Computer Networks
Application Layer

Adrian Sergiu DARABANT

Lecture 4
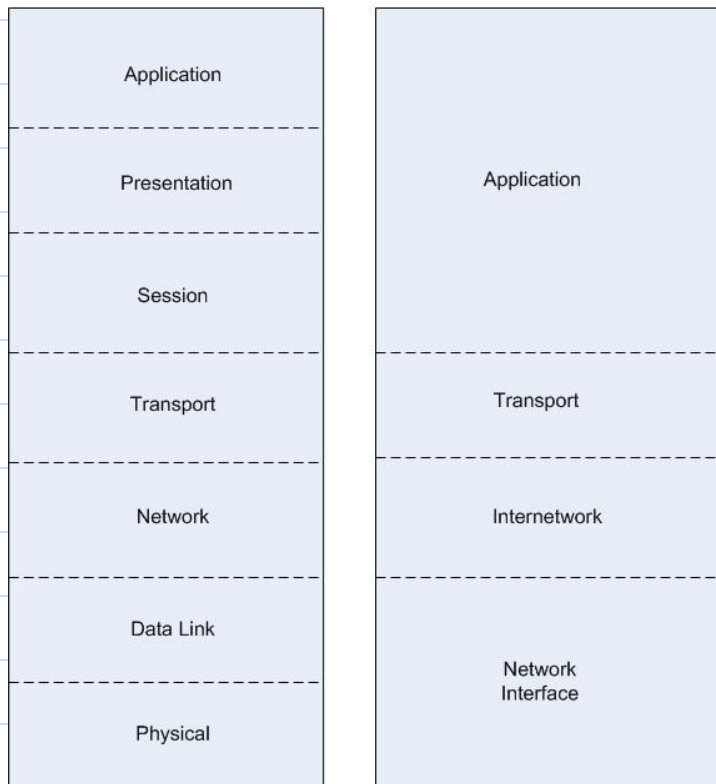
The Application Layer
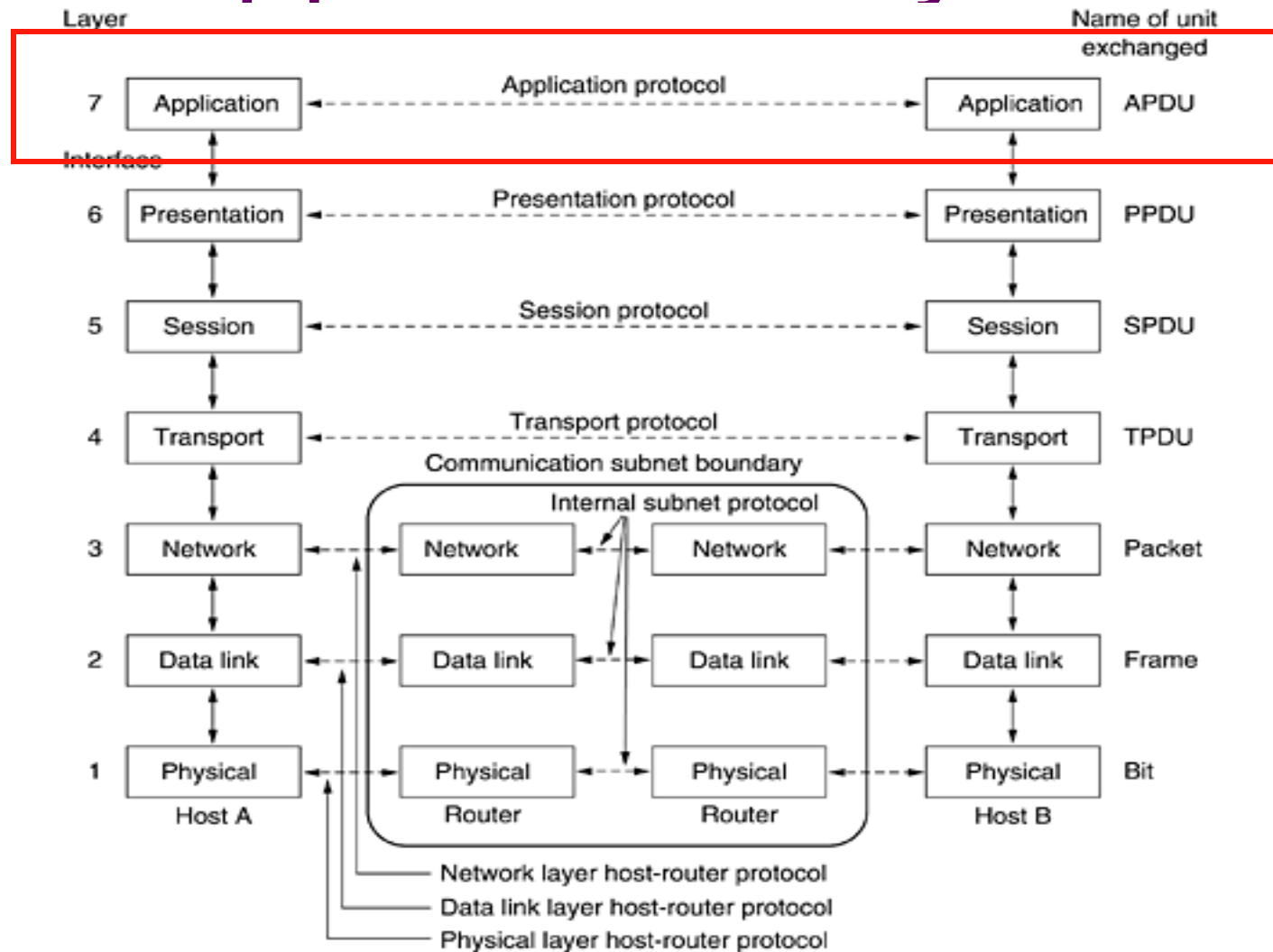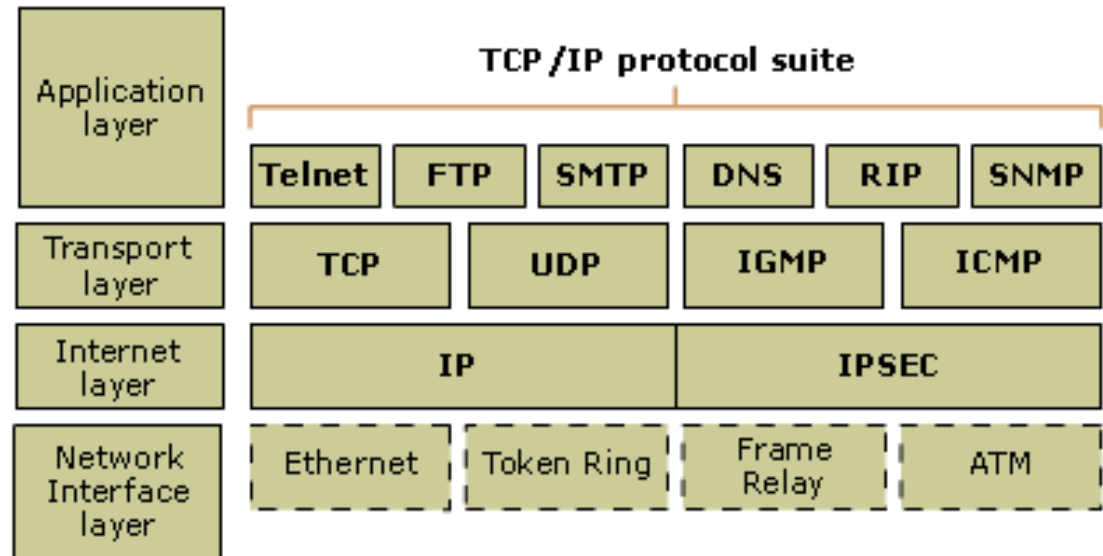

All **P**eople **S**eem **T**o **N**eed **D**ata **P**rocessing

OSI vs TCP/IP Model

Comparing The OSI Model And TCP / IP Architecture.

OSI Model	TCP/IP
Application	Application
Presentation	
Session	
Transport	Transport
Network	Internetwork
Data Link	Network Interface
Physical	

TCP/IP model

TCP/IP protocol suite

| Application layer	Telnet	FTP	SMTP	DNS	RIP	SNMP
Transport layer	TCP		UDP	IGMP		ICMP
Internet layer	IP			IPSEC		
Network Interface layer	Ethernet		Token Ring	Frame Relay		ATM

Application Layer Protocols

◆ Defines :

- the types of messages exchanged, e.g., request messages and response messages
- the syntax of the various message types, i.e., the fields in the message and how the fields are delineated
- the semantics of the fields, i.e., the meaning of the information in the fields
- rules for determining when and how a process sends messages and responds to messages

The Client-Server Paradigm

- Introduced by the communication architecture:
  - Service Provider - **Server**
  - Service Consumer – **Client**
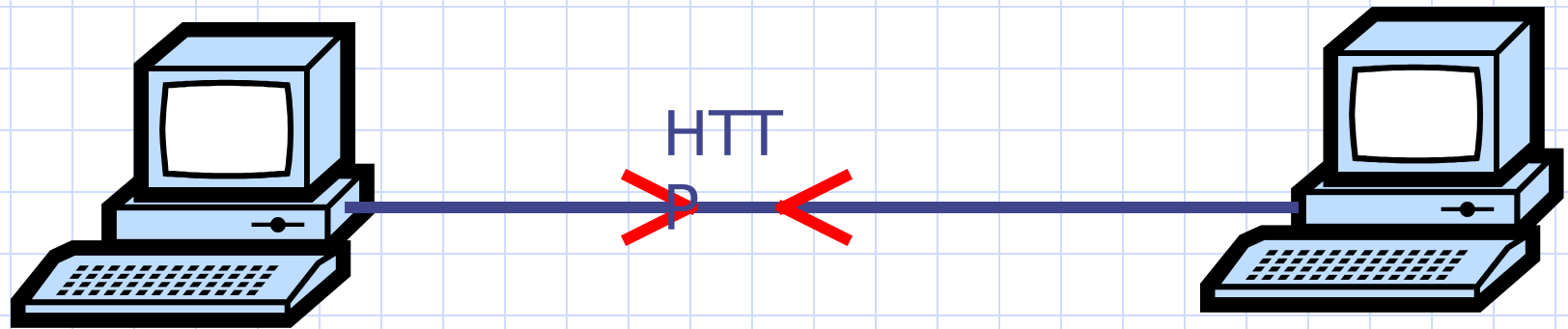- A host can implement both sides of a service : client and server !

Communicating Processes
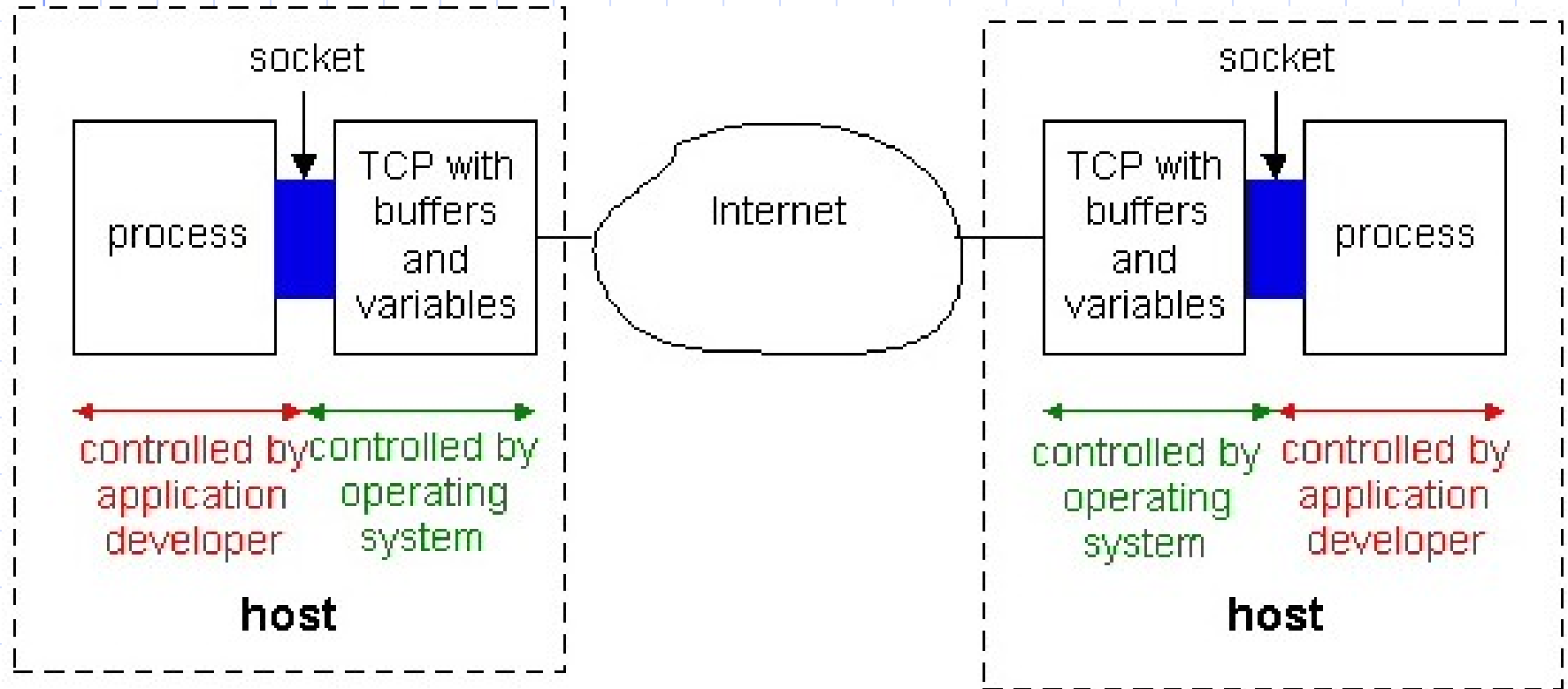
TCP/IP Communication

- Hosts identified by IP Addresses (unique)
- Applications on each host are identified by ports (0-65535)
- Some of the available ports are *well-known* and assign to popular applications: ftp, http, dns, telnet, ssh, etc - **rfc1700**

TCP/IP Peer to peer communication

HTTP

193.231.20.34
Port: 1563

63.78.171.45
Port: 80

IPAddress + Port:
Identify communicating applications
on the source and destination machines

Application Level Protocols

- DNS
- SMTP
- FTP
- HTTP
- TELNET, SSH
- IMAP, POP3
- FINGER, etc

The DNS Protocol

- In the TCP/IP world each machine is uniquely identified by its IP Address.
- IPAddress – 4 bytes = 32 bits
- Numbers are hard to remember, names are easier.
- Each machine is assigned a name in a tree-like structure.

DNS as a service

- Domain Names (FQDN) or URLs are used by users – *www.google.com*
- IP Address needed by programs – *66.249.93.104*
- The DNS Service Provides IP Name Resolution
- DNS is a distributed database of Domain Names and their corresponding IP Addresses
- RFC 1034, 1035

Domain Naming System

- A hierarchical naming system used to give each server on the Internet a unique name.

- www.google.com (URL or FQDN) **HostName.Domain.TLD**

- HostName and the Domain Name = Fully Qualified Domain Name (FQDN)

- Initial Implementation: **hosts file**

The DNS Namespace
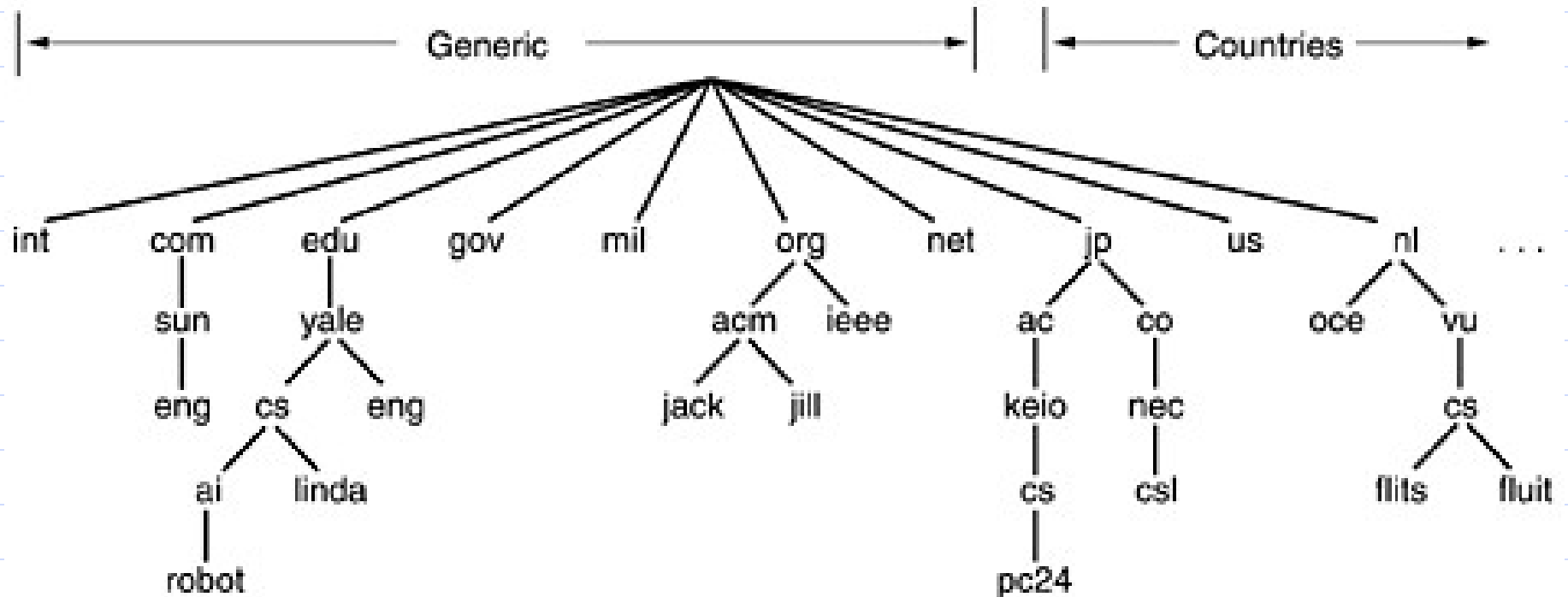
Robot.ai.cs.yale.edu

Sources of Domain Names

- **ICANN** (*Internet Corporation For Assigned Names and Numbers*) Oversees the Domain Name Registration Process (www.icann.org)
  - Shared Database of Domain Names (Master Database)
  - Maintained under Contract by Network Solutions (originally InterNIC)
- Domain registrars- keep things organized
  - Network Solutions, America Online, register.com, Tucows.com, **RNC.RO**
  - **Complete List of Registrars:**
    - **http://www.icann.org/registrars/accredited-list.html**

Registering a Domain Name

- Contact a Domain Register
- Choose a Unique Domain Name http://www.rnc.ro/ or other Register!
- To See Who Currently Owns a Name http://www.rnc.ro (Whois Query) or whois(Unix)
- Register the Domain Name
  - $5-35 a year
  - You need the FQDN's Names and IP Addresses of (2) Two DNS Servers That Store DNS Information for Your Domain

Whois – ubbcluj.ro

[Querying whois.rotld.ro]

[whois.rotld.ro]

% whois.rotld.ro :

% Rights restricted by copyright.

% Este INTERZISA folosirea datelor de pe acest server in oricare

%   alt scop decat operarea retelei. In special este INTERZISA

%   folosirea lor in scopuri publicitare.

%

domain-name: ubbcluj.ro

description: BABES-BOLYAI UNIVERSITY

description: 1, M.Kogalniceanu, Cluj-Napoca

description: Phone: 40-64-194315, int. 204

description: Fax: 40-64-191906

admin-contact: GC106-ROTLD

technical-contact: IP75-ROTLD

zone-contact: CL143-ROTLD

nameserver: Zeus.UBBCluj.Ro 193.231.18.18

nameserver: Ns2.UBBCluj.Ro 193.231.20.1

nameserver: Ns3.UBBCluj.Ro 193.231.18.20

info: object maintained by ro.rnc local registry

notify: domain-admin@listserv.rnc.ro

object-maintained-by: ROTLD-MNT

mnt-lower: ROTLD-MNT

updated: hostmaster@rnc.ro 20010109

updated: hostmaster@rnc.ro 20010610

updated: hostmaster-cmircea@rotld.ro 20011126

updated: hostmaster-cmircea@rotld.ro 20011126

updated: hostmaster-cmircea@rotld.ro 20020320

updated: hostmaster-cmircea@rotld.ro 20020926

updated: danp@rnc.ro 20031003

source: ROTLD

person: Gabriel Ciplea

address: Mihail Kogalniceanu, Nr. 1

address: Cluj-Napoca, Romania

phone: +40 264 405 333

fax-no: +40 264 591 906

Whois-2

info:object maintained by ro.rnc local registry

notify: domain-admin@listserv.rnc.ro

object-maintained-by: ROTLD-MNT

updated:hostmaster-cmircea@rotld.ro 20020926

source: ROTLD

person: Ioan Ploscariu

address: Mihail Kogalniceanu, Nr. 1

address: Cluj-Napoca, Romania

phone: +40 264 405 344

fax-no: +40 264 191 906

e-mail: john@ubbcluj.ro

nic-hdl: IP75-ROTLD

info: object maintained by ro.rnc local
    registry

notify: domain-admin@listserv.rnc.ro

object-maintained-by: ROTLD-MNT

updated: hostmaster-cmircea@rotld.ro
    20020926

source: ROTLD

person: Cristian Leonte
address: Mihail Kogalniceanu, Nr. 1
address: Cluj-Napoca, Romania
phone: +40 264 405 333
fax-no: +40 264 591 906
e-mail: romb@ubbcluj.ro
nic-hdl: CL143-ROTLD
info: object maintained by ro.rnc local
registry
notify: domain-admin@listserv.rnc.ro
object-maintained-by: ROTLD-MNT
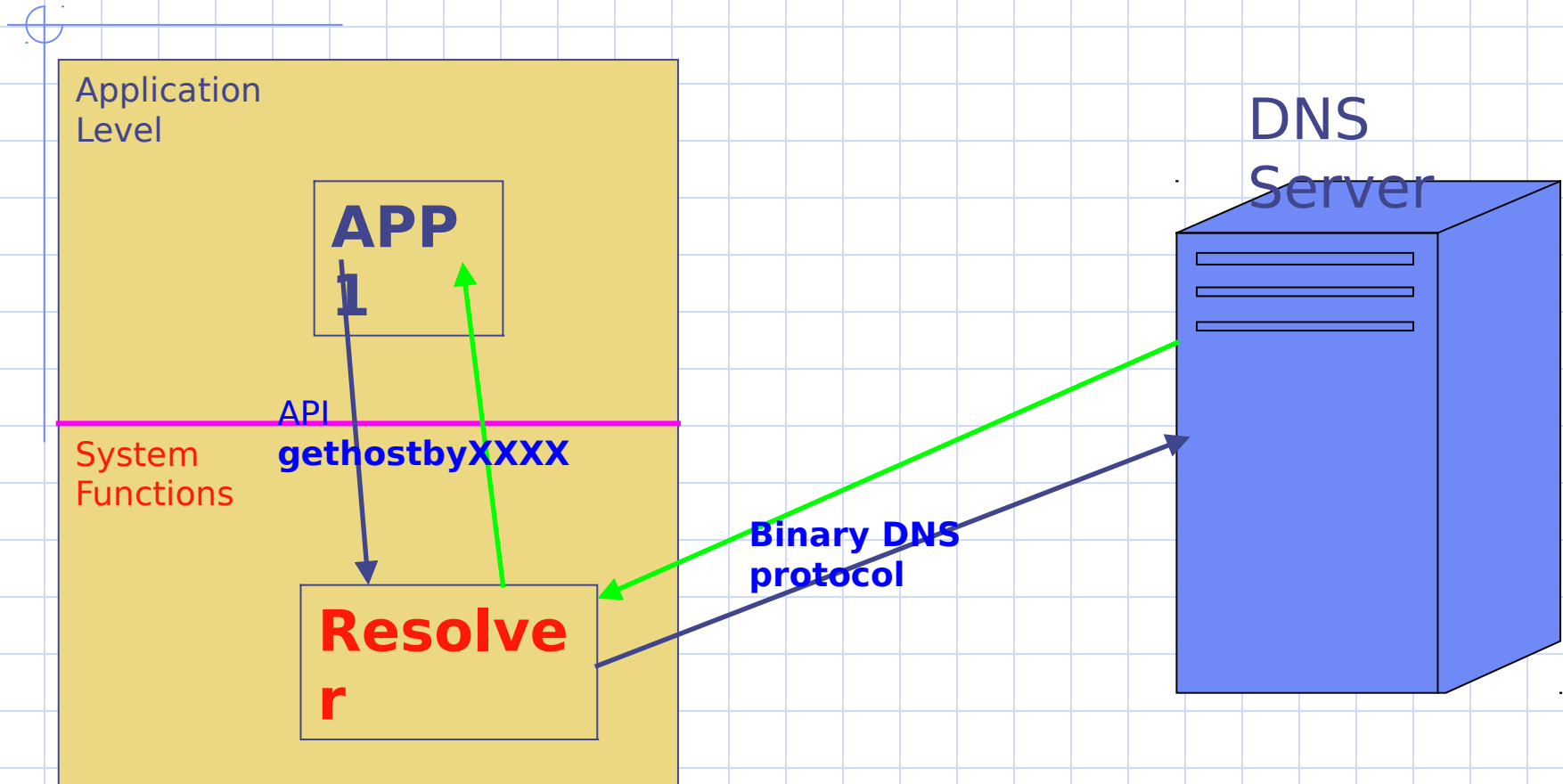updated: danp@rnc.ro 20031003
source: ROTLD

DNS Software

- Resolver
  - Built into Client TCP/IP Software
  - Ask Designated Name Server for IP Address When Client Enters FQDN (URL)
- Name Server
  - DNS Server (Available with Most OS's)
  - Retrieves IP Addresses for Clients
  - Supplies IP Address to other Name Servers
  - Provided by the Internet, ISP, or at the client.

DNS Software

Application Level

APP 1

API
gethostbyXXXX

System Functions

Resolver

DNS Server

Binary DNS protocol

DNS System

- ◆ Originally one single central huge table. **(hosts file) /etc/hosts**
- ◆ Hierarchical structure:
  - Root DNS servers (serving .com .org .net...)
  - DNS servers – serve domain queries.
- ◆ DNS Servers
  - Primary/Master – Authoritative on a zone (ubbcluj.ro)
  - Secondary/Slaves – Temporarily Authoritative
  - Forwarders/Caching DNS – no local database
- ◆ Types of queries:
  - Recursive queries
  - Non-recursive (iterative) queries

DNS Design Goals

- Creation Of A Global, Scalable, Consistent Name Space
- Local Control Over Local Resources
- Distributed Design To Avoid Bottlenecks
- Application Universality
- Multiple Underlying Protocol Support
- Hardware Universality

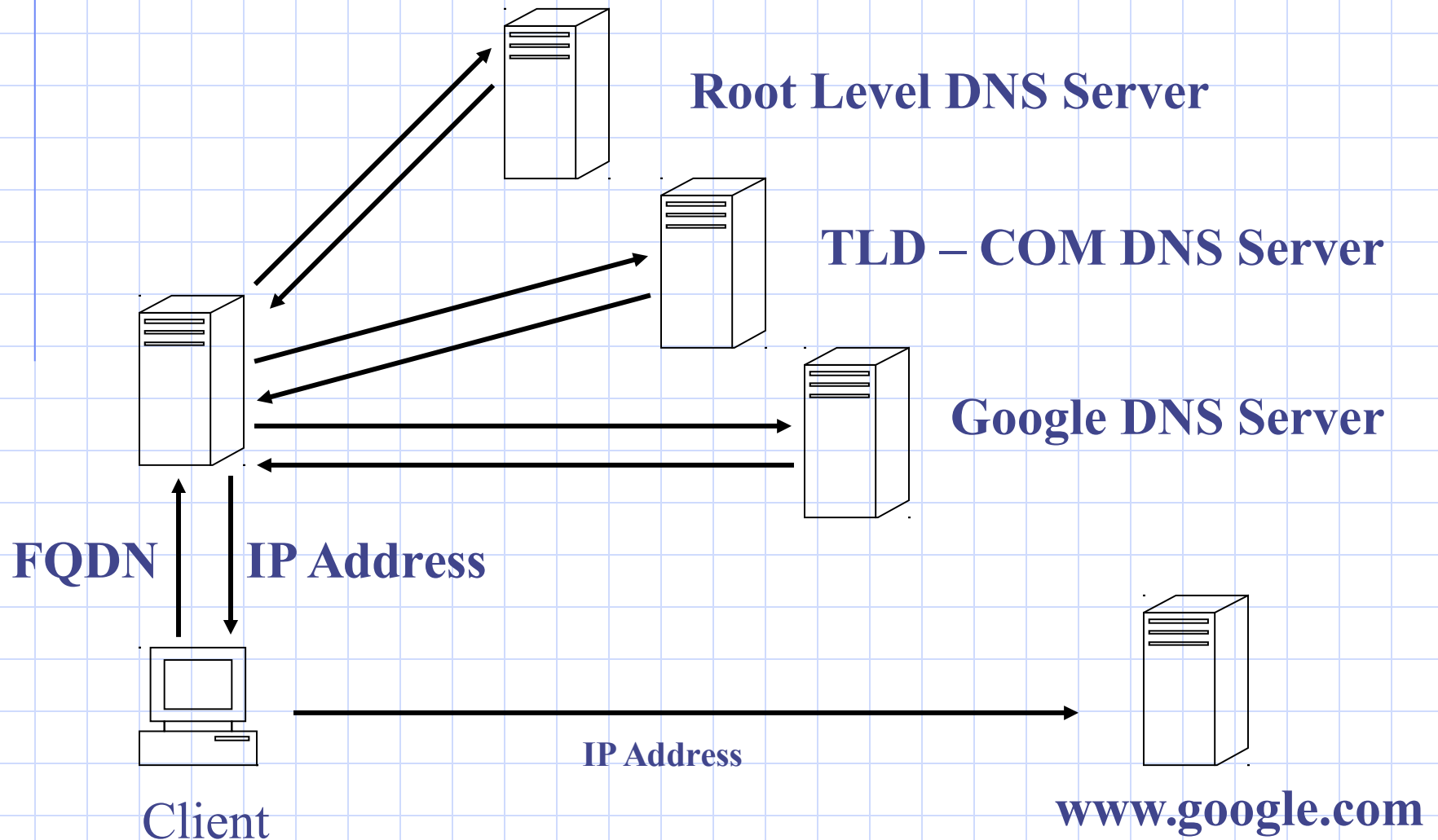# DNS – Non Recursive & Caching

Connect at www.yahoo.com

1. Ask the <u>Root Server</u> for the .com (*a.gtld-servers.net*)

2. *<u>a.gtld-servers.net</u>* asks the DNS server of the yahoo.com (*ns1.yahoo.com)*

3. *<u>ns1.yahoo.com</u>* determines that *www.yahoo.com =>* is an alias for *www.yahoo.akadns.net*

4. Response gets back to the client *www.yahoo.akadns.net*

DNS Recursive & caching

Connect at www.yahoo.com

1. Ask <u>Local Server(LS)</u> for the www.yahoo.com
2. (LS)
   1. www.yahoo.com – cached *216.109.118.68*
   2. Or asks Root Server for the .com
3. (LS) asks <u>a.gtld-servers.net</u> who is the DNS server for yahoo.com => ns1.yahoo.com
4. Ask *<u>ns1.yahoo.com</u>* who is *www.yahoo.com* => is alias for *www.yahoo.akadns.net*
5. Ask *<u>ns1.yahoo.com</u>* who is *www.yahoo.akadns.net* =>*216.109.118.68*

How DNS Works (The Two Key Functions)

Root Level DNS Server

TLD – COM DNS Server

Google DNS Server

FQDN   IP Address

IP Address

Client

www.google.com

DNS Example

DNS at Work example

Try this applet and check the DNS functioning.

Configuring DNS

- ◆ DNS
  - Information Stored in a Zone File
  - Text Files
  - Information About One or More Domains
  - S   tatic (Manually Updated)
- ◆ Dynamic DNS – *see dyndns.org*
  - Same Process/Types on Information
  - Each Computer Dynamically Updates Its Information
  - RFC
  - Windows Server, Netware, etc

Placing DNS Servers on Internet

- ◆ Need Two Name Servers
- ◆ Yours or ISP's
- ◆ Register with Name Register (Rnc.Ro)
  - ▪ Create a Host Record for Each Name Server (Host Name and IP Address)
  - ▪ Register Domain Names With the Host Names and IP Addresses of Name Servers

Root Servers and TLDs

- Root-Level Servers
  - Authoritative (A.ROOT-SERVERS.NET)
  - Maintained by VeriSign (Network Solutions) under contract with ICANN
- Duplicate (B-M.ROOT-SERVERS.NET)
  - Maintained by other organizations and businesses around the world
  - http://www.root-servers.org/

DNS Zone Division

Root Name Servers

a NSI Herndon, VA
c PSInet Herndon, VA
d U Maryland College Park, MD
g DISA Vienna, VA
h ARL Aberdeen, MD
j NSI (TBD) Herndon, VA

k RIPE London
i NORDUnet Stockholm

m WIDE Tokyo

e NASA Mt View, CA
f Internet Software C. Palo Alto, CA

b USC-ISI Marina del Rey, CA
l ICANN Marina del Rey, CA
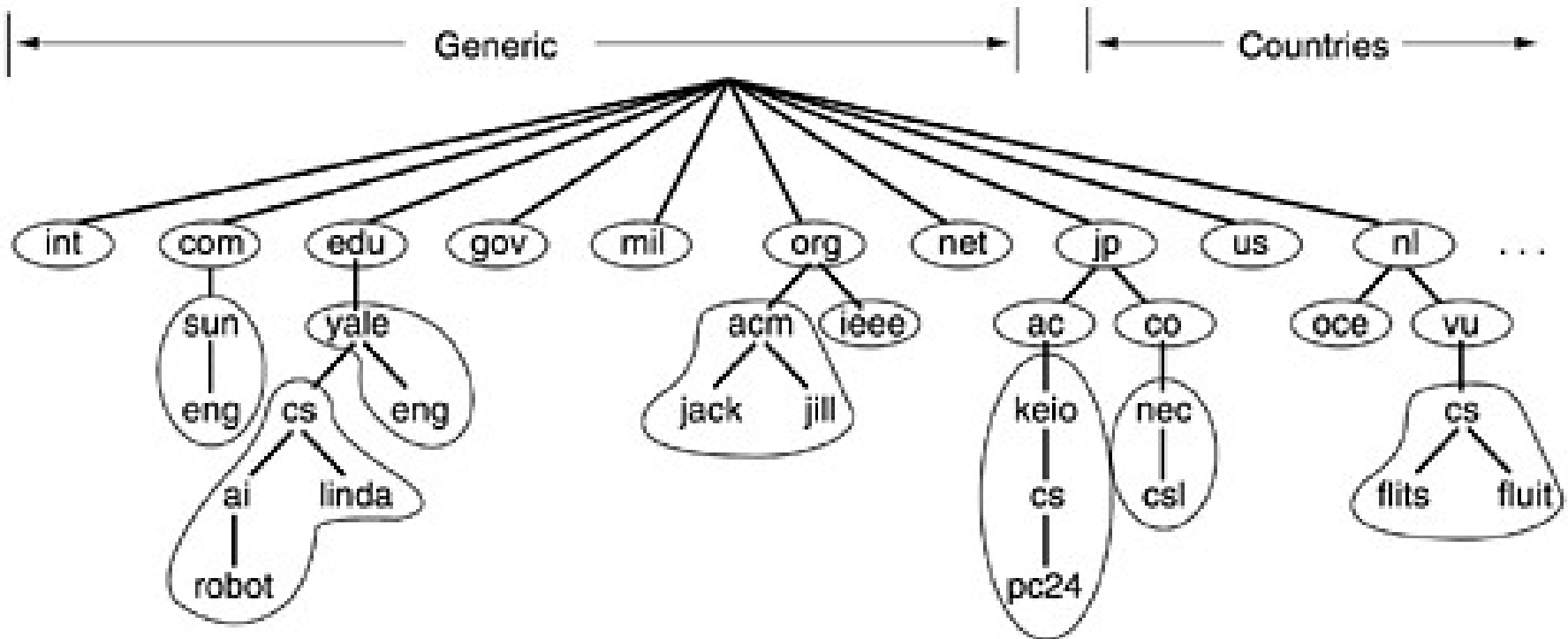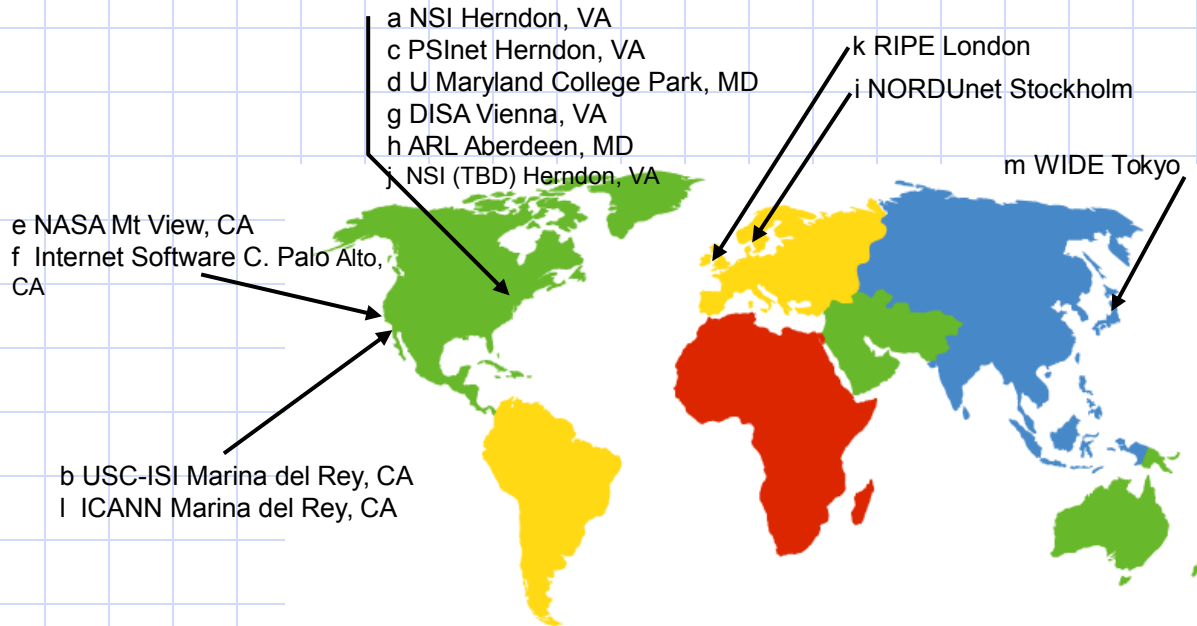
13 root name servers worldwide

Resource records

RR=(Domain_name, Time_to_live, Class, Type, Value)

Type:

A – Name=hostname, Value = IP address

NS – Name =domain (ubbcluj.ro), Value=IP Addr of Authoritative NS

CNAME – Name=alias for canonical (real) name

MX – Name (implicit) domain, Value = name of mailserver for domain

Example:

www.ubbcluj.ro   1800 IN   CNAME   zeus.ubbcluj.ro

zeus.ubbcluj.ro   1800 IN   A   193.226.40.33

DNS Database-Record types

Type	Meaning	Value
SOA	Start of Authority	Parameters for this zone
A	IP address of a host	32-Bit integer
MX	Mail exchange	Priority, domain willing to accept e-mail
NS	Name Server	Name of a server for this domain
CNAME	Canonical name	Domain name
PTR	Pointer	Alias for an IP address
HINFO	Host description	CPU and OS in ASCII
TXT	Text	Uninterpreted ASCII text

DNS Database

<u>Linux BIND DNS implements it in a file, Windows in Registry:</u>
utcluj.ro SOA hercule.utcluj.ro. root.hercule.utcluj.ro.
2004101451 ; serial no
36000   ; refresh
3600   ; update retry
2390400   ; expiry
360000   ; minimum or TTL
utcluj.ro NS ns.edu.ro.
utcluj.ro NS ns.roedu.net.
utcluj.ro NS ns-a.rnc.ro.
utcluj.ro NS hercule.utcluj.ro.
utcluj.ro MX 30 hercule.utcluj.ro.
www.utcluj.ro CNAME orion.cluj.roedu.net.
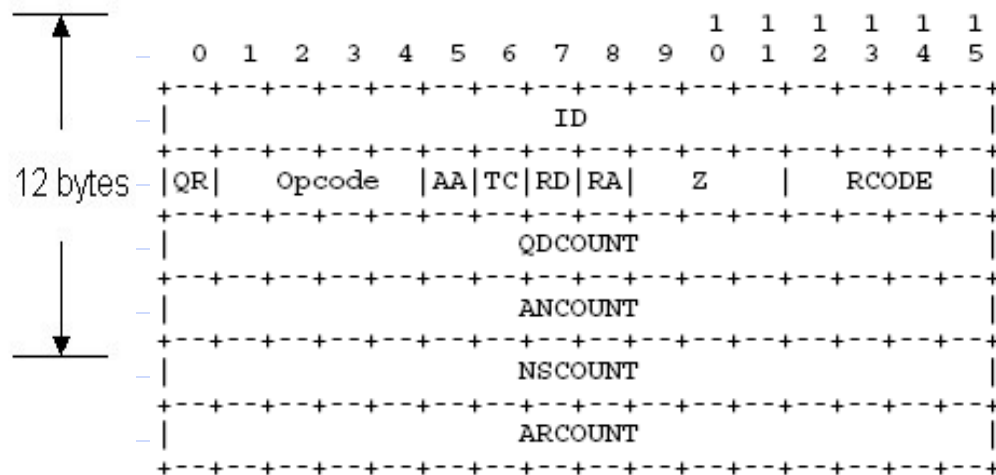webmail.utcluj.ro CNAME bavaria.utcluj.ro.
ana.utcluj.ro A 192.129.4.93
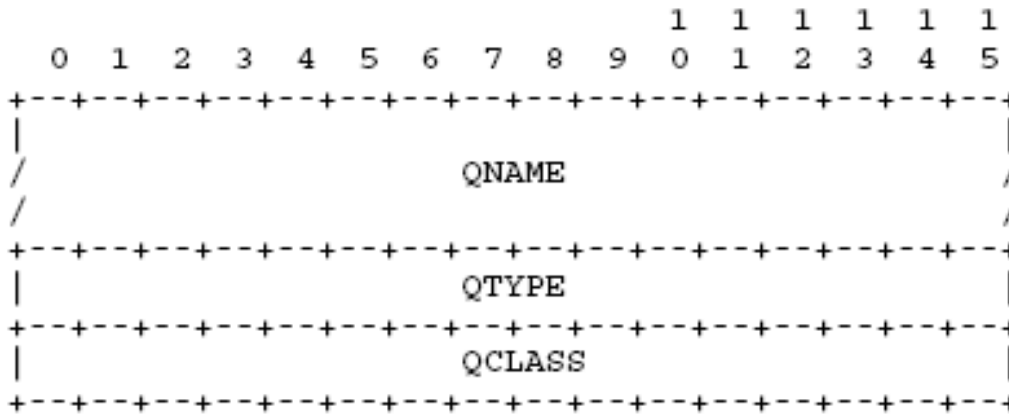apollo.utcluj.ro A 193.226.7.154
hercule.utcluj.ro A 193.226.5.33

DNS Packet Structure

identification	flags
number of questions	number of answer RRs
number of authority RRs	number of additional RRs

questions (variable number of questions)
answers (variable number of resource records)
authority (variable number of resource records)
additional information (variable number of resource records)

12 bytes

```
                              1   1   1   1   1   1
  0   1   2   3   4   5   6   7   8   9   0   1   2   3   4   5
+--+--+--+--+--+--+--+--+--+--+--+--+--+--+--+--+
|                      ID                       |
+--+--+--+--+--+--+--+--+--+--+--+--+--+--+--+--+
|QR|   Opcode  |AA|TC|RD|RA|    Z    |   RCODE   |
+--+--+--+--+--+--+--+--+--+--+--+--+--+--+--+--+
|                    QDCOUNT                     |
+--+--+--+--+--+--+--+--+--+--+--+--+--+--+--+--+
|                    ANCOUNT                     |
+--+--+--+--+--+--+--+--+--+--+--+--+--+--+--+--+
|                    NSCOUNT                     |
+--+--+--+--+--+--+--+--+--+--+--+--+--+--+--+--+
|                    ARCOUNT                     |
+--+--+--+--+--+--+--+--+--+--+--+--+--+--+--+--+
```

Query DNS Packet Structure

```
                    1   1   1   1   1   1
  0   1   2   3   4   5   6   7   8   9   0   1   2   3   4   5
+--+--+--+--+--+--+--+--+--+--+--+--+--+--+--+--+
|                                               |
/                   QNAME                       /
/                                               /
+--+--+--+--+--+--+--+--+--+--+--+--+--+--+--+--+
|                   QTYPE                        |
+--+--+--+--+--+--+--+--+--+--+--+--+--+--+--+--+
|                   QCLASS                       |
+--+--+--+--+--+--+--+--+--+--+--+--+--+--+--+--+
```
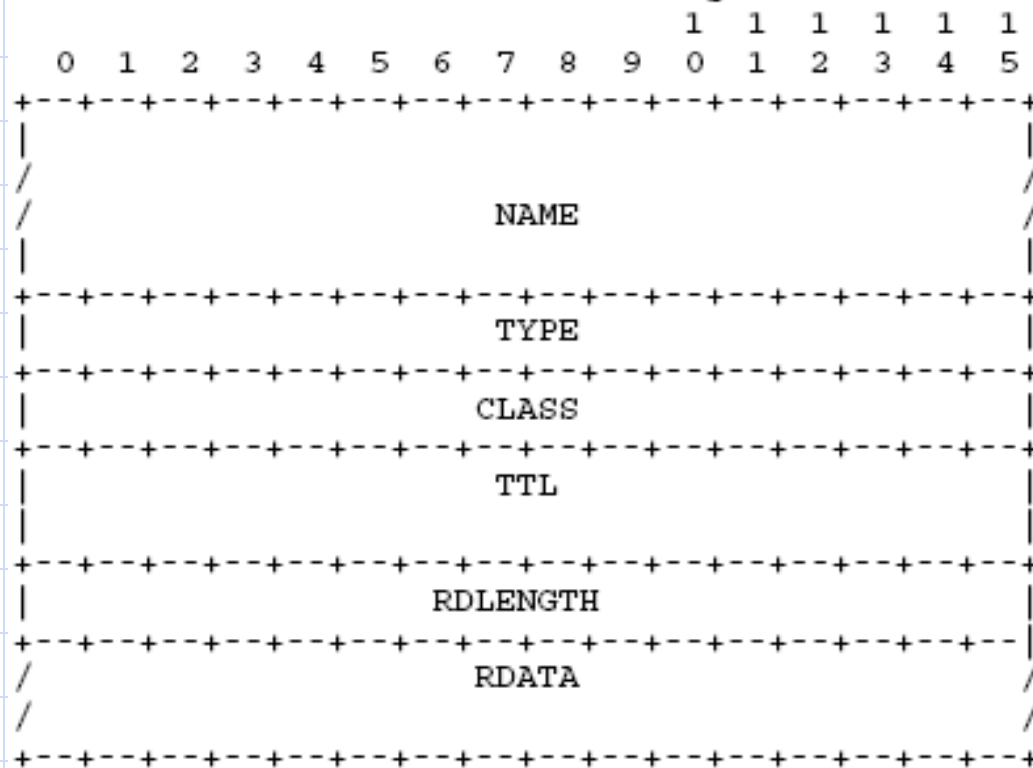
QName – host name or query data (www.cs.ubbcluj.ro)

QType- A, PTR, MX, NS, SOA, etc

QClass – the query class (type of adressing-IN=Internet)

Answer - (RR) DNS Packet Structure

```
                      1 1 1 1 1 1
  0 1 2 3 4 5 6 7 8 9 0 1 2 3 4 5
+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
|                               |
/                               /
/            NAME               /
|                               |
+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
|            TYPE               |
+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
|            CLASS              |
+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
|            TTL                |
|                               |
+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
|           RDLENGTH            |
+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-|
/            RDATA              /
/                               /
+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
```

NAME – the domain name to which this RR pertains

TYPE – RR Type

TTL- Time to Live (cache)

RDLENGTH – length of the RDATA (answer)

RDATA – data. For an IN A query => 4 bytes address

The FTP Protocol

- Allows exchanging files between two machines.
- Text protocol
- RFCs - [RFC 959].
- It is designed to cope with different machine architectures.

Architecture
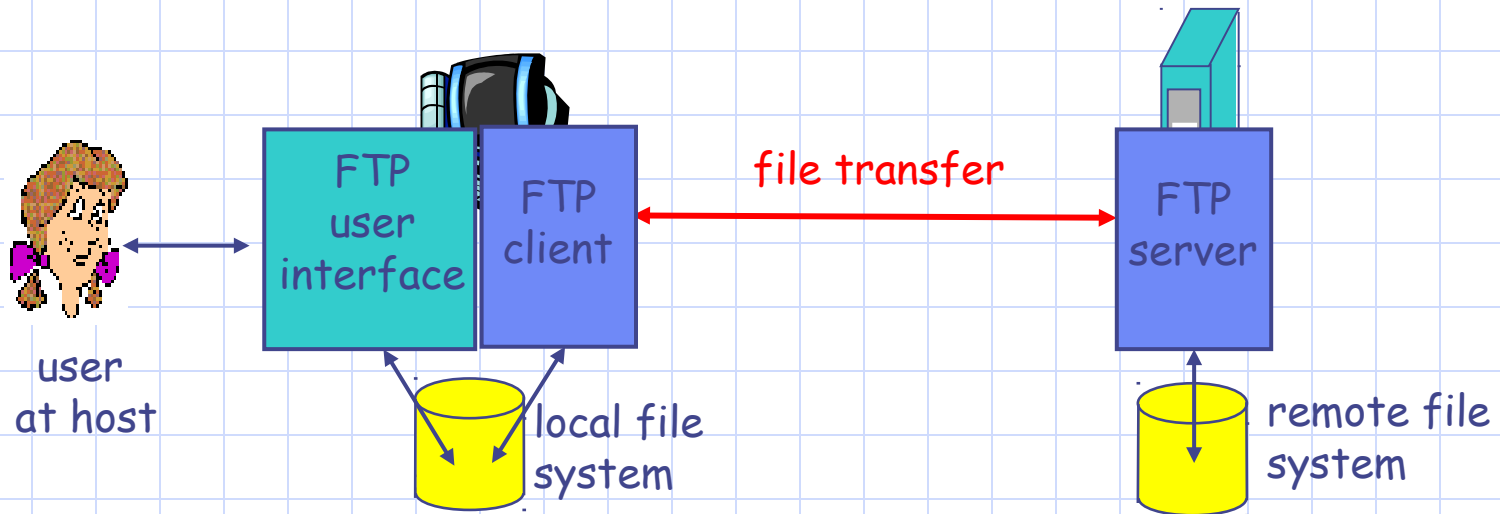
client: side that initiates transfer (either to/from remote)
server: remote host

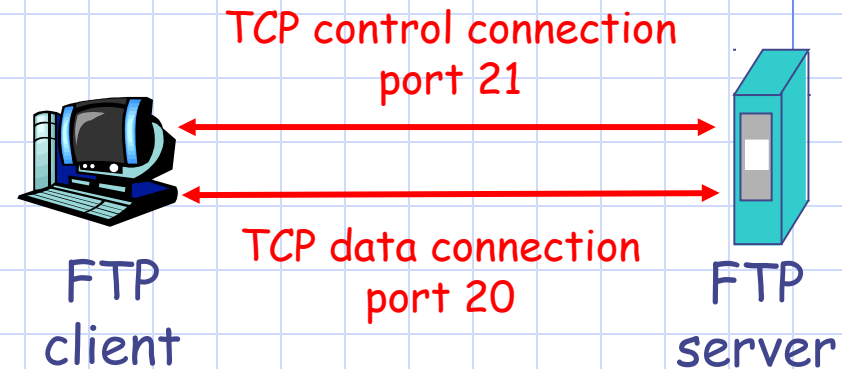# Control and data connections

- FTP uses 2 comm channels
  - The control channel
  - The data channel

- FTP modes
  - Active
  - Passive

Ftp

- FTP client contacts FTP server at port 21, specifying TCP as transport protocol
- Client obtains authorization over control connection
- Client browses remote directory by sending commands over control connection.
- When server receives a command for a file transfer, the server opens a TCP data connection to client
- After transferring one file, server closes connection.

TCP control connection
port 21

TCP data connection
port 20

FTP client

FTP server

- Server opens a second TCP data connection to transfer another file.
- Control connection: "out of band"
- FTP server maintains "state": current directory, earlier authentication

FTP commands

ftp> quote help

214-The following commands are recognized (* =>'s unimplemented):

CWD   XCWD   CDUP   XCUP   SMNT*   QUIT   PORT   PASV

EPRT   EPSV   ALLO*   RNFR   RNTO   DELE   MDTM   RMD
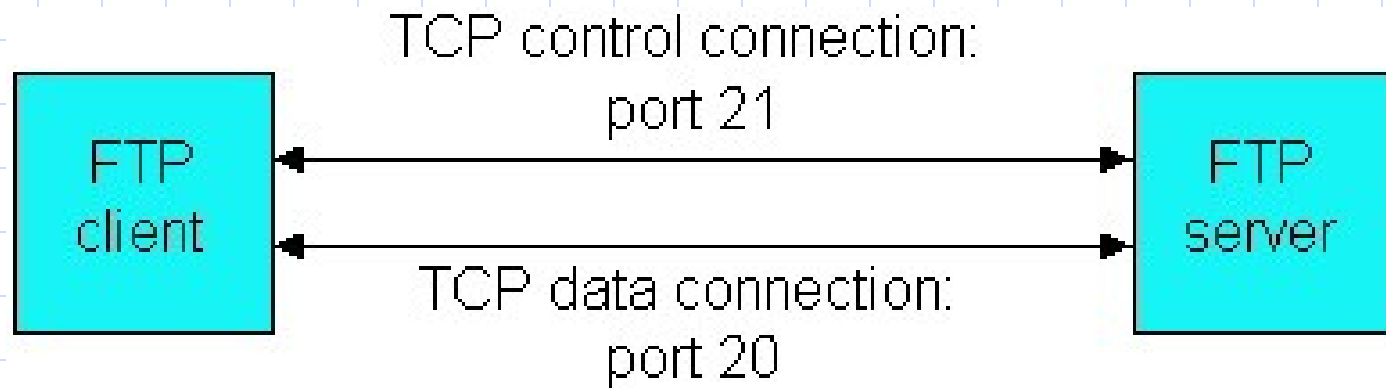
XRMD   MKD   XMKD   PWD   XPWD   SIZE   SYST   HELP

NOOP   FEAT   OPTS   AUTH*   CCC*   CONF*   ENC*   MIC*

PBSZ*   PROT*   TYPE   STRU   MODE   RETR   STOR   STOU

APPE   REST   ABOR   USER   PASS   ACCT*   REIN*   LIST

FTP Channels

FTP client ↔ FTP server

TCP control connection: port 21

TCP data connection: port 20

Active connection

testbox1:{/home/p-t/slacker/public_html} % **ftp -d testbox2** Connected to testbox2.slacksite.com. 220 testbox2.slacksite.com FTP server ready.

Name (testbox2:slacker): **slacker**

---> USER slacker

331 Password required for slacker.

Password: **TmpPass** –

--> PASS XXXX

230 User slacker logged in.

---> SYST 215 UNIX Type: L8

Remote system type is UNIX. Using binary mode to transfer files.

ftp> **ls**

ftp: setsockopt (ignored): Permission denied ---> PORT 192,168,150,80,14,178

200 PORT command successful.

---> LIST

150 Opening ASCII mode data connection for file list.

drwx------ 3 slacker users 104 Jul 27 01:45 public_html

226 Transfer complete.

ftp> **quit**

 ---> QUIT

221 Goodbye.

Passive connection

testbox1:[/home/p/slacker/public_html] % **ftp -d testbox2**
Connected to testbox2.slacksite.com.
220 testbox2.slacksite.com FTP server ready.
Name (testbox2:slacker): **slacker**
---> USER slacker
331 Password required for slacker.
Password: **TmpPass**
---> PASS XXXX
230 User slacker logged in.
---> SYST 215 UNIX Type: L8
Remote system type is UNIX. Using binary mode to transfer files.
ftp> **passive** Passive mode on.
ftp> **ls**
ftp: setsockopt (ignored): Permission denied
---> PASV
227 Entering Passive Mode (192,168,150,90,195,149).
---> LIST
150 Opening ASCII mode data connection for file list
drwx------ 3 slacker users 104 Jul 27 01:45 public_html
226 Transfer complete.
ftp> **quit**
---> QUIT
221 Goodbye.

The SMTP Protocol
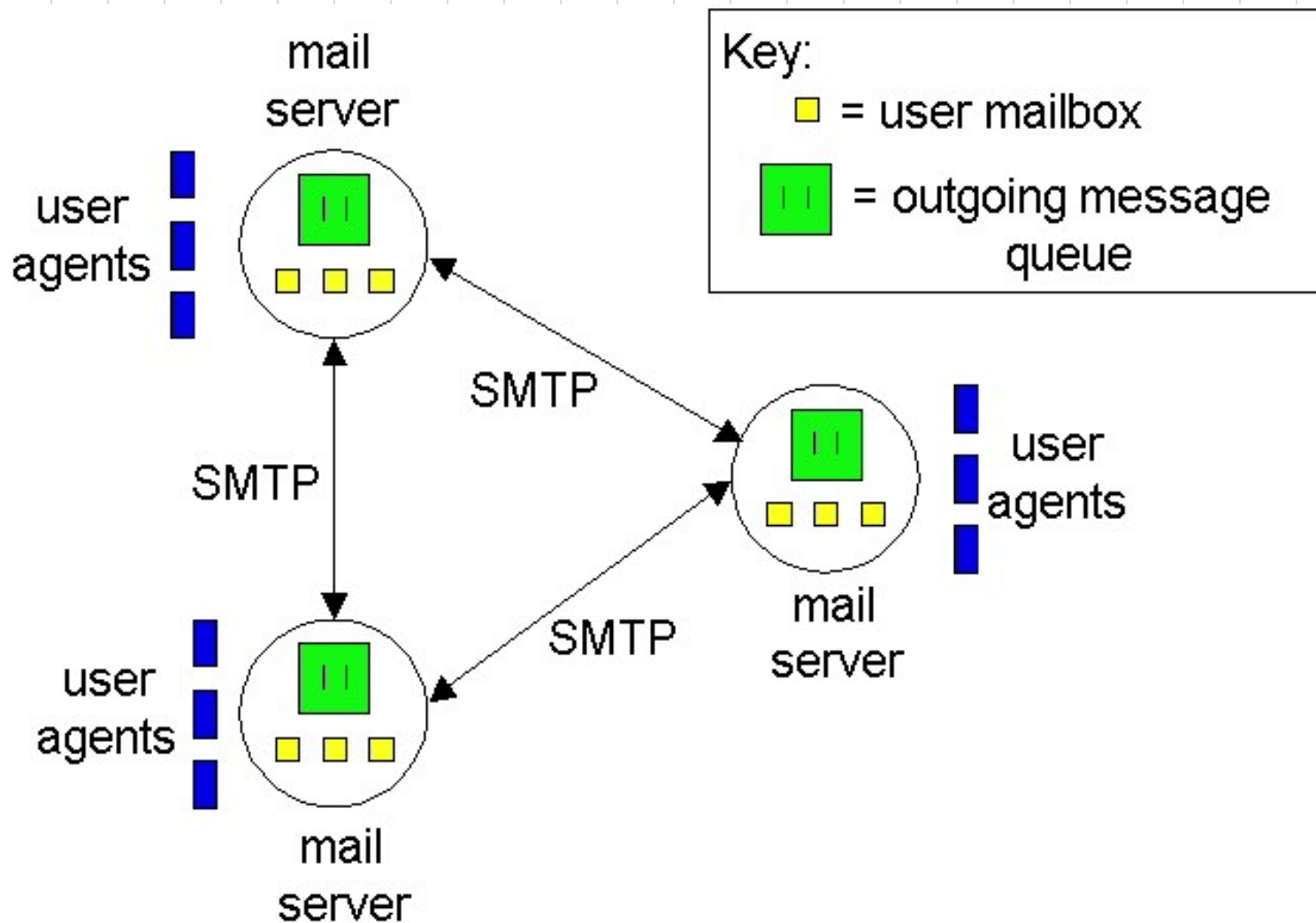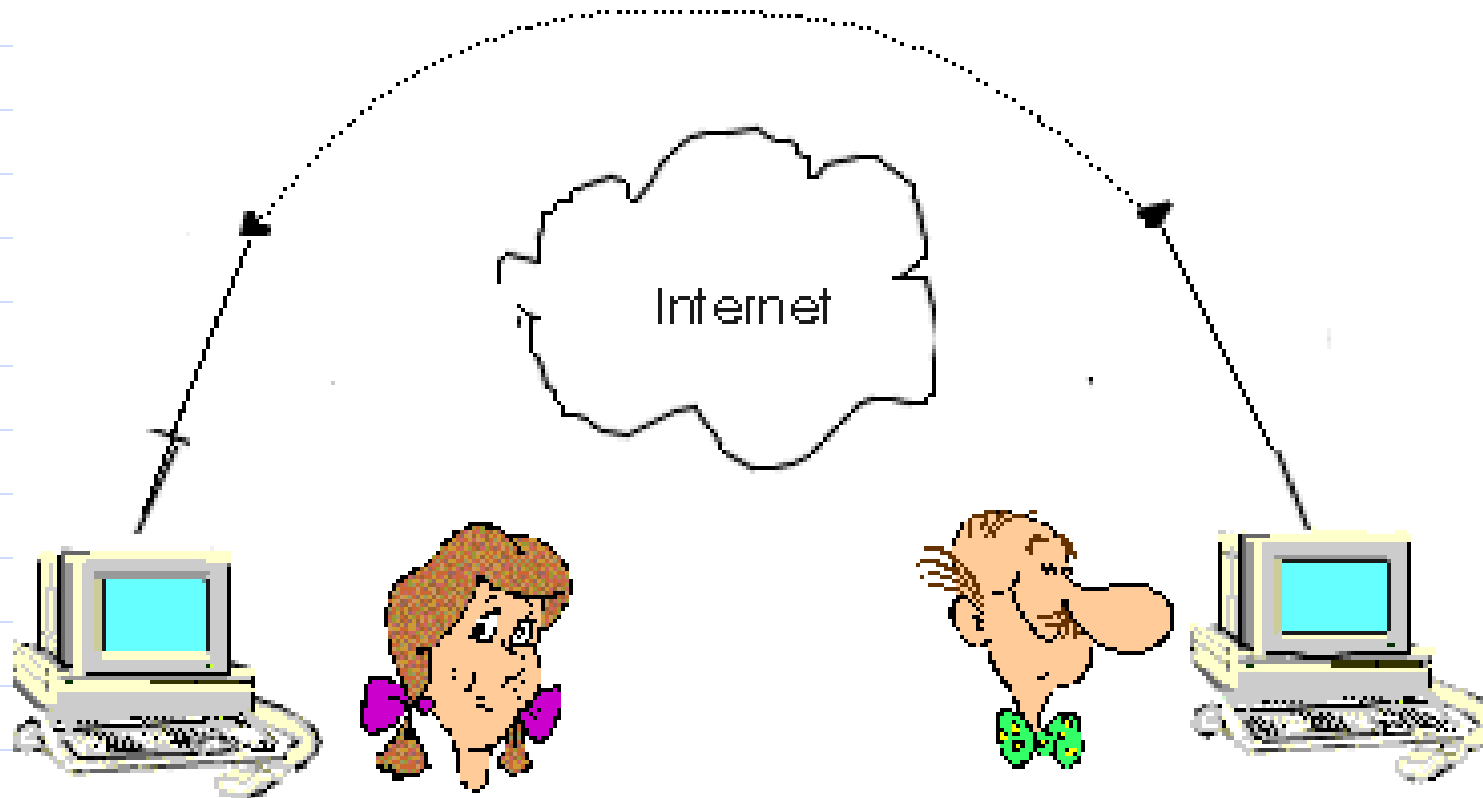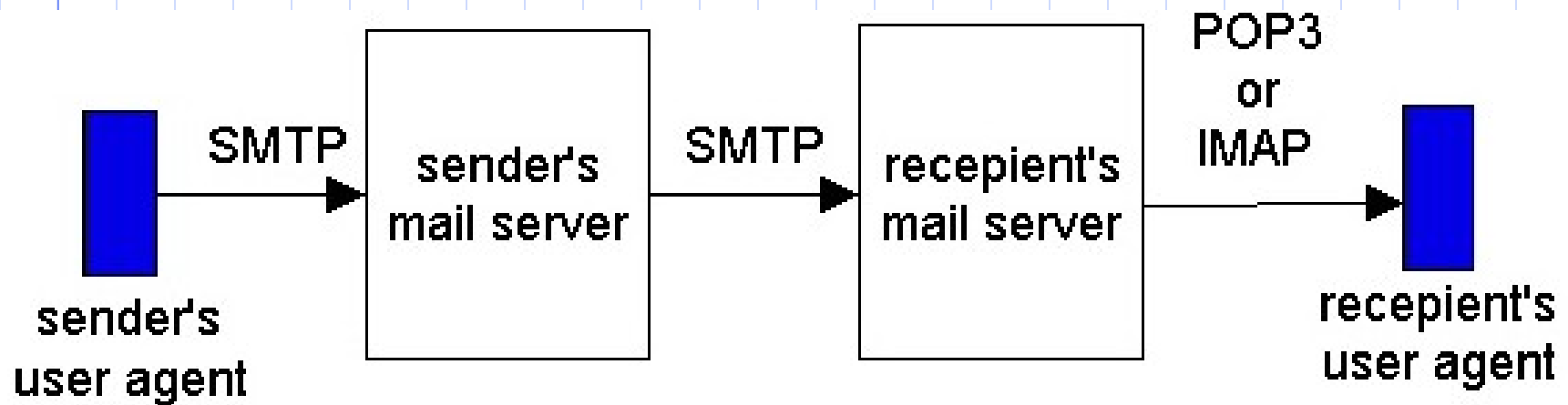
The SMTP protocol

- Server port is 25
- The protocol is text
- Allows for offline message exchanging

Mail system – Offline/Online ?

Offline Mail Sistem (Agents)

Mail system

- SMTP – mail exchange protocol
- Mail Reading
  - POP3 Post Office Protocol
  - IMAP Internet Mail Access Protocol

```
home05122 root]# telnet evolution.cs.ubbcluj.ro 25
Trying 193.226.40.136...
Connected to evolution.cs.ubbcluj.ro.
Escape character is '^]'.
220 evolution.cs.ubbcluj.ro ESMTP Sendmail 8.12.11/8.12.11; Fri, 5 Nov
    2004 01:28:14 +0200
helo astral.ro
250 evolution.cs.ubbcluj.ro Hello Home05122.cluj.astral.ro
    [194.102.147.61], pleased to meet you
mail from: asergiu@yahoo.co.uk
250 2.1.0 asergiu@yahoo.co.uk... Sender ok
rcpt to:dadi@evolution.cs.ubbcluj.ro
250 2.1.5 dadi@evolution.cs.ubbcluj.ro... Recipient ok
data
354 Enter mail, end with "." on a line by itself
From:asergiu@yahoo.co.uk
To:dadi@evolution.cs.ubbcluij.ro
Subject: This is a teste message
Well just a test ...
See ya.
.
250 2.0.0 iA4NSEqa029960 Message accepted for delivery
```

The World Wide Web

- HTML Language – to describe Web pages =>RFC1866 and RFC1942
- HTTP protocol – to transmit web pages
- The Uniform Resource Locator – to name Web pages
- Hypertext – a way of describing documents and data that reference other documents/data.

HTTP Protocol

- Allows exchange of HTML and Web data.
- Works on TCP port 80 and is human readable.

Ex: Connect to www.cs.ubbcluj.ro

GET / HTTP/1.0 >

>

< HTTP/1.0 200 OK

< Date: Wed, 18 Sep 1996 20:18:59 GMT

< Server: Apache/1.0.0

< Content-type: text/html

< Content-length: 1579

< Last-modified: Mon, 22 Jul 1996 22:23:34 GMT

<

< *HTML document*