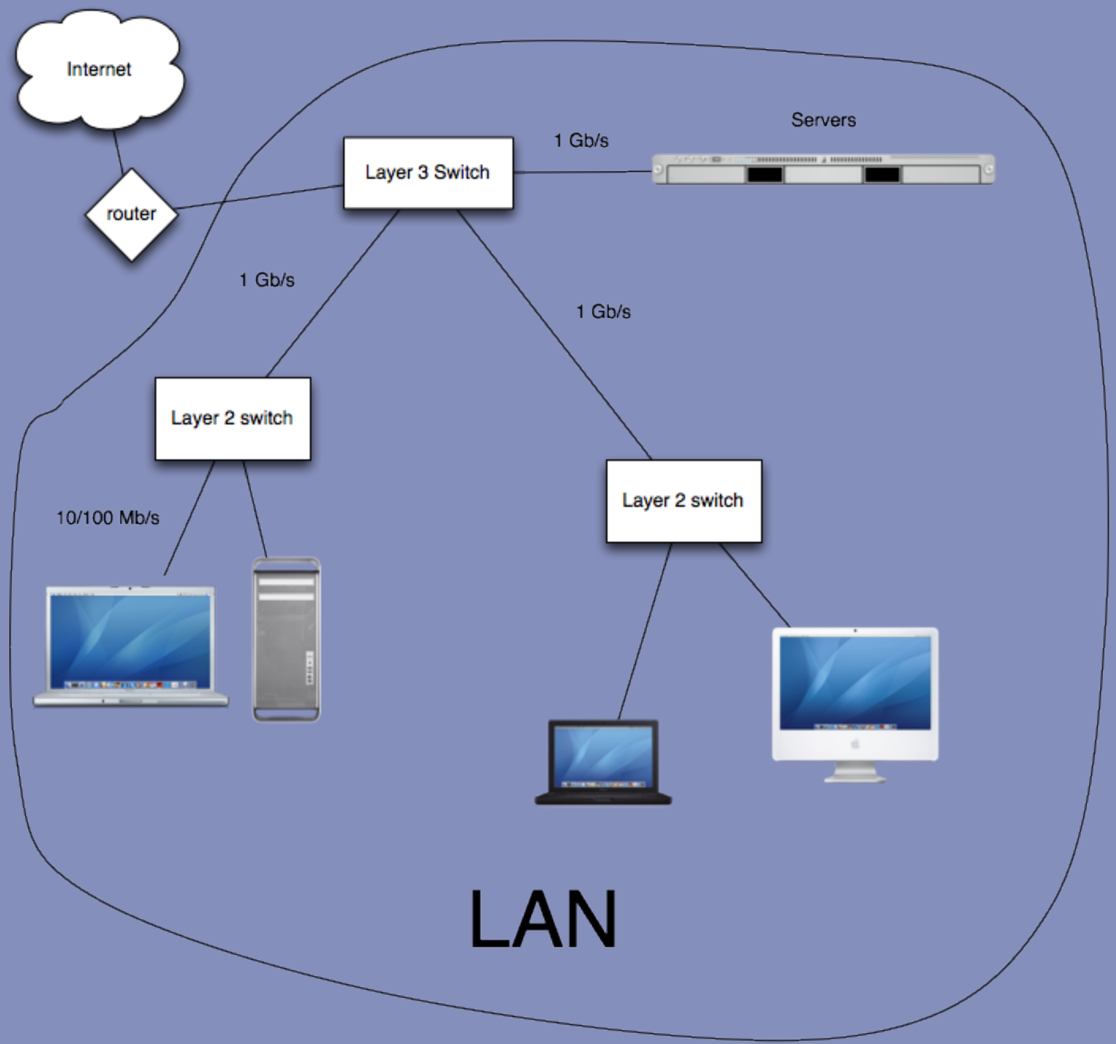
Step 17

- Finally, the server unpacks the TCP/IP packet and recognizes that the destination port (80) is used by the web server.
- The HTTP message is read by the web server that interprets the request line as a GET command.
- The web server generates a HTTP packet with the entity body containing the requested html page.
- HTTP response packet is sent to the source address.

Scenario 4B/ Step 16

- PC/Laptop at work / university and is connected to a router at work / university with fast ethernet.

Step 4B


Internet
router
Layer 3 Switch
1 Gb/s
Servers
1 Gb/s
1 Gb/s
Layer 2 switch
Layer 2 switch
10/100 Mb/s
LAN

Illustration

https://www.youtube.com/watch?v=1z0ULvg_pW8

Step 4B

IEEE 802 Media Access Protocol (MAC) + Logical Link Control (LLC).

MAC frame:

7	1	2/6	2/6	2	46-1500	>0	4
Preamble	SFD	DA	SA	type/ length	LLC data	pad	FCS

Step 4B

- Preamble: 10101...010
- SFD: Start Frame Delimiter: 10101011
- DA: Destination Address, MAC address of the network interface.
  - E.g. d1:21:f4:4c:31:0a, written in hexadecimal.
  - Each digit correspond to 4 bits (1 nibble).
  - Unique per interface, administrated by the IEEE.
- SA: Source Address (see DA)

Step 4B

- Type / length: Used by different protocols (e.g. IPX, AppleTalk) to indicate that the frame contains an LLC header.
  - Without LLC header the field contains the length of the data.
- Data
  - If the packet > 1500 B, then fragmentation
  - If the packet < 46 B, then padding
- FCS/CRC: 32 bit CRC code

Step 4B

- How to determine the MAC addresses?
- Address Resolution Protocol (ARP)
  - Similar to DNS, but translates local network addresses to hardware addresses.
  - ARP packet with sender MAC is broadcasted with MAC address ff:ff:ff:ff:ff:ff and IP address of destination.
  - If an adapter receives the ARP packet and its IP address matches, the matching adapter will send a reply to the sender with its MAC.
  - Every host has and ARP table caching the IP, MAC for a limited time (typically 20 minutes).

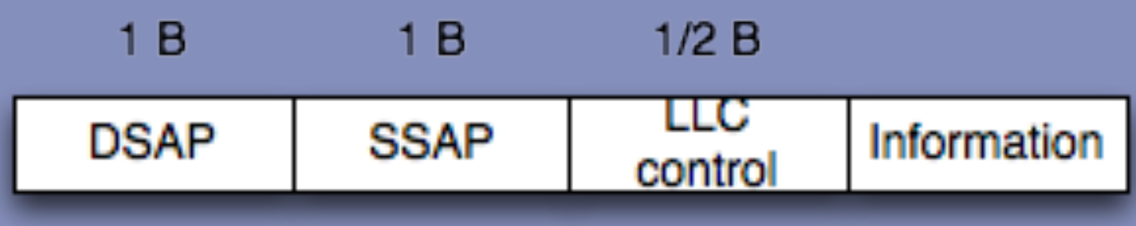
Step 4B (IPv6)

- Neighbour Discovery Protocol (NDP)
  - Roughly the same functionality as ARP but for IPv6

Step 4B

Note that Ethernet does not implement flow control. This is sufficient for IP traffic, but if flow control is needed, then MAC/LLC is used.

In the latter case, the payload will consist of:



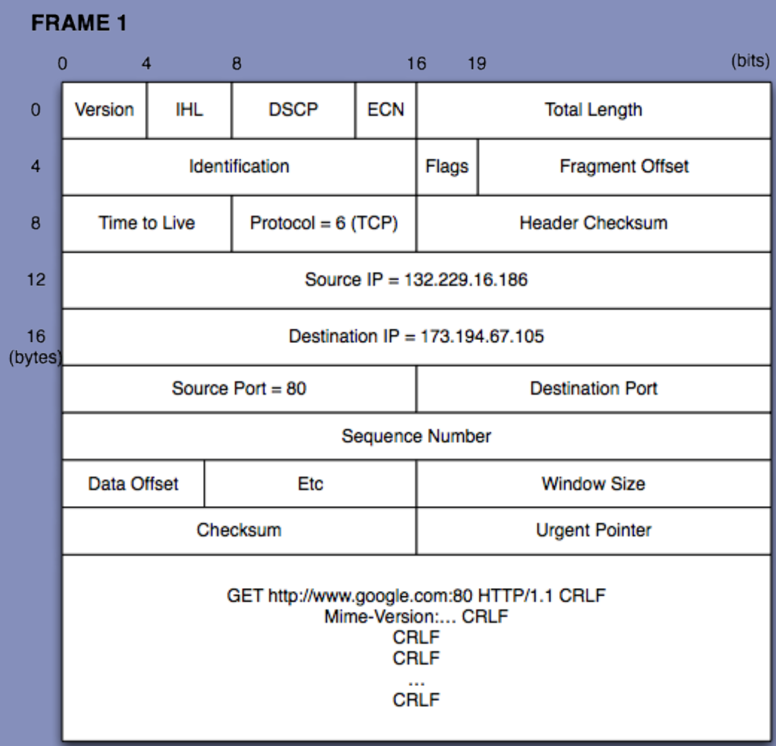
Step 4B

- DSAP (Destination Service Access Point), 8 bits, where the first bit means *group* or *individual*. Remnant of the OSI protocols.
- SSAP (Source Service Access Point), 8 bits, first bit means *command* or *response*.
- LLC control: “same” as HDLC control

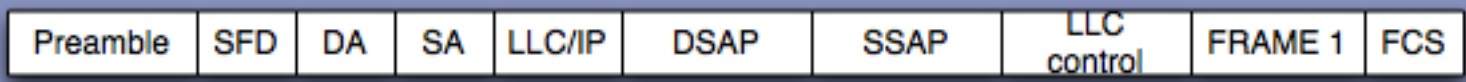
1	2 3 4	5	6 7 8
0	N(S)	P/F	N(R)

etc.

Step 4B



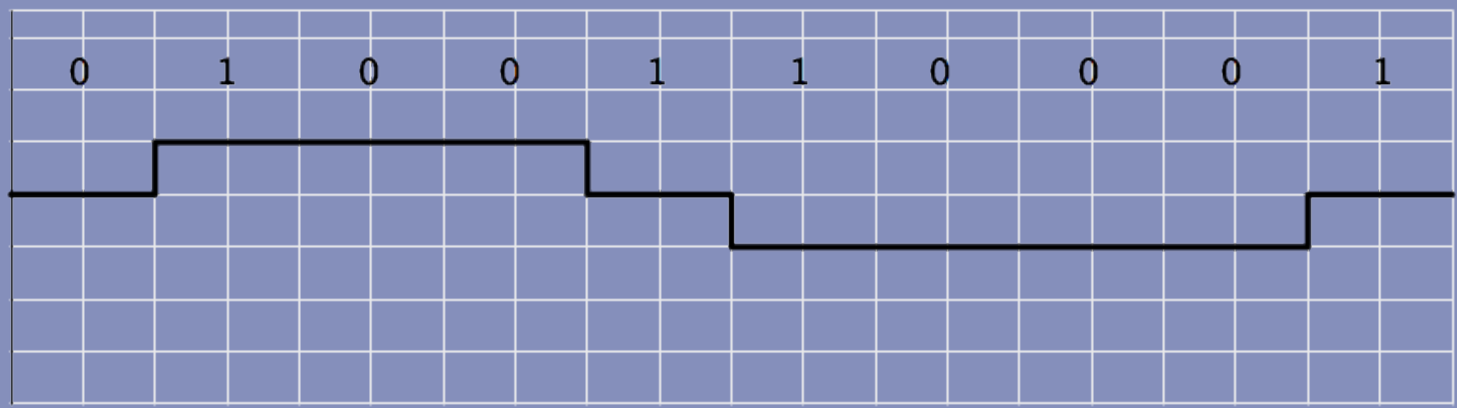
FRAME 1 is packed in an ethernet frame:



Step 4B

The data is sent over a twisted pair cable to the nearest switch via 100 BASE TX

MLT-3 signal



etc...

Step 5B

- The layer 2 switch looks up (using ARP) the MAC address of the next (potentially a layer 3) switch.
- The received frame is repacked with a new DA and SA.
- When the packet arrives at the router talking to the outside world, the MAC/LLC is unpacked and the packet proceeds using step 12.

Illustration

https://www.youtube.com/watch?v=PBWhzz_Gn10