



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)*

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

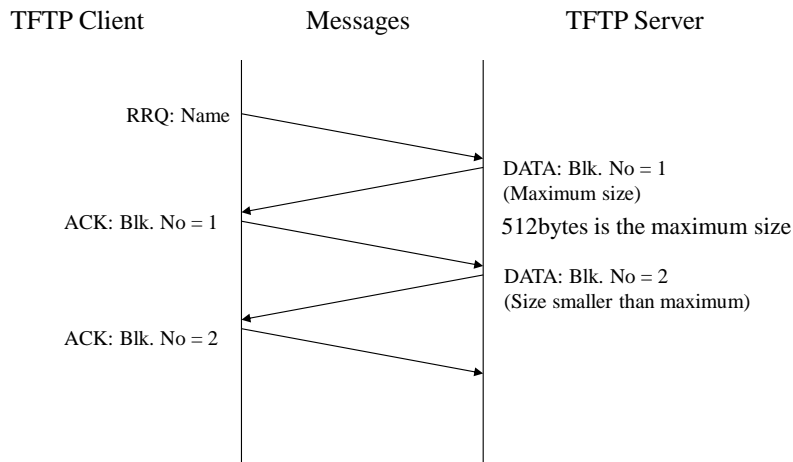
WRQ: permite o cliente pedir para escrever um ficheiro para o servidor

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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 additional data block is sent with **0** bytes of data. RRQ always with odd number of packets (RRQ+pairs of data and ACK).

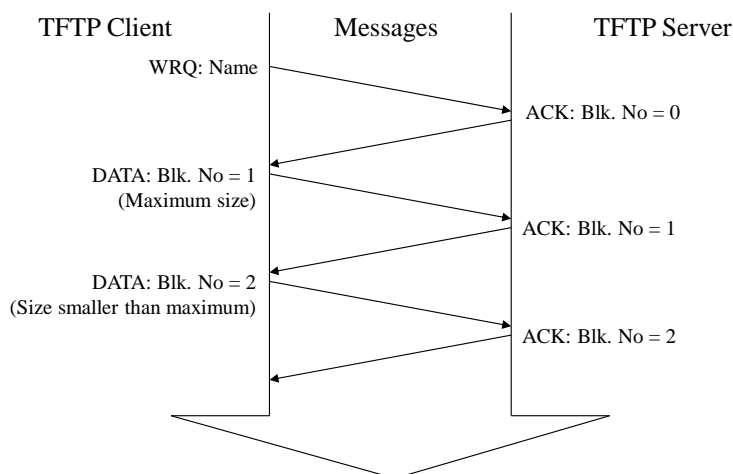
Uma sessão TFTP é sempre iniciada pelo cliente ou com um WRQ (para enviar um ficheiro) ou com um RRQ (para receber um ficheiro).

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 additional data block is sent with **0** bytes of data. WRQ always with even number of packets (WRQ+ACK0+pairs of data and ACK).

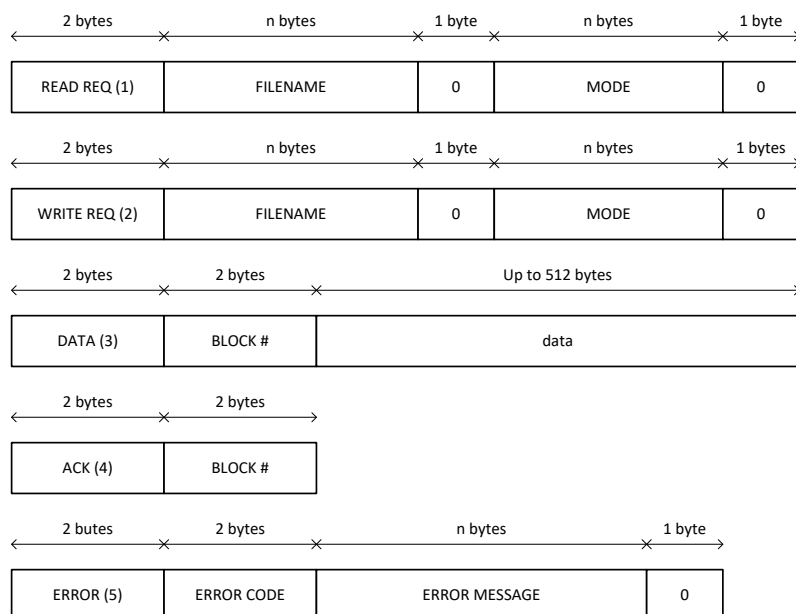
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Messages format



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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

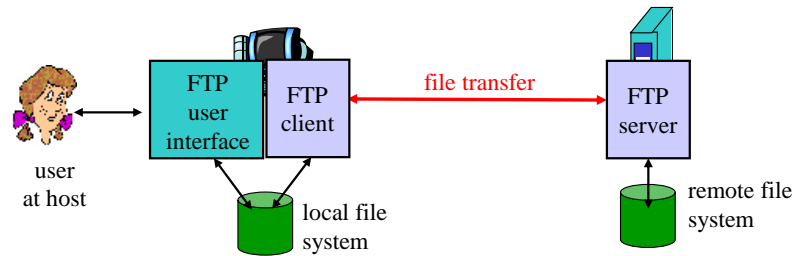
06 – File already exists

07 – No such user

FTP – FILE TRANSFER PROTOCOL

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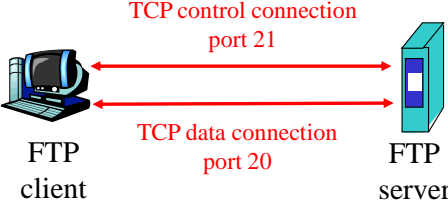
FTP: the file transfer protocol



- ❑ 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

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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.
- 
- The diagram illustrates the two types of connections in FTP. On the left is an 'FTP client' represented by a computer icon. On the right is an 'FTP server' represented by a server rack icon. Two red double-headed arrows connect them. The top arrow is labeled 'TCP control connection port 21'. The bottom arrow is labeled 'TCP data connection port 20'.
- ❑ 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...

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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**

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FTP client: user commands



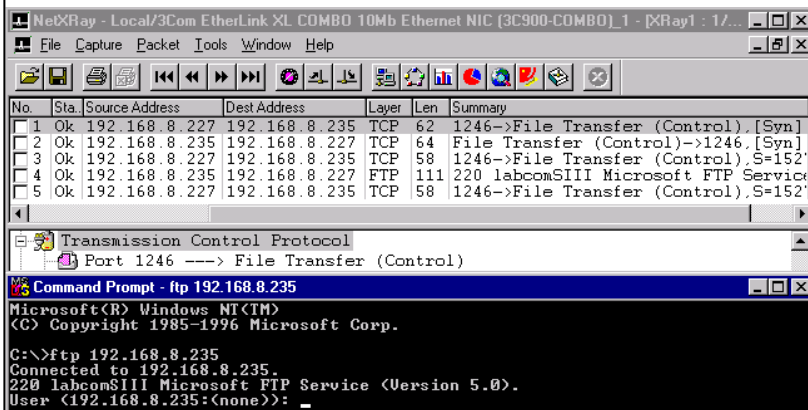
```
MS-DOS Command Prompt - ftp
Microsoft(R) Windows NT(TM)
(C) Copyright 1985-1996 Microsoft Corp.

C:\>ftp
ftp> help
Commands may be abbreviated.  Commands are:

?          delete      literal    prompt    send
?          debug       ls         put        status
append     dir           mdelete   pwd        trace
ascii     disconnect   mdir      quit       type
bell      get          mget      quote      user
binary    glob         mkdir     recv       verbose
bye       hash         mls       remotehelp
cd        help        mput     rename
close    lcd         open     rmdir
ftp> _
```

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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

Introduction of username

The screenshot displays two windows from a Windows NT environment. The top window is NetXRay, showing a packet capture for the interface 'Local/3Com EtherLink XL COMBO 10Mb Ethernet NIC (3C900-COMBO)_1'. It lists three packets: a USER anonymous login, a 331 Password required message, and a File Transfer (Control) packet on port 1246. The bottom window is a Command Prompt titled 'Command Prompt - ftp 192.168.8.235', showing the execution of the 'ftp' command and the subsequent login process, including the password prompt.

NetXRay - Local/3Com EtherLink XL COMBO 10Mb Ethernet NIC (3C900-COMBO)_1 - [XRay2 : 1/...

File Capture Packet Tools Window Help

No.	Sta.	Source Address	Dest Address	Layer	Len	Summary
1	Ok	192.168.8.227	192.168.8.235	FTP	74	USER anonymous
2	Ok	192.168.8.235	192.168.8.227	FTP	96	331 Password required for anonymous
3	Ok	192.168.8.227	192.168.8.235	TCP	58	1246->File Transfer (Control),S=152'

Transmission Control Protocol
Port 1246 ----> File Transfer (Control)

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 Password required for anonymous.  
Password: _
```

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Introduction of password

The screenshot displays two windows from a Windows NT environment. The top window, titled "NetXRay - Local/3Com EtherLink XL COMBO 10Mb Ethernet NIC (3C900-COMBO)_1 - [XRay3 : 1/...", shows a packet capture table with three entries:

No.	Sta.	Source Address	Dest Address	Layer	Len	Summary
1	Ok	192.168.8.227	192.168.8.235	FTP	76	PASS curso@ua.pt
2	Ok	192.168.8.235	192.168.8.227	FTP	89	230 Anonymous user logged in.
3	Ok	192.168.8.227	192.168.8.235	TCP	58	1249->File Transfer (Control),S=153'

Below the table, the "Transmission Control Protocol" pane shows "Port 1249 ---> File Transfer (Control)". The bottom window, titled "Command Prompt - ftp 192.168.8.235", shows the following text:

```
Microsoft(R) Windows NT(TM)
(C) Copyright 1985-1996 Microsoft Corp.

C:\>ftp 192.168.8.235
Connected to 192.168.8.235.
220 labcom$III 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> _
```

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	TCP	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 labcom\$III 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

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)

The screenshot displays two windows. The top window is NetXRay, showing a packet capture table with 8 packets. The bottom window is a Command Prompt showing an FTP session being terminated.

No.	Sta.	Source Address	Dest Address	Layer	Len	Summary
3	Ok	192.168.8.227	192.168.8.235	FTP	64	QUIT
4	Ok	192.168.8.235	192.168.8.227	FTP	65	221
5	Ok	192.168.8.235	192.168.8.227	TCP	64	File Transfer (Control)->1252.[Fir
6	Ok	192.168.8.227	192.168.8.235	TCP	58	1252->File Transfer (Control).S=15
7	Ok	192.168.8.227	192.168.8.235	TCP	58	1252->File Transfer (Control).[Fir
8	Ok	192.168.8.235	192.168.8.227	TCP	64	File Transfer (Control)->1252.S=25

```
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 FIP 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> CursorTCP_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> quit
221
C:\>
```

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

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

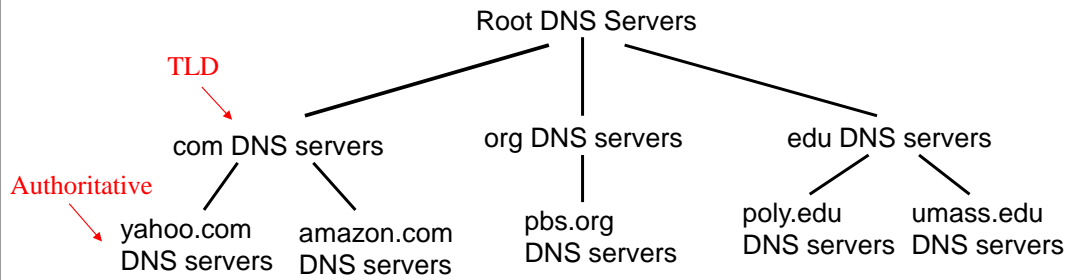
Domain Name System:

- ❑ *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"

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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

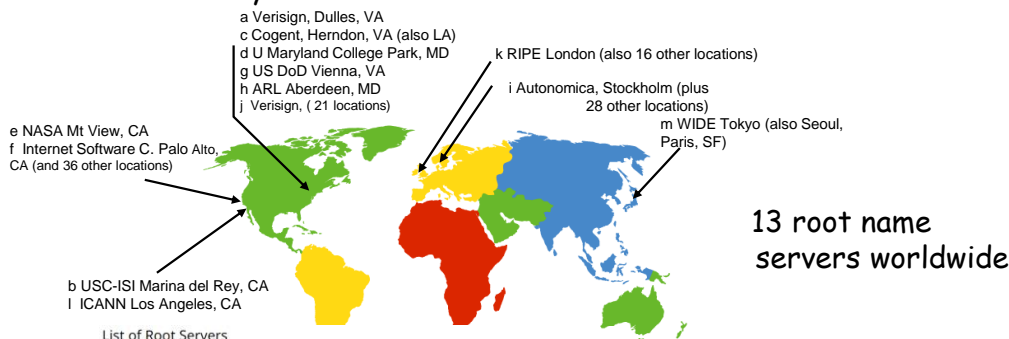
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DNS: Root Name Servers

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	<i>tba</i>	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



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

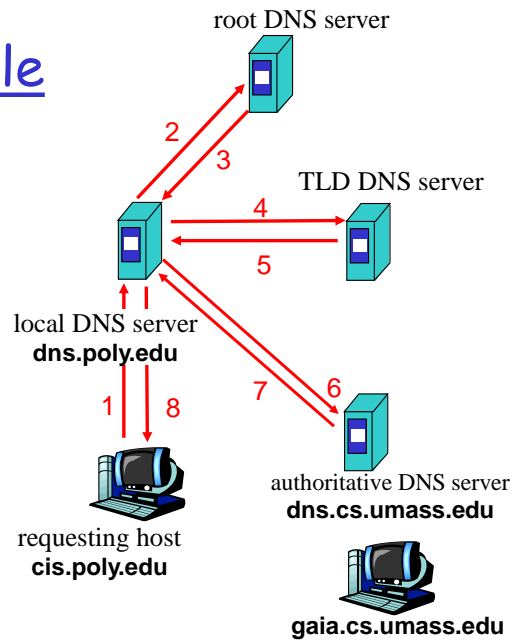
- ❑ does not strictly belong to hierarchy
- ❑ each ISP (residential ISP, company, university) has one.
 - ❖ also called "default Name Server"
- ❑ when host makes DNS query, query is sent to its local DNS server
 - ❖ acts as proxy, forwards query into hierarchy

DNS name resolution example

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

iterated query:

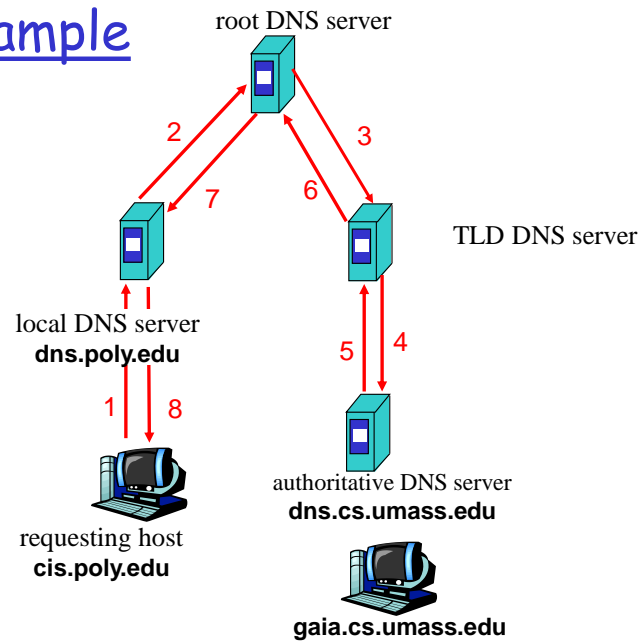
- contacted server replies with name of server to contact
- "I don't know this name, but ask this server"



DNS name resolution example

recursive query:

- ❑ puts burden of name resolution on contacted name server



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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

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DNS messages

host: 192.1.1.1

DNS: 192.1.1.40

C:\>ping labcom02.curso.pt

The image shows a Wireshark packet capture titled "XRay8 : 1/14 Ethernet packets". The main pane displays a list of 14 packets. The first two packets are ARP-related: an ARP Request from 192.1.1.1 to 192.1.1.40 (packet 1) and an ARP Response from 192.1.1.40 to 192.1.1.1 (packet 2). The next two packets are DNS-related: a Query Question from 192.1.1.1 to 192.1.1.40 (packet 3) and a Query Answer from 192.1.1.40 to 192.1.1.1 (packet 4). The remaining 10 packets are ICMP Echo (ping) requests and replies between 192.1.1.1 and 192.1.1.2. The bottom pane shows the details of the selected packet (packet 4, a DNS Query Answer). It lists fields such as Hardware Type (1), Protocol Type (800), Hardware Address Length (6), Protocol Address Length (4), Operations (ARP Request), Source Hardware Address (00-60-97-9B-9E-07), IP Source Address (192.1.1.1), Destination Hardware Address (00-00-00-00-00-00), and IP Destination Address (192.1.1.40). The IP Source and Destination addresses are circled in blue.

Source Address	Dest Address	Layer	Summary
This station	Broadcast	ARP	Op=ARP Request, Src IP=192.1.1.1, Dest IP=192.1.1.40
0060979B9B3F	This station	ARP	Op=ARP Response, Src IP=192.1.1.40, Dest IP=192.1.1.1
192.1.1.1	192.1.1.40	DNS	Query Question:Type=A,Class=IN,Name=labcom02.curso.pt
192.1.1.40	192.1.1.1	DNS	Query Answer:Type=A,Class=IN,Name=labcom02.curso.pt
This station	Broadcast	ARP	Op=ARP Request, Src IP=192.1.1.1, Dest IP=192.1.1.2
00104B4E687D	This station	ARP	Op=ARP Response, Src IP=192.1.1.2, Dest IP=192.1.1.1
192.1.1.1	192.1.1.2	ICMP	Type=Echo Request, ID=256, Seq No=3328
192.1.1.2	192.1.1.1	ICMP	Type=Echo Reply, ID=256, Seq No=3328
192.1.1.1	192.1.1.2	ICMP	Type=Echo Request, ID=256, Seq No=3584
192.1.1.2	192.1.1.1	ICMP	Type=Echo Reply, ID=256, Seq No=3584
192.1.1.1	192.1.1.2	ICMP	Type=Echo Request, ID=256, Seq No=3840
192.1.1.2	192.1.1.1	ICMP	Type=Echo Reply, ID=256, Seq No=3840
192.1.1.1	192.1.1.2	ICMP	Type=Echo Request, ID=256, Seq No=4096
192.1.1.2	192.1.1.1	ICMP	Type=Echo Reply, ID=256, Seq No=4096

Address Resolution Protocol

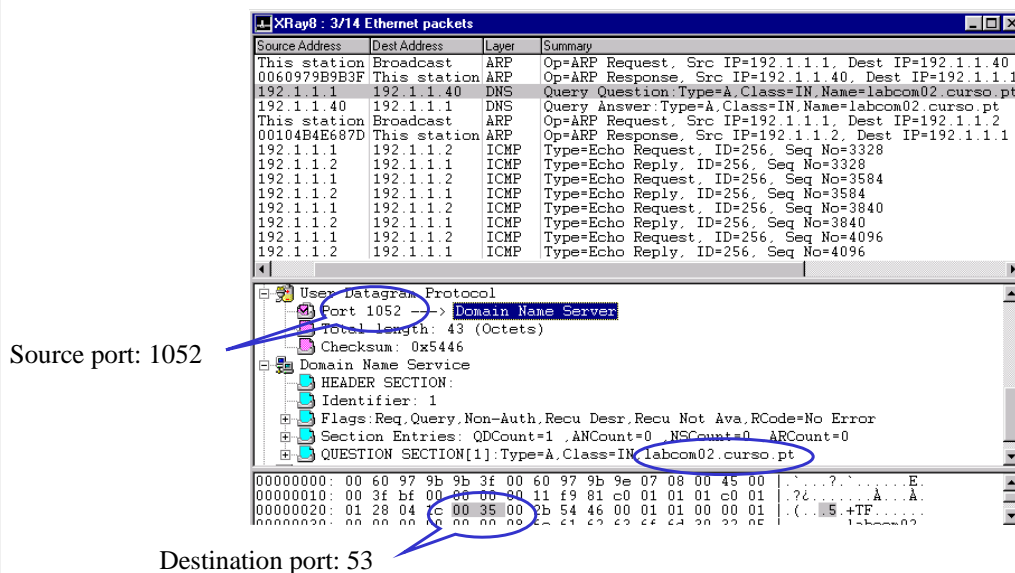
- Hardware Type: 1 (Ethernet)
- Protocol Type: 800
- Hardware Address Length: 6
- Protocol Address Length: 4
- Operations: ARP Request
- Source Hardware Address: 00-60-97-9B-9E-07
- IP Source Address: 192.1.1.1
- Destination Hardware Address: 00-00-00-00-00-00
- IP Destination Address: 192.1.1.40

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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



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

No.	Stat.	Source Address	Dest Address	Layer	Summary
1	Ok	This station	Broadcast	ARP	Op=ARP Request, Src IP=192.1.1.1, Dest IP=192
2	Ok	0060979B9B3F	This station	ARP	Op=ARP Response, Src IP=192.1.1.40, Dest IP=1
3	Ok	192.1.1.1	192.1.1.40	DNS	Query Question: Type=A, Class=IN, Name=labcom02.
4	Ok	192.1.1.40	192.1.1.1	DNS	Query Answer: Type=A, Class=IN, Name=labcom02.
5	Ok	This station	Broadcast	ARP	Op=ARP Request, Src IP=192.1.1.1, Dest IP=192
6	Ok	00104B4E687D	This station	ARP	Op=ARP Response, Src IP=192.1.1.2, Dest IP=19
7	Ok	192.1.1.1	192.1.1.2	ICMP	Type=Echo Request, ID=256, Seq No=3328
8	Ok	192.1.1.2	192.1.1.1	ICMP	Type=Echo Reply, ID=256, Seq No=3328
9	Ok	192.1.1.1	192.1.1.2	ICMP	Type=Echo Request, ID=256, Seq No=3584
10	Ok	192.1.1.2	192.1.1.1	ICMP	Type=Echo Reply, ID=256, Seq No=3584
11	Ok	192.1.1.1	192.1.1.2	ICMP	Type=Echo Request, ID=256, Seq No=3840
12	Ok	192.1.1.2	192.1.1.1	ICMP	Type=Echo Reply, ID=256, Seq No=3840
13	Ok	192.1.1.1	192.1.1.2	ICMP	Type=Echo Request, ID=256, Seq No=4096
14	Ok	192.1.1.2	192.1.1.1	ICMP	Type=Echo Reply, ID=256, Seq No=4096

User Datagram Protocol	
Port	Domain Name Server ---> 1052
Total length:	59 (Octets)
Checksum:	0xA915
Domain Name Service	
HEADER SECTION:	
Identifier:	1
Flags:	Resp, Query, Auth, Recu Desr, Recu Ava, RCode=No Error
Section Entries:	QDCount=1, ANCount=1, NSCount=0, ARCount=0
QUESTION SECTION[1]:	Type=A, Class=IN, labcom02, curso.pt
ANSWER SECTION[1]:	Type=A, Class=IN, 192.1.1.2

00000020:	01 01 00 35 04 1c 00 3b a9 15 00 01 85 80 00 01	...5.....
00000030:	00 01 00 00 00 00 08 6c 61 62 63 6f 6d 30 32 05labcom02.

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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

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Web and HTTP

First some basic concepts

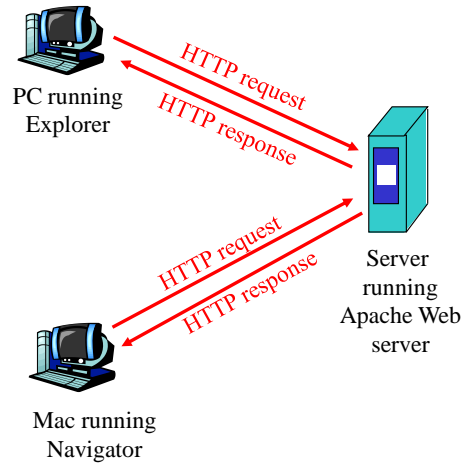
- ❑ Web page consists of objects
- ❑ Object can be HTML file, JPEG image, Java applet, audio file,...
- ❑ Web page consists of base HTML-file which includes several referenced objects
- ❑ Each object is addressable by a URL
- ❑ Example URL:

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

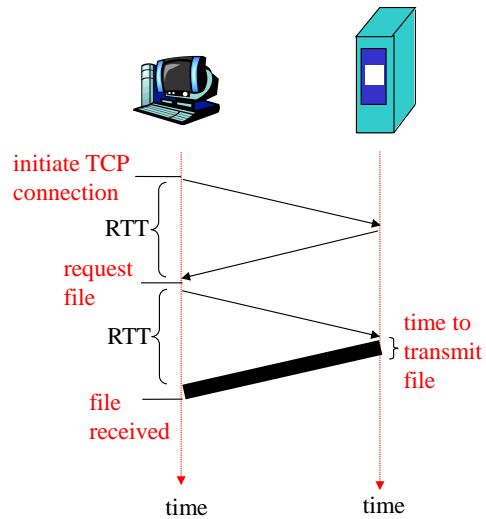
Nonpersistent HTTP: Response time

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)

header
lines

Carriage return,
line feed
indicates end
of message

```
GET /somedir/page.html HTTP/1.1
Host: www.someschool.edu
User-agent: Mozilla/4.0
Connection: close
Accept-language: fr
(extra carriage return, line feed)
```

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

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HTTP response message

status line
(protocol
status code
status phrase)

header
lines

data, e.g.,
requested
HTML file

```
HTTP/1.1 200 OK
Connection: close
Date: Thu, 06 Aug 1998 12:00:15 GMT
Server: Apache/1.3.0 (Unix)
Last-Modified: Mon, 22 Jun 1998 .....
Content-Length: 6821
Content-Type: text/html

data data data data data ...
```

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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	TCP 3-way handshake to initiate the HTTP connect in port 80
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	GET: request of HTTP version 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	200 OK: answer with data transmission
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-5d5dd3551e77-gzip"\r\n

If-Modified-Since: Tue, 18 Jan 2022 16:33:13 GMT\r\n

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

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HTTP Request - answers with data, ACKed with TCP

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
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	0.003895	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

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

> Frame 8: 473 bytes on wire (3784 bits), 473 bytes captured (3784 bits) on interface \Device\NPF_{0C3D097D-3D58-4976-978E-B168}

> 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

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

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