universidade de aveiro
theoria poiesis praxis

Camada Protocolar de Aplicação (Application Layer)

Redes de Comunicações 1

Licenciatura em Engenharia de Computadores e Informática

TFTP - TRIVIAL FILE TRANSFER PROTOCOL

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Trivial File Transfer Protocol (TFTP)

- Transfer file service with very simple client/server interactions.
- A TFTP client, to receive a file, needs to know the name and directory where the file is stored.
- This service can be used to configure network elements.
- Most *Routers* and *Switches* allow its configuration to be performed through a TFTP server to receive the configuration file.
  - They need the IP address of the server and the name of the file.
  - Very small files.

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O TFTP é um protocolo de suporte a um serviço de transferência de ficheiros em que as necessidades de interacção entre cliente e servidor são simples. Um cliente TFTP, para receber um ficheiro do servidor, precisa de saber o seu nome e em que directório do servidor ele está armazenado. Este serviço é muito usado na configuração de elementos de rede. A maior parte dos *routers* e *switches* existentes no mercado permitem a sua configuração através de TFTP. No arranque estes equipamentos ligam-se a um servidor de TFTP e recebem o seu ficheiro de configuração. Para isso, basta configurar-lhes o endereço IP do servidor e o nome do ficheiro a pedir.

Este protocolo é implementado sobre o UDP e o porto normalizado do servidor é o 69. Dado que o UDP não garante fiabilidade, o TFTP implementa um mecanismo de controlo de fluxos simples (bem menos complexo que o do TCP) de modo a garantir a integridade da informação transferida (como veremos ilustrado no próximo slide).

O TFTP baseia-se apenas em 5 tipos de mensagens:

RRQ: permite o cliente pedir para ler um ficheiro do servidor

WRQ: permite o cliente pedir para escrever um ficheiro para o servidor

DATA: permite enviar um conjunto de bytes do ficheiro

ACK: permite validar a recepção de uma das primitivas anteriores

ERR: permite sinalizar a impossibilidade de uma das primitivas anteriores

Trivial File Transfer Protocol (TFTP)

- Basic file transfer service (IETF RFC 1350)
  - It does not allow to list server files
  - It does not support authentication
- TFTP runs over **UDP**
  - The initial client message is sent to server port number **69**
  - **TFTP is the one that has to address packet retransmission**
  - TFTP server answers from another locally selected port number
  - The following messages are exchanged with the selected port number
- TFTP uses *Stop and Wait* ARQ mechanism
- TFTP has 5 messages:
  - *Read Request* (RRQ)
  - *Write Request* (WRQ)
  - *Data*
  - *Acknowledgement* (ACK)
  - *Error* (ERR)

4

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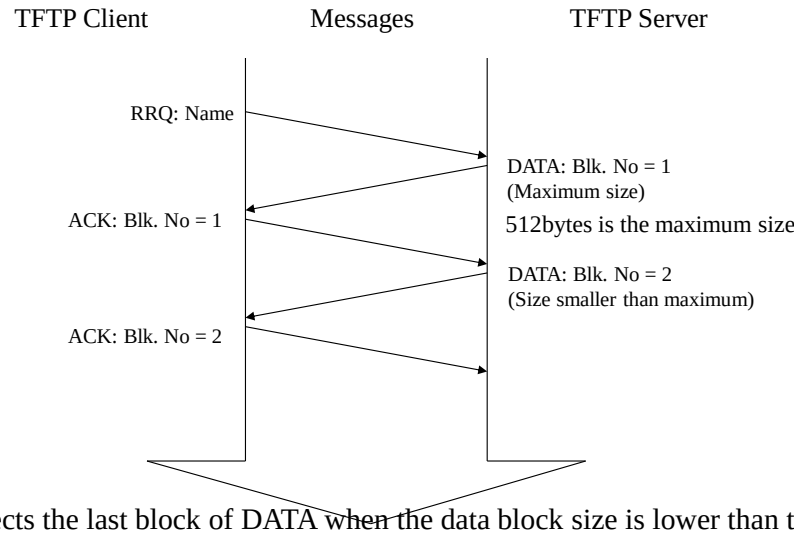
Read Request session



Client detects the last block of DATA when the data block size is lower than the maximum size. If the size of the file is **multiple** of the maximum size, an aditional data block is sent with **0** bytes of data. RRQ always with odd number of packets (RRQ+pairs of data and ACK).

5

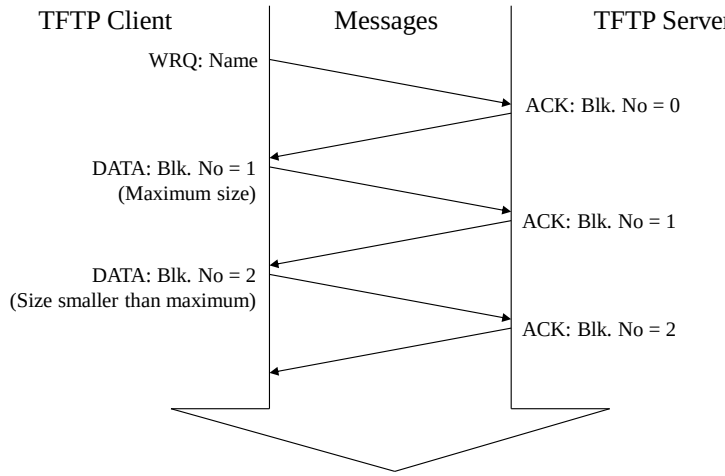
Uma sessão TFTP é sempre iniciada pelo cliente ou com um WRQ (para enviar um ficheiro) ou com um RRQ (para receber um ficheiro).

Numa sessão *Write Request*, após o envio do WRQ, o servidor responde com um ACK para confirmar que está preparado para receber o ficheiro. Depois, o cliente começa a enviar o ficheiro com mensagens DATA seccionando a informação em blocos do tamanho máximo definido por configuração. A cada mensagem DATA, o servidor responde com um ACK confirmando que recebeu o respectivo bloco. O cliente só manda um DATA após receber o ACK do DATA anterior. Se uma qualquer mensagem DATA não chega ao destino (ou o respectivo ACK), o cliente tem um mecanismo de timeout (também configurável na aplicação) em que ao fim do tempo máximo de espera se não recebeu o respectivo ACK, volta a enviar o mesmo bloco de dados.

O servidor detecta a última mensagem DATA quando o tamanho do bloco de dados é menor que o tamanho máximo. Neste caso, a mensagem ACK serviu para o servidor validar a recepção das mensagens WRQ e DATA enviadas pelo cliente.

Cada um dos lados implementa timeout e retransmissão. Se o lado que está a transmitir dados faz timeout, retransmite o último bloco de dados; se o lado responsável por transmitir ACKs faz timeout, retransmite o último ACK.

Write Request session



Server detects the last block of DATA when the data block size is lower than the maximum size. ThIfe the size of the file is **multiple** of the maximum size, an aditional data block is sent with **0** bytes of data. WRQ always with even number of packets (WRQ+ACK0+pairs of data and ACK).

6

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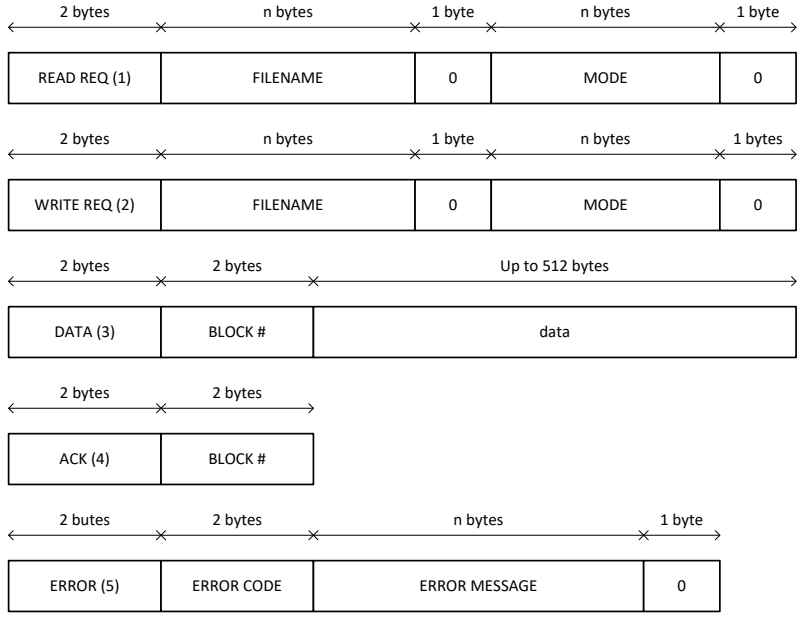
Messages format



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FILENAME – string de caracteres ASCII que especifica o nome do ficheiro a ler ou a escrever.

MODE – string de caracteres ASCII que especifica o modo da mensagem; octet ou netascii; octet – 8 bits de raw data, usado para transferir ficheiros; netascii – ASCII de 7 bits standard, usado para enviar mensagens (strings de caracteres).

BLOCK # no ACK é igual ao número de bloco da mensagem recebida. O servidor utiliza o ACK para confirmar a recepção dos blocos de dados e o cliente usa os blocos de dados para confirmar a recepção dos ACK, excepto no caso de ACKs duplicados e de um ACK que termina uma ligação. A recepção de um ACK duplicado pode acontecer apenas quando o primeiro ACK se atrasa, provocando o envio de um bloco de dados (duplicado). Para quebrar o ciclo de transmissões duplicadas (Sorcerer's Apprentice Bug), o bloco de dados corrente nunca é retransmitido como resultado da recepção de um ACK duplicado.

ERROR actua como um NACK; pode causar retransmissão da mensagem ou quebra da ligação.

ERROR MESSAGE – string ASCII que explica o tipo de erro.

ERROR CODE:

00 – Not defined

01 – File not found

02 – Access violation

03 – Disk full

04 – Invalid operation code

05 – Unknown port number

06 – File already exists

07 – No such user

FTP – FILE TRANSFER PROTOCOL

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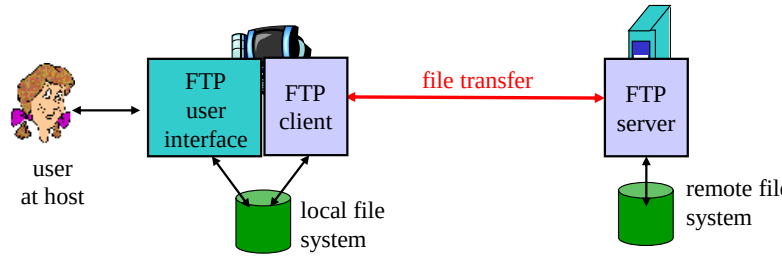
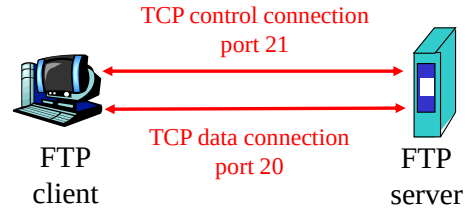
FTP: the file transfer protocol



- transfer file to/from remote host (IETF RFC 959)
- client/server model
  - *client:* side that initiates file transfer (either to/from remote host)
  - *server:* remote host
- ftp: runs over **TCP (TCP takes care of packet retransmission)**
- ftp server ports: **21** and **20**
  - **21** for the control connection
  - **20** for each data connection

FTP: separate control, data connections

- FTP client contacts FTP server at port 21, TCP is transport protocol
- client authorized over control connection
- client browses remote directory by sending commands over control connection
- when server receives file transfer command, server opens 2nd TCP connection (for file transfer) to client
- after transferring one file, server closes data connection.



- server opens another TCP data connection to transfer another file.
- control connection: "out of band"
- FTP server maintains the "state" of client interactions: current directory, earlier authentication, etc…

FTP commands, responses

Sample commands:

- sent as ASCII text over control channel:

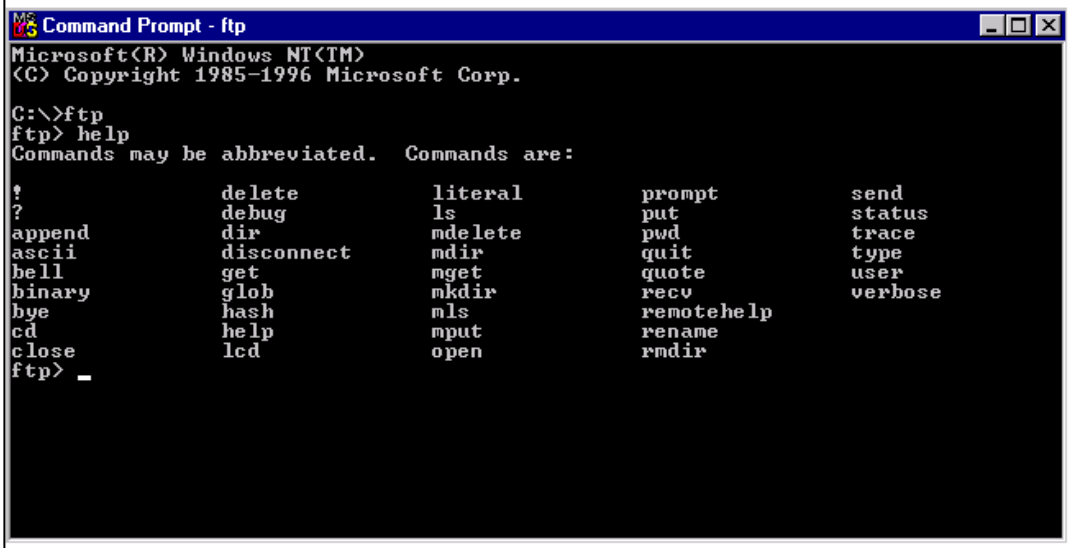
- **USER** ***username***
- **PASS** ***password***
- **LIST** (return list of files in current directory)
- **RETR filename** (retrieves file from server)
- **STOR filename** (stores file onto server)

Sample return codes

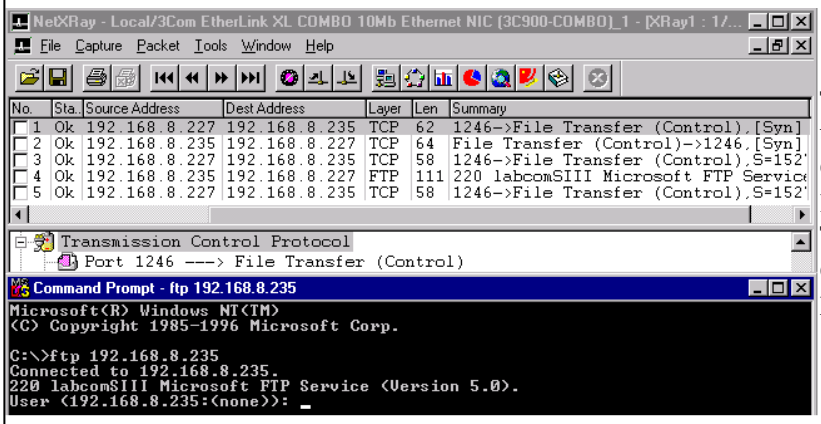
- status code and phrase (as in HTTP):

- **331 Username OK, password required**
- **125 Data connection already open; transfer starting**
- **425 Can't open data connection**
- **452 Error writing file**

FTP client: user commands



Initial connection to FTP server



TCP 3-way handshake to initiate the control connection in port 21

For each packet sent, a TCP ACK is needed to confirm the previous packet

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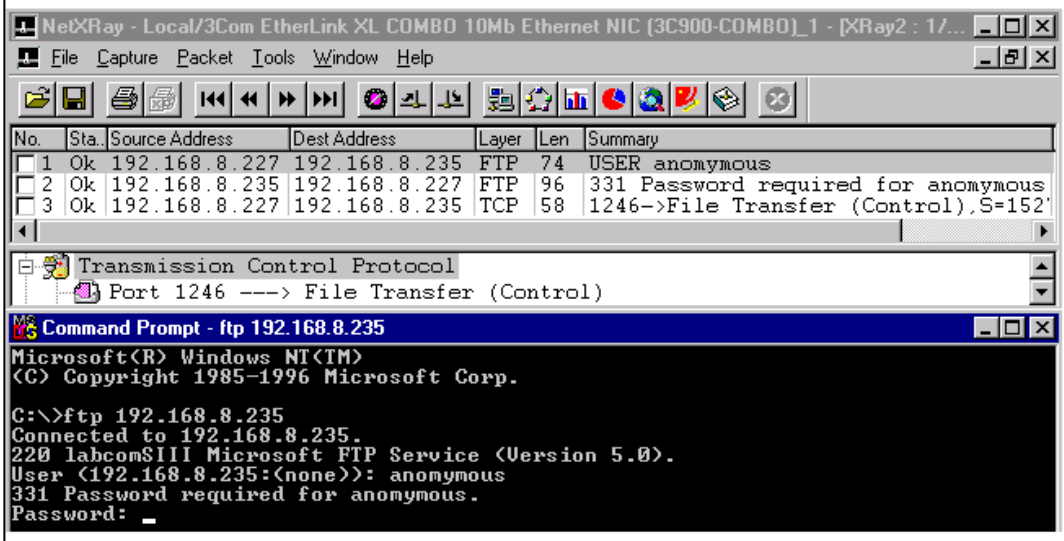
Introduction of username



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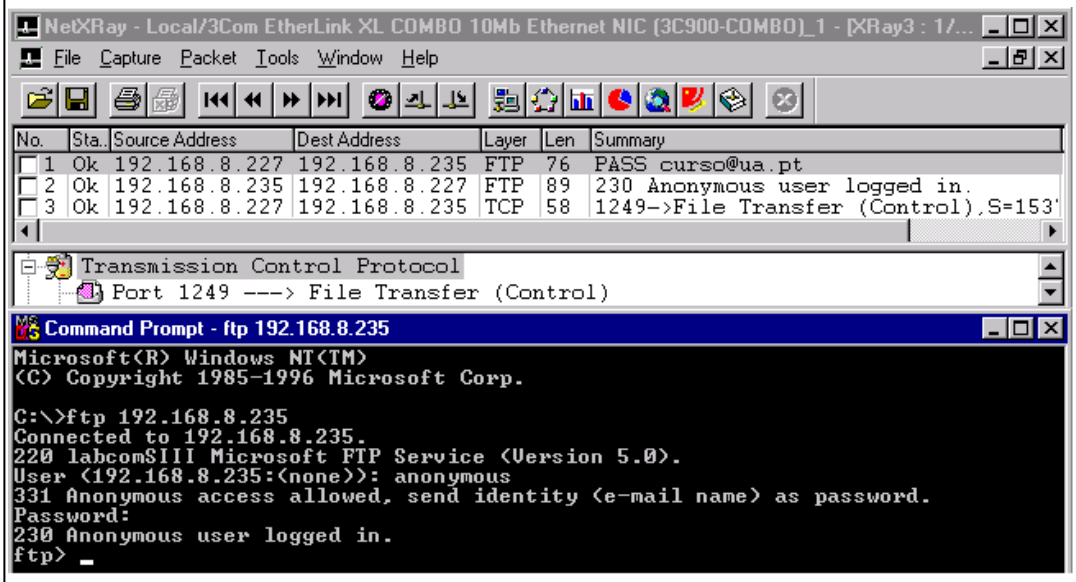
Introduction of password



Introduction of DIR command

No.	Sta.	Source Address	Dest Address	Layer	Len	Summary
1	Ok	192.168.8.227	192.168.8.235	FTP	84	PORT 192,168,8,227,4,229
2	Ok	192.168.8.235	192.168.8.227	FTP	88	200 PORT command successful.
3	Ok	192.168.8.227	192.168.8.235	FTP	64	LIST
4	Ok	192.168.8.235	192.168.8.227	FTP	111	150 Opening ASCII mode data connect
5	Ok	192.168.8.235	192.168.8.227	TCP	66	File Transfer (Default Data)->1253,
6	Ok	192.168.8.227	192.168.8.235	TCP	62	1253->File Transfer (Default Data),
7	Ok	192.168.8.235	192.168.8.227	TCP	64	File Transfer (Default Data)->1253,
8	Ok	192.168.8.235	192.168.8.227	FTP	210	Data (total 152 bytes),(More data)
9	Ok	192.168.8.235	192.168.8.227	TCP	64	File Transfer (Default Data)->1253,
10	Ok	192.168.8.227	192.168.8.235	TCP	58	1253->File Transfer (Default Data),
11	Ok	192.168.8.227	192.168.8.235	TCP	58	1253->File Transfer (Default Data),
12	Ok	192.168.8.235	192.168.8.227	TCP	64	File Transfer (Default Data)->1253,
13	Ok	192.168.8.227	192.168.8.235	TCP	58	1252->File Transfer (Control),S=154
14	Ok	192.168.8.235	192.168.8.227	FTP	82	226 Transfer complete.
15	Ok	192.168.8.227	192.168.8.235	TCP	58	1252->File Transfer (Control),S=154

File Transfer Protocol
PORT 192,168,8,227,4,229

```
Command Prompt - ftp 192.168.8.235
Microsoft(R) Windows NT(TM)
(C) Copyright 1985-1996 Microsoft Corp.

C:\>ftp 192.168.8.235
Connected to 192.168.8.235.
220 labcomSIII Microsoft FTP Service (Version 5.0).
User (192.168.8.235:(none)): anonymous
331 Anonymous access allowed, send identity (e-mail name) as password.
Password:
230 Anonymous user logged in.
ftp> dir
200 PORT command successful.
150 Opening ASCII mode data connection for /bin/ls.
10-05-00  12:02PM       <DIR>          CursoTCP_IP
08-27-00  12:32AM                 1024 f1024.txt
08-27-00  12:32AM                 1268 f1268.txt
226 Transfer complete.
152 bytes received in 0.00 seconds (152000.00 Kbytes/sec)
ftp>
```

Information to start the data connection

FTP command for DIR

TCP 3-way handshake to initiate the data connection in port 20

Data is sent

FIN and ACK packets (4 in total) to finish the data connection in port 20

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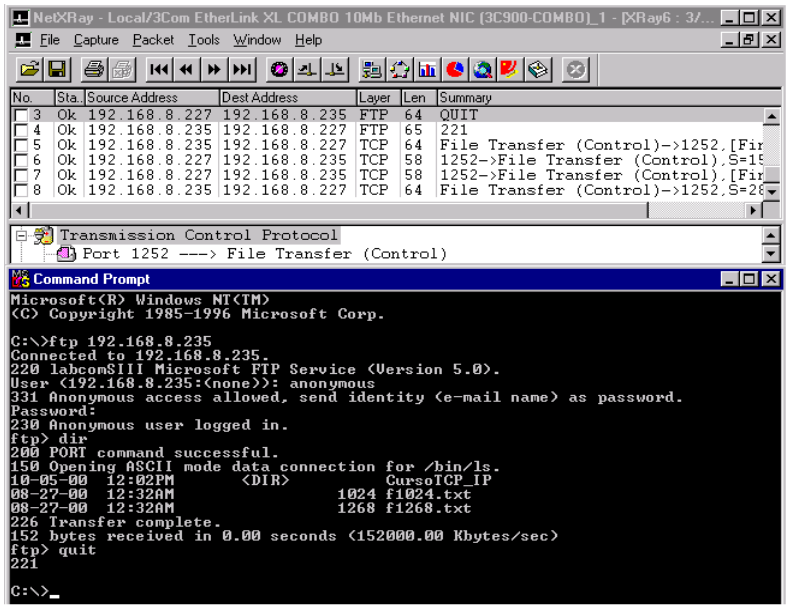
O comando PORT indica o porto usado para a ligação de dados. Cliente (227) indica porto para a ligação de dados. Servidor (235) inicia o estabelecimento da ligação. Depois do comando Data os 4 segmentos TCP fecham a ligação.

Termination of connection (quit)



FIN and ACK packets (4 in total) to finish the control connection in port 21

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DNS – DOMAIN NAME SYSTEM

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DNS: Domain Name System

People: many identifiers:
- SSN, name, passport #

Internet hosts, routers:
- IP address (32 bit) - used for addressing datagrams
- "name" (for example, www.yahoo.com) - used by humans

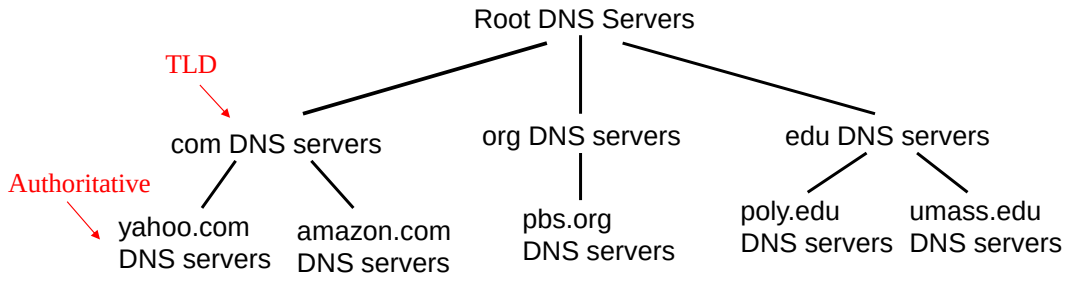
DNS: provides a mapping between IP addresses and names

Works in **UDP port 53**

Domain Name System:
- *distributed database* implemented in a hierarchy of many *Name Servers*
- *application-layer protocol* hosts communicate with Name Servers to *resolve* names (name - IP address translation)
  - note: core Internet function, implemented as application-layer protocol
  - complexity at network's "edge"

Dynamic DNS is a system which allows the domain name data held in a name server to be updated in real time. The most common use for this is in allowing an Internet domain name to be assigned to a computer with a varying (dynamic) IP address. This makes it possible for other sites on the Internet to establish connections to the machine without needing to track the IP address themselves. A common use is for running server software on a computer that has a dynamic IP address, as is the case with many consumer Internet service providers.

Distributed, Hierarchical Database



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

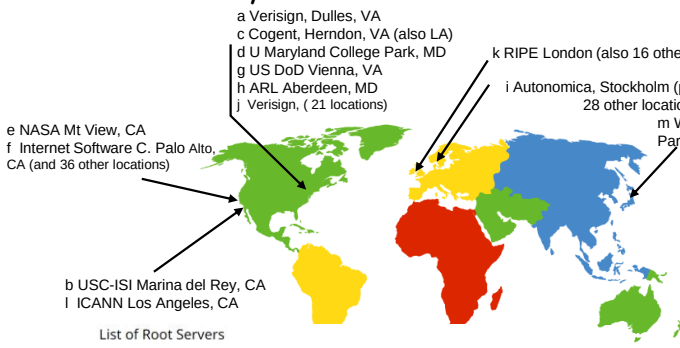
- client queries a root server to find 'com' DNS server
- client queries 'com' DNS server to get 'amazon.com' DNS server
- client queries 'amazon.com' DNS server to get IP address for www.amazon.com

DNS: Root Name Servers

Server	Operator	Cities	IP Addr	Home AS	Answers ICMP?
A	VeriSign Global Registry Services	Herndon VA, US	198.41.0.4	19836	*yes*
B	Information Sciences Institute	Marina Del Rey CA, US	128.9.0.107	*tba*	*yes*
C	Cogent Communications	Herndon VA, US	192.33.4.12	2149	*yes*
D	University of Maryland	College Park MD, US	128.8.10.90	27	*yes*
E	NASA Ames Research Center	Mountain View CA, US	192.203.230.10	297	*yes*
F	Internet Software Consortium	Palo Alto CA, US; San Francisco CA, US; Madrid, ES; San Jose, CA, US; New York, NY, US; Hong Kong, HK	IPv4: 192.5.5.241 IPv6: 2001:500::1035	3557	*yes*
G	U.S. DOD Network Information Center	Vienna VA, US	192.112.36.4	568	*no*
H	U.S. Army Research Lab	Aberdeen MD, US	IPv4: 128.63.2.53 IPv6: 2001:500:1::803f:235	13	*yes*
I	Autonomica	Stockholm, SE	192.36.148.17	8674	*yes*
J	VeriSign Global Registry Services	Herndon VA, US	192.58.128.30	26415	*yes*
K	Reseaux IP Europeens - Network Coordination Centre	London, UK	193.0.14.129	5459	*yes*
L	Internet Corporation for Assigned Names and Numbers	Los Angeles CA, US	198.32.64.12	20144	*no*
M	WIDE Project	Tokyo, JP	202.12.27.33	7500	*yes*

DNS: Root Name Servers

- contacted by local Name Server that cannot resolve name



13 root name servers worldwide

List of Root Servers

HOSTNAME	IP ADDRESSES	OPERATOR
a.root-servers.net	198.41.0.4, 2001:503:ba3e::2:30	Verisign, Inc.
b.root-servers.net	170.247.170.2, 2801:1b8:10::b	University of Southern California, Information Sciences Institute
c.root-servers.net	192.33.4.12, 2001:500:2::c	Cogent Communications
d.root-servers.net	199.7.91.13, 2001:500:2d::d	University of Maryland
e.root-servers.net	192.203.230.10, 2001:500:a8::e	NASA (Ames Research Center)
f.root-servers.net	192.5.5.241, 2001:500:2f::f	Internet Systems Consortium, Inc.
g.root-servers.net	192.112.36.4, 2001:500:12::d0d	US Department of Defense (NIC)
h.root-servers.net	198.97.190.53, 2001:500:1::53	US Army (Research Lab)
i.root-servers.net	192.36.148.17, 2001:7fe::53	Netnod
j.root-servers.net	192.58.128.30, 2001:503:c27::2:30	Verisign, Inc.
k.root-servers.net	193.0.14.129, 2001:7fd::1	RIPE NCC
l.root-servers.net	199.7.83.42, 2001:500:9f::42	ICANN
m.root-servers.net	202.12.27.33, 2001:dc3::35	WIDE Project

Top Level Domains (TLD)

- Organizational domains:
  - com - commercial organizations
  - edu - educational institutions
  - gov - govern institutions
  - mil - military institutions
  - net - network operators
  - int - international organizations
  - org - other organizations
- Country domains:
  - pt - Portugal
  - es - Spain

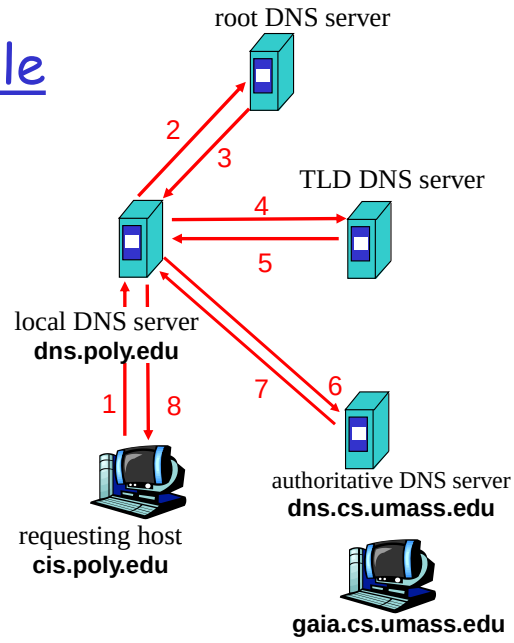
Local Name Server

- does not strictly belong to hierarchy
- each ISP (residential ISP, company, university) has one.
  - also called "default Name Server"
- when host makes DNS query, query is sent to its local DNS server
  - acts as proxy, forwards query into hierarchy

DNS name resolution example

- Host at cis.poly.edu wants IP address for gaia.cs.umass.edu

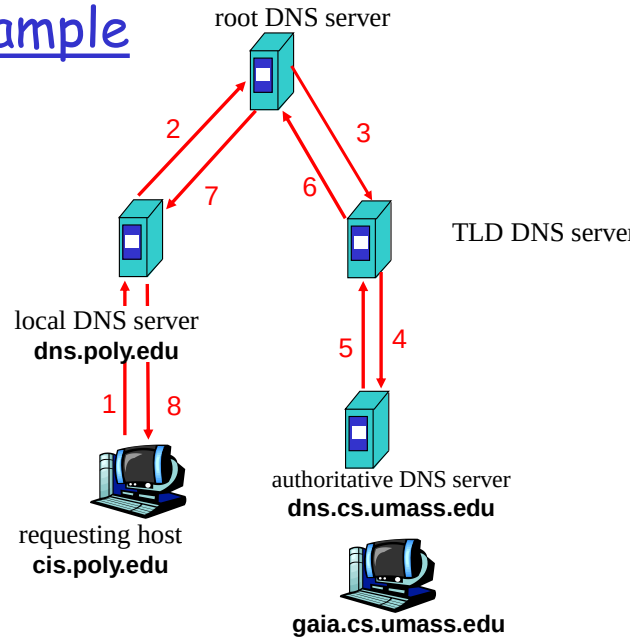
iterated query:
- contacted server replies with name of server to contact
- "I don't know this name, but ask this server"



DNS name resolution example

recursive query:

- puts burden of name resolution on contacted name server



Recursive vs. iterated resolution

- Recursive resolution:
  - More efficient: minimizes the time between the query and the answer
  - Requires more processing power in DNS servers: each server has more simultaneous ongoing requests, on average
- Iterated resolution:
  - Less efficient: the time between the query and the answer is larger, on average
  - Minimizes the processing power required on DNS servers: each server replies immediately to each received query

DNS: caching and updating records

- once (any) Name Server learns mapping, it *caches* mapping
  - cache entries timeout (disappear) after some time
  - TLD server addresses are typically cached in local Name Servers
    - Thus, Root Name Servers are not often visited

DNS records

DNS: distributed database storing Resource Records (RR)

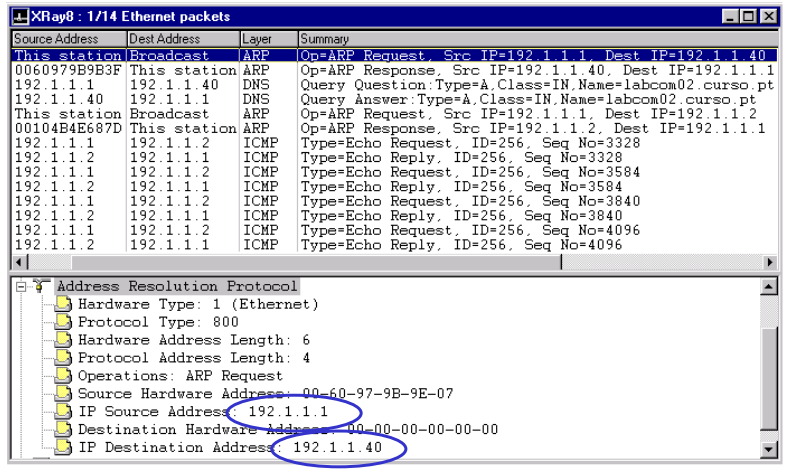
RR format: `(name, value, type, ttl)`

- Type=A
  - **name** is hostname
  - **value** is IP address
  - e.g. (relay1.bar.foo.com, 145.37.93.126, A)
- Type=NS
  - **name** is domain (e.g. foo.com)
  - **value** is hostname of authoritative name server for this domain
  - e.g. (foo.com, dns.foo.com, NS)
- Type=CNAME
  - **name** is alias name for some "canonical" (the real) name
  - **value** is canonical name
  - e.g. (foo.com, relay1.bar.foo.com, CNAME)
- Type=MX
  - **value** is name of mailserver associated with **name**
  - e.g. (foo.com, mail.bar.foo.com, MX)
- Type=AAAA
  - **name** is hostname
  - **value** is IPv6 address

DNS messages

host: 192.1.1.1
DNS: 192.1.1.40

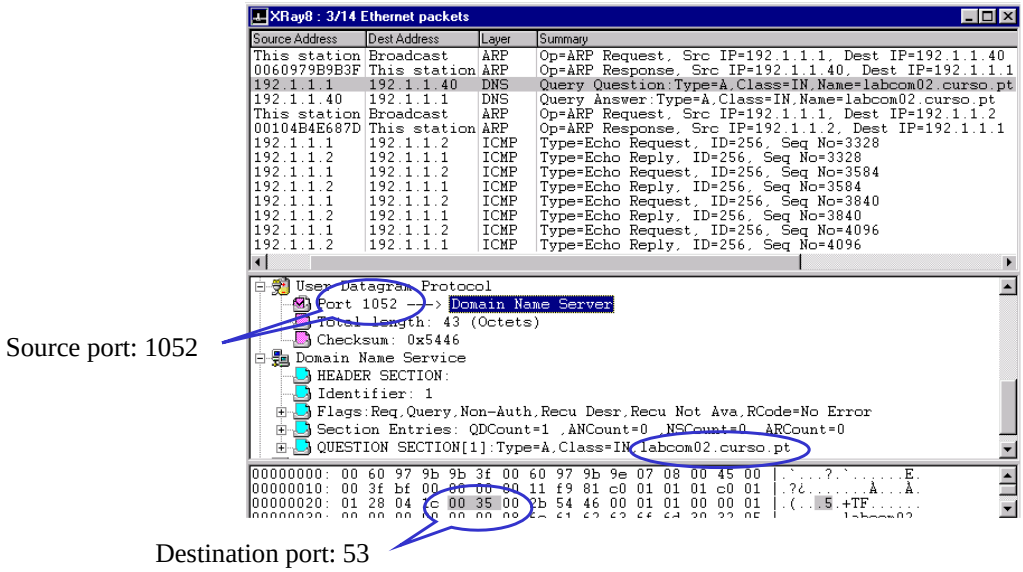
```
C:\>ping labcom02.curso.pt
```



A captura apresenta uma captura de um pedido bem sucedido de resolução do nome *labcom02.curso.pt* feito pelo terminal com endereço 192.1.1.1 configurado com o endereço de DNS 192.1.1.40. Este pedido de resolução de endereço foi originado pelo comando *ping labcom02.curso.pt*.

Como inicialmente o terminal não sabe o endereço MAC do DNS, começa por emitir um *ARP Request* para o endereço 192.1.1.40 (pacote 1) e recebe de seguida do servidor de DNS o *ARP Response* respectivo.

DNS messages



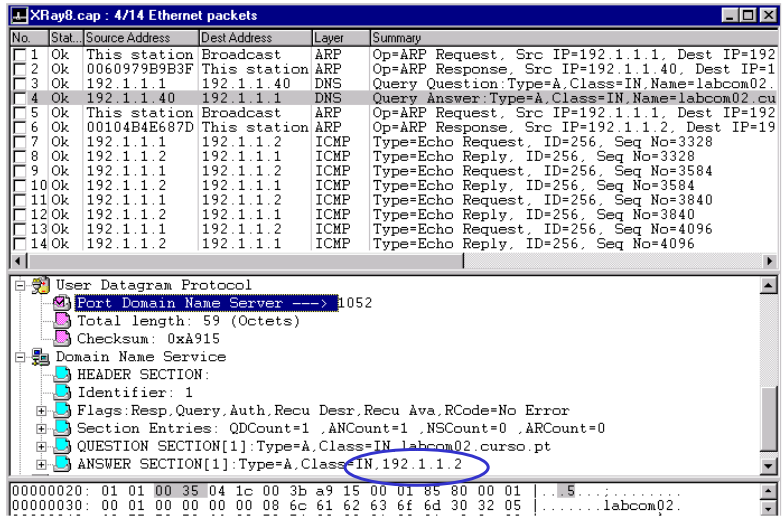
Source port: 1052

Destination port: 53

Após a identificação do endereço MAC do servidor DNS, o terminal envia um comando DNS encapsulado num pacote UDP com um número de porto origem escolhido localmente (no exemplo, 1052) e o número de porto destino típico do serviço DNS (porto 53).

Este comando DNS contém apenas um *QUESTION SECTION* em que é enviado o nome que se pretende resolver (conforme assinalado na figura).

DNS messages



O comando DNS enviado pelo terminal é recebido pelo servidor que responde com outro comando DNS. Este comando é encapsulado num pacote UDP em que os números de porto usados são os mesmos do comando recebido.

A resposta a um pedido de resolução DNS é constituída por dois *Section Entries*: o *QUESTION SECTION* que foi recebido e o *ANSWER SECTION* com o endereço IP associado ao nome recebido.

Após a recepção do endereço IP pretendido, os pacotes seguintes têm um comportamento semelhante ao que se observa se o comando *ping* tivesse sido executado com o endereço IP. Neste caso, é primeiro executado o protocolo ARP para descobrir o endereço MAC do destino e depois são gerados os pacotes ICMP típicos.

HTTP

33

Web and HTTP

First some basic concepts

- Web page consists of objects
- Object can be HTML file, JPEG image, Java applet, audio file,…
- Web page consists of base HTML-file which includes several referenced objects
- Each object is addressable by a URL
- Example URL:

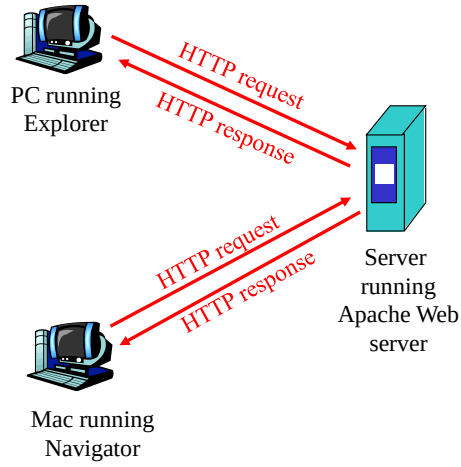
`www.someschool.edu/someDept/pic.gif`

host name | path name

HTTP overview

HTTP: HyperText Transfer Protocol

- Web's application layer protocol
- client/server model
  - *client:* browser that requests, receives, "displays" Web objects
  - *server:* Web server sends objects in response to requests
- HTTP 1.0: RFC 1945
- HTTP 1.1: RFC 2068



HTTP overview (continued)

Uses TCP:

- client initiates TCP connection (creates socket) to server, port 80
- server accepts TCP connection from client
- HTTP messages (application-layer protocol messages) exchanged between browser (HTTP client) and Web server (HTTP server)
- TCP connection closed

HTTP is "stateless"

- server maintains no information about past client requests

aside

Protocols that maintain "state" are complex!

- past history (state) must be maintained
- if server/client crashes, their views of "state" may be inconsistent, must be reconciled

HTTP connections

Nonpersistent HTTP

- At most one object is sent over a TCP connection
- HTTP/1.0 uses nonpersistent HTTP

Persistent HTTP

- Multiple objects can be sent over single TCP connection between client and server
- HTTP/1.1 uses persistent connections in default mode

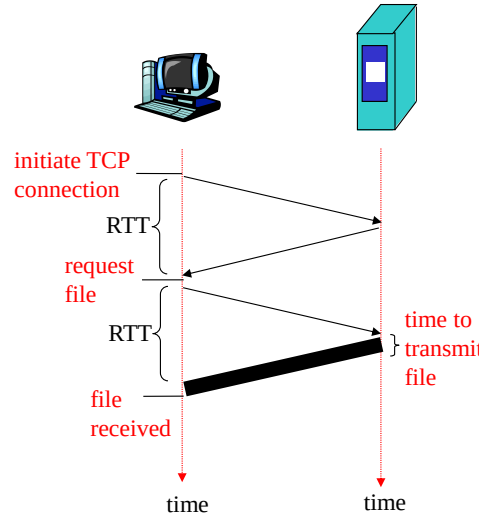
Nonpersistent HTTP: Response time

Round Trip Time (RTT: time to send a small packet to travel from client to server and back.

Response time:

- one RTT to initiate TCP connection
- one RTT for HTTP request and first few bytes of HTTP response to return
- file transmission time

total = 2RTT+transmit time



Persistent HTTP

Nonpersistent HTTP issues:

- requires 2 RTTs per object
- OS overhead for *each* TCP connection
- browsers often open parallel TCP connections to fetch referenced objects

Persistent HTTP

- server leaves connection open after sending response
- subsequent HTTP messages between same client/server sent over open connection

Persistent ***without*** pipelining:

- client issues new request only when previous response has been received
- one RTT for each referenced object

Persistent ***with*** pipelining:

- default in HTTP/1.1
- client sends requests as soon as it encounters a referenced object
- as little as one RTT for all the referenced objects

HTTP request message

- two types of HTTP messages: *request, response*
- HTTP request message:
  - ASCII (human-readable format)

request line (GET, POST, HEAD commands)

```
GET /somedir/page.html HTTP/1.1
Host: www.someschool.edu
User-agent: Mozilla/4.0
Connection: close
Accept-language: fr
```

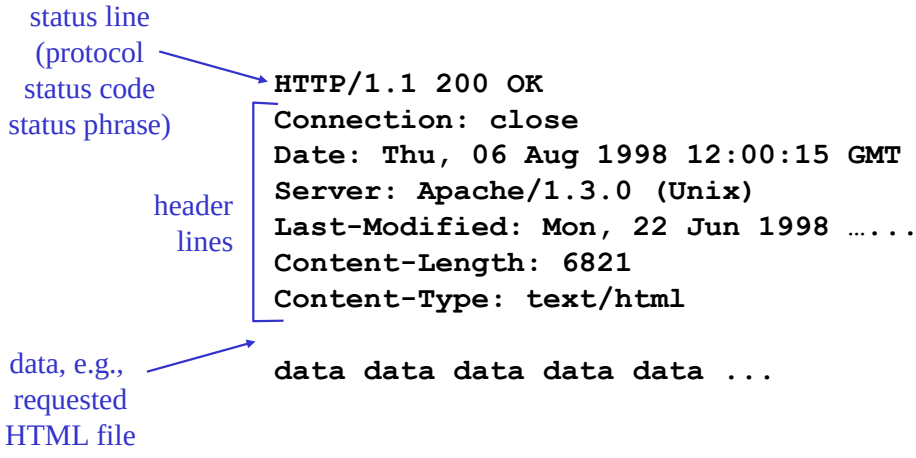
header lines

Close: nonpersistent connection – 1 TCP connection per object to send

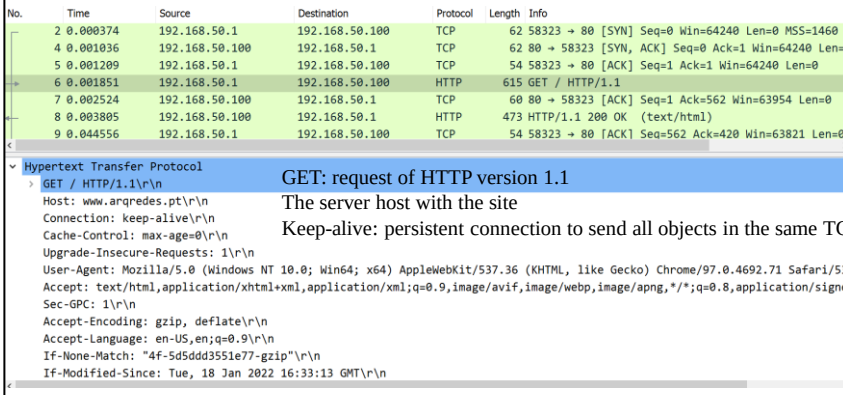
(extra carriage return, line feed)

Carriage return, line feed indicates end of message

HTTP response message



HTTP Request – starts with TCP connection



No.	Time	Source	Destination	Protocol	Length	Info
2	0.000374	192.168.50.1	192.168.50.100	TCP	62	58323 → 80 [SYN] Seq=0 Win=64240 Len=0 MSS=1460 S
4	0.001036	192.168.50.100	192.168.50.1	TCP	62	80 → 58323 [SYN, ACK] Seq=0 Ack=1 Win=64240 Len=0
5	0.001209	192.168.50.1	192.168.50.100	TCP	54	58323 → 80 [ACK] Seq=1 Ack=1 Win=64240 Len=0
6	0.001851	192.168.50.1	192.168.50.100	HTTP	615	GET / HTTP/1.1
7	0.002524	192.168.50.100	192.168.50.1	TCP	60	80 → 58323 [ACK] Seq=1 Ack=562 Win=63954 Len=0
8	0.003805	192.168.50.100	192.168.50.1	HTTP	473	HTTP/1.1 200 OK (text/html)
9	0.044556	192.168.50.1	192.168.50.100	TCP	54	58323 → 80 [ACK] Seq=562 Ack=420 Win=63821 Len=0

```
Hypertext Transfer Protocol
  GET / HTTP/1.1\r\n
  Host: www.arqredes.pt\r\n
  Connection: keep-alive\r\n
  Cache-Control: max-age=0\r\n
  Upgrade-Insecure-Requests: 1\r\n
  User-Agent: Mozilla/5.0 (Windows NT 10.0; Win64; x64) AppleWebKit/537.36 (KHTML, like Gecko) Chrome/97.0.4692.71 Safari/53
  Accept: text/html,application/xhtml+xml,application/xml;q=0.9,image/avif,image/webp,image/apng,*/*;q=0.8,application/signe
  Sec-GPC: 1\r\n
  Accept-Encoding: gzip, deflate\r\n
  Accept-Language: en-US,en;q=0.9\r\n
  If-None-Match: "4f-5d5ddd3551e77-gzip"\r\n
  If-Modified-Since: Tue, 18 Jan 2022 16:33:13 GMT\r\n
```

TCP 3-way handshake to initiate the HTTP connect in port 80

GET: request of HTTP version 1.1

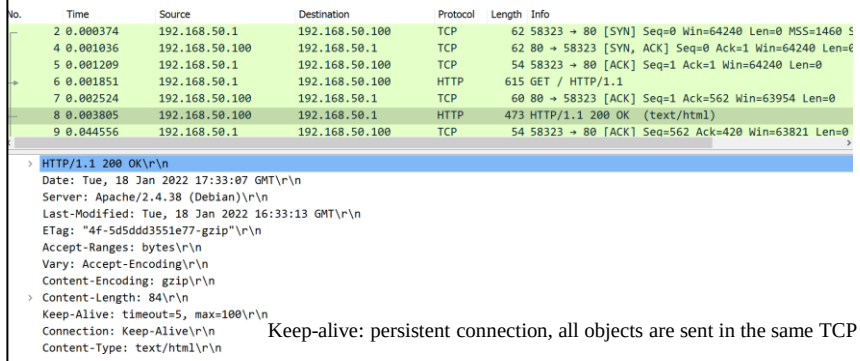
200 OK: answer with data transmission

GET: request of HTTP version 1.1

The server host with the site

Keep-alive: persistent connection to send all objects in the same TCP connection

HTTP Request – answers with data, ACKed with TCP



No.	Time	Source	Destination	Protocol	Length	Info
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5	0.001209	192.168.50.1	192.168.50.100	TCP	54	58323 → 80 [ACK] Seq=1 Ack=1 Win=64240 Len=0
6	0.001851	192.168.50.1	192.168.50.100	HTTP	615	GET / HTTP/1.1
7	0.002524	192.168.50.100	192.168.50.1	TCP	60	80 → 58323 [ACK] Seq=1 Ack=562 Win=63954 Len=0
8	0.003805	192.168.50.100	192.168.50.1	HTTP	473	HTTP/1.1 200 OK (text/html)
9	0.044556	192.168.50.1	192.168.50.100	TCP	54	58323 → 80 [ACK] Seq=562 Ack=420 Win=63821 Len=0

```
HTTP/1.1 200 OK\r\n
Date: Tue, 18 Jan 2022 17:33:07 GMT\r\n
Server: Apache/2.4.38 (Debian)\r\n
Last-Modified: Tue, 18 Jan 2022 16:33:13 GMT\r\n
ETag: "4f-5d5ddd3551e77-gzip"\r\n
Accept-Ranges: bytes\r\n
Vary: Accept-Encoding\r\n
Content-Encoding: gzip\r\n
Content-Length: 84\r\n
Keep-Alive: timeout=5, max=100\r\n
Connection: Keep-Alive\r\n
Content-Type: text/html\r\n
```

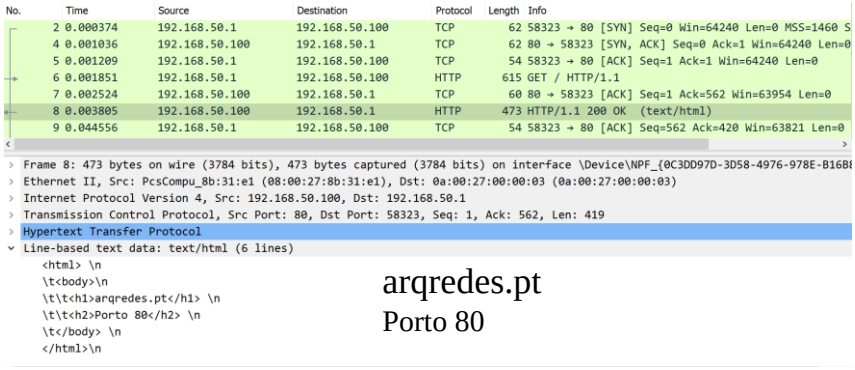
TCP 3-way handshake to initiate the HTTP connect in port 80

GET: request of HTTP version 1.1

200 OK: answer sending the data

Keep-alive: persistent connection, all objects are sent in the same TCP connection

HTTP: The content of the page



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9	0.044556	192.168.50.1	192.168.50.100	TCP	54	58323 → 80 [ACK] Seq=562 Ack=420 Win=63821 Len=0

```
> Frame 8: 473 bytes on wire (3784 bits), 473 bytes captured (3784 bits) on interface \Device\NPF_{0C3DD97D-3D58-4976-978E-B16B8
> Ethernet II, Src: PcsCompu_8b:31:e1 (08:00:27:8b:31:e1), Dst: 0a:00:27:00:00:03 (0a:00:27:00:00:03)
> Internet Protocol Version 4, Src: 192.168.50.100, Dst: 192.168.50.1
> Transmission Control Protocol, Src Port: 80, Dst Port: 58323, Seq: 1, Ack: 562, Len: 419
> Hypertext Transfer Protocol
v Line-based text data: text/html (6 lines)
    <html> \n
    \t<body>\n
    \t\t<h1>arqredes.pt</h1> \n
    \t\t<h2>Porto 80</h2> \n
    \t</body> \n
    </html>\n
```

arqredes.pt
Porto 80