Computer Networks
Application Layer

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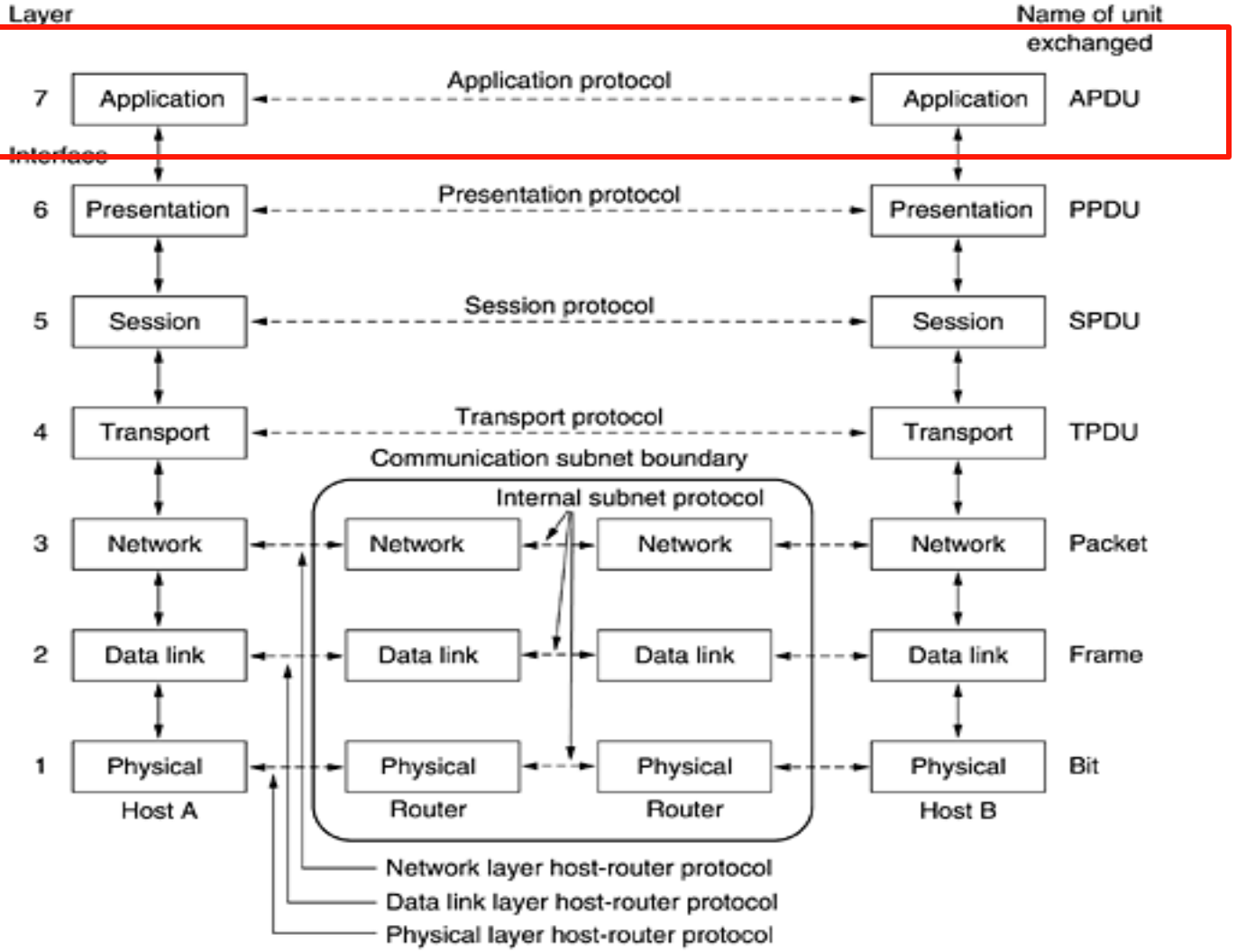
Lecture 4

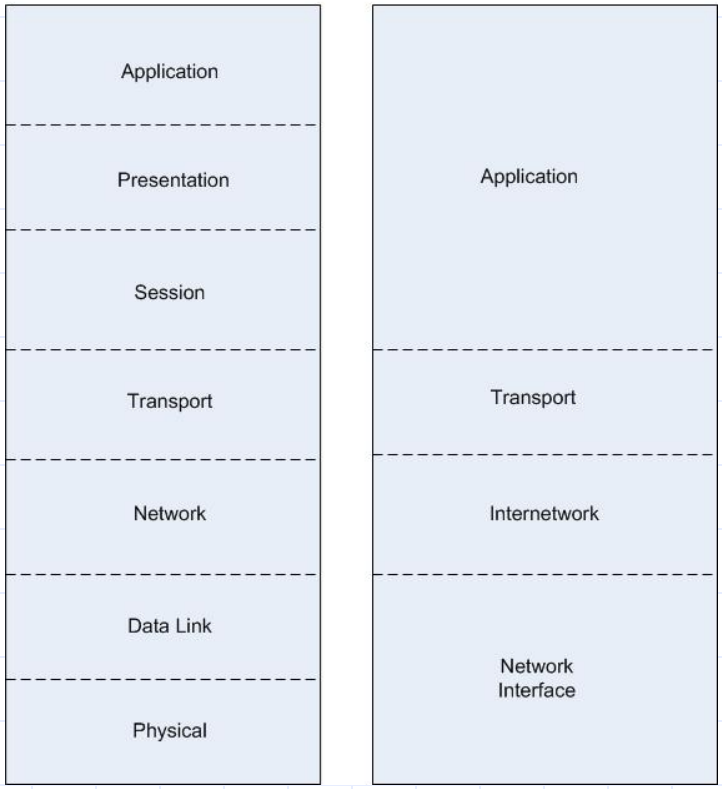
The Application Layer

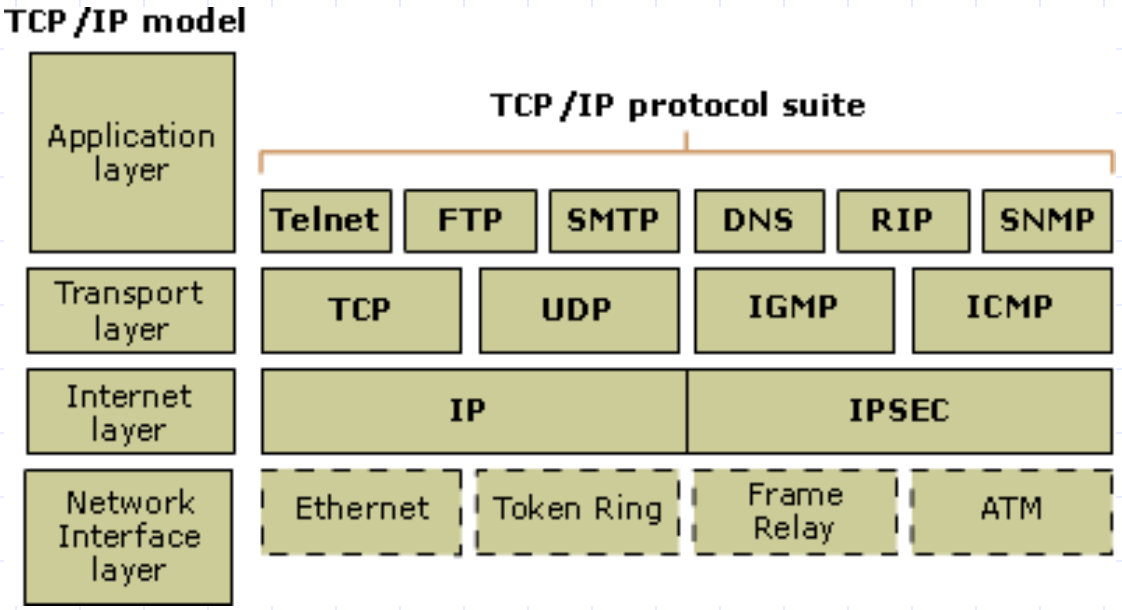


All People Seem To Need Data Processing

OSI vs TCP/IP Model

Comparing The OSI Model And TCP / IP Architecture.





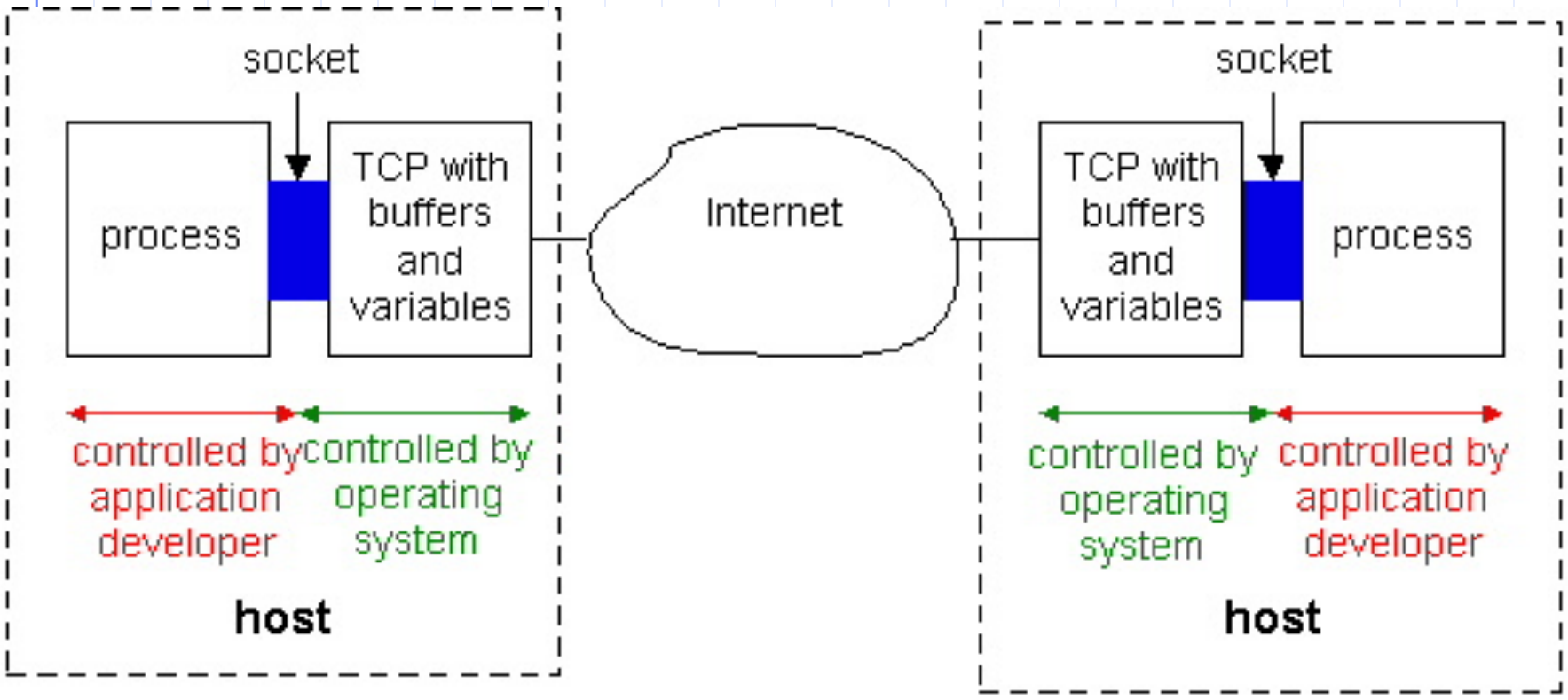
Application Layer Protocols

- 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 !

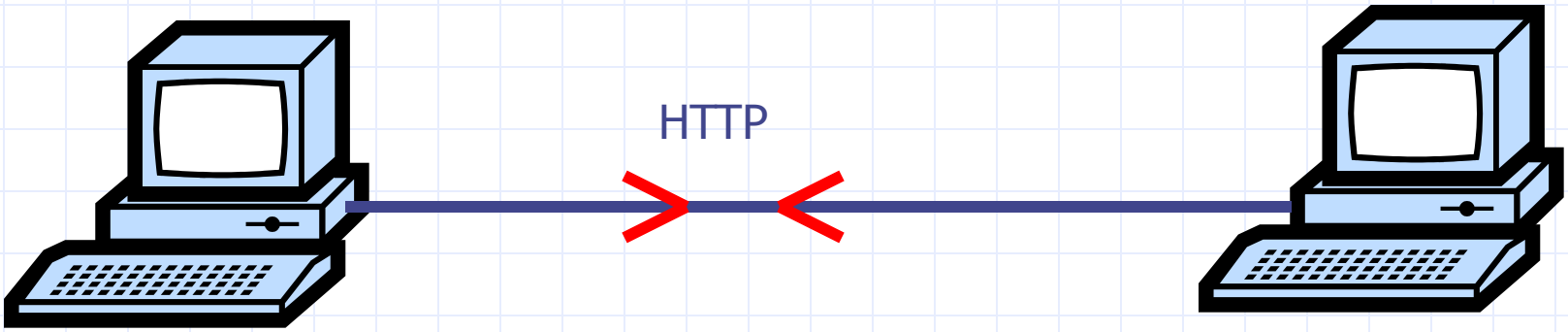
Communicating Processes



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



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.

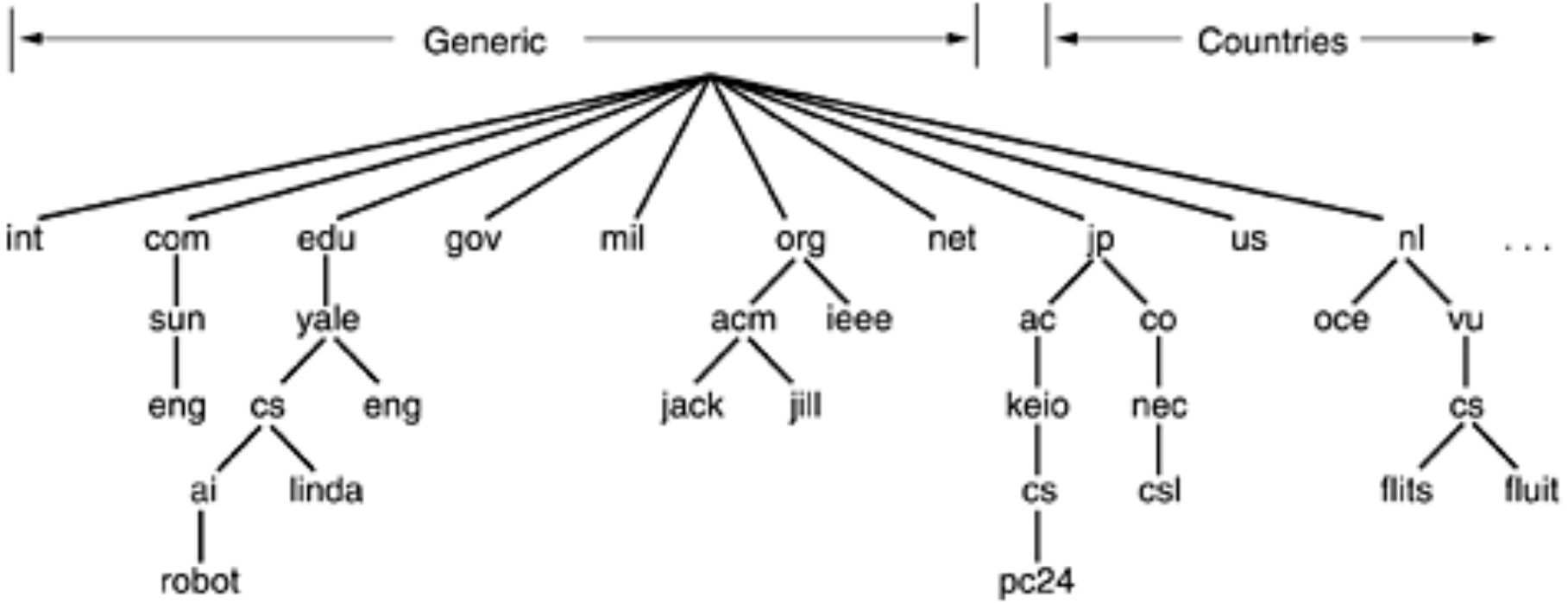
DNS as a service

- 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
e-mail: tchiplea@ubbcluj.ro
nic-hdl: GC106-ROTLD

Whois-2

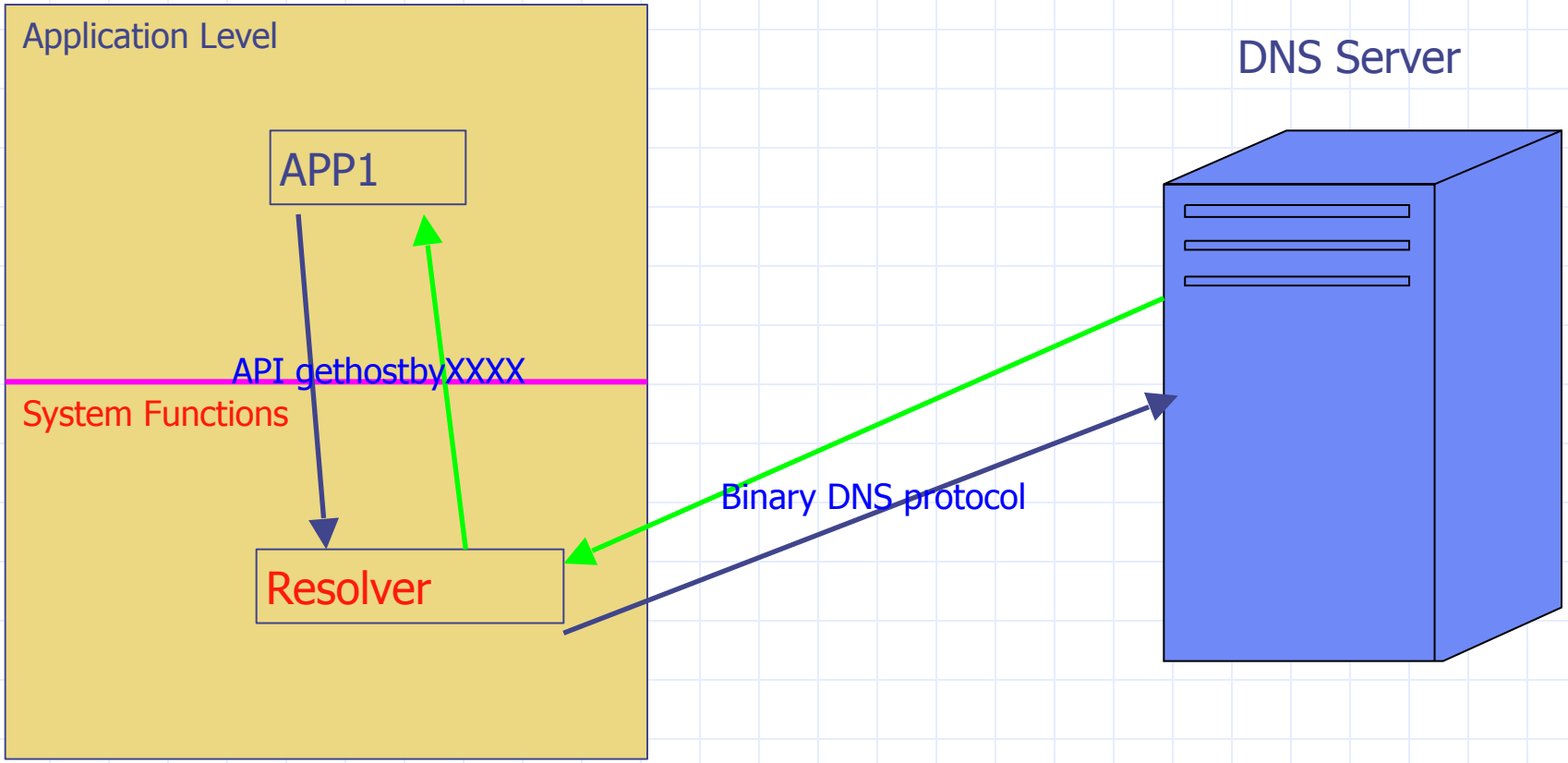
info:object maintained by ro.rnc local registry
notify: domain-admin@listserv.rnc.ro
object-maintained-by: ROTLD-MNT
updated:hostmaster-cmircea@rotld.ro 20020926
source: ROTLD
person: Ioan Ploscariu
address: Mihail Kogalniceanu, Nr. 1
address: Cluj-Napoca, Romania
phone: +40 264 405 344
fax-no: +40 264 191 906
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



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

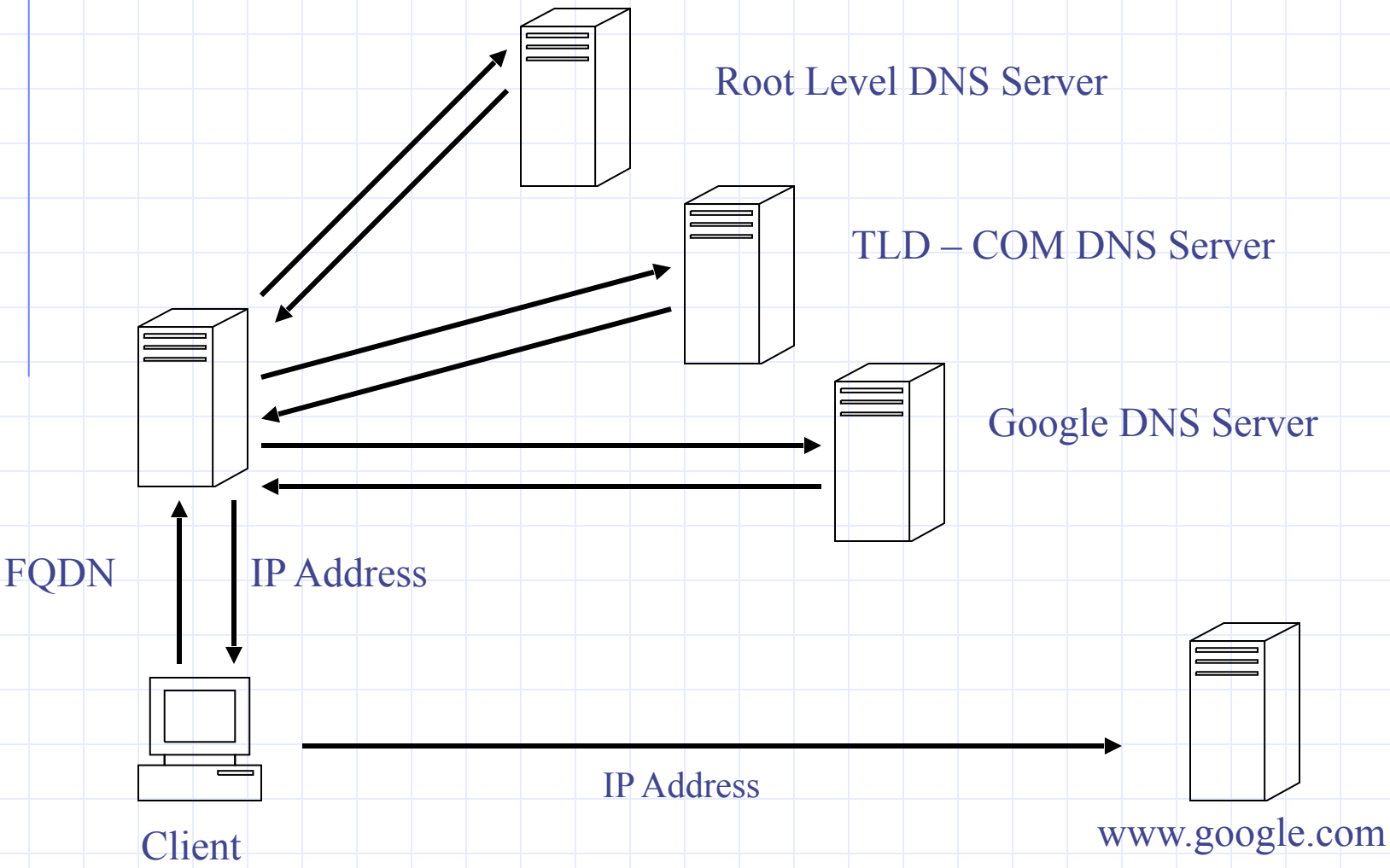
1. Ask the Root Server for the .com (a.gtld-servers.net)
2. a.gtld-servers.net asks the DNS server of the yahoo.com (ns1.yahoo.com)
3. ns1.yahoo.com determines that www.yahoo.com => is an alias for www.yahoo.akadns.net
4. Response gets back to the client www.yahoo.akadns.net

DNS Recursive & caching

Connect at www.yahoo.com

1. Ask Local Server(LS) 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 a.gtld-servers.net who is the DNS server for yahoo.com => ns1.yahoo.com
4. Ask ns1.yahoo.com who is www.yahoo.com => is alias for www.yahoo.akadns.net
5. Ask ns1.yahoo.com who is www.yahoo.akadns.net =>216.109.118.68

How DNS Works (The Two Key Functions)



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
  - Static (Manually Updated)
- Dynamic DNS – **see dyndns.org**
  - Same Process/Types on Information
  - Each Computer Dynamically Updates Its Information
  - RFC
  - Windows Server, Netware, etc

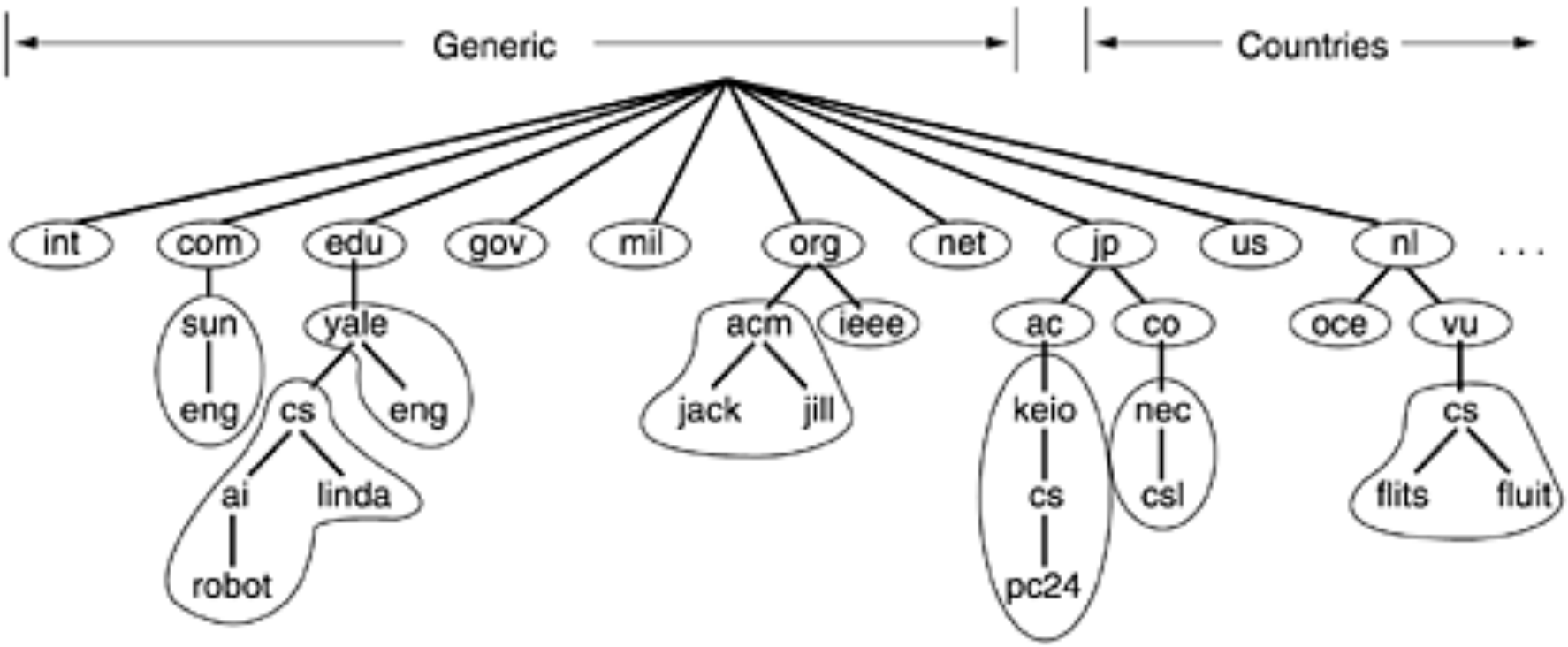
Placing DNS Servers on Internet

- 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

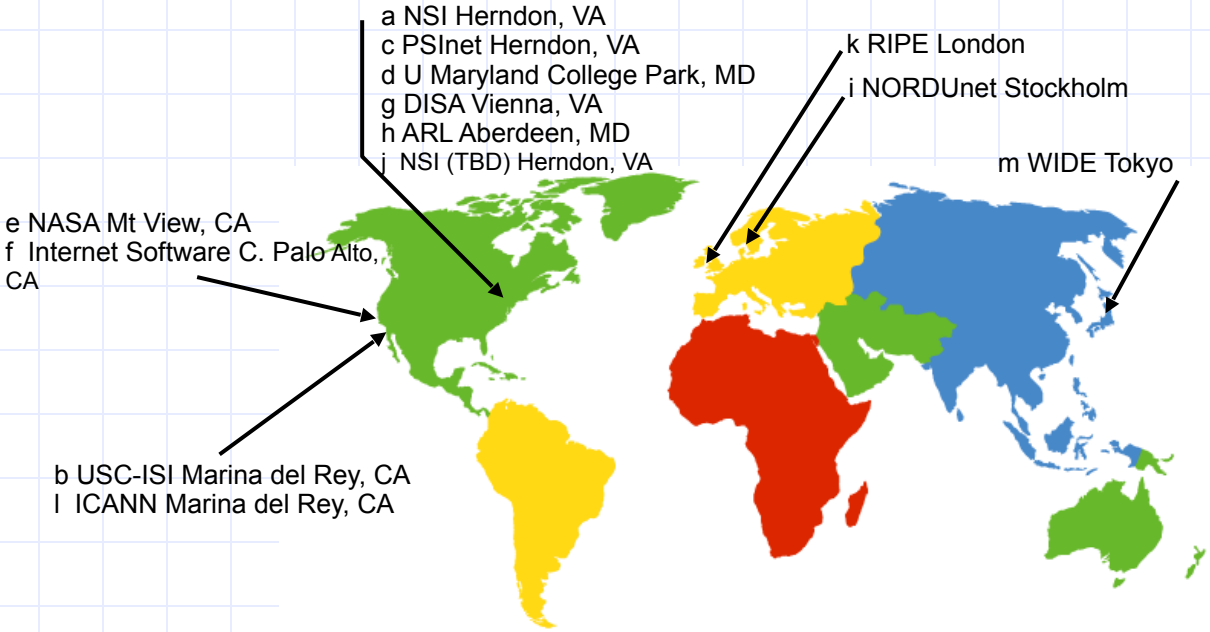
Root Servers and TLDs

- 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



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

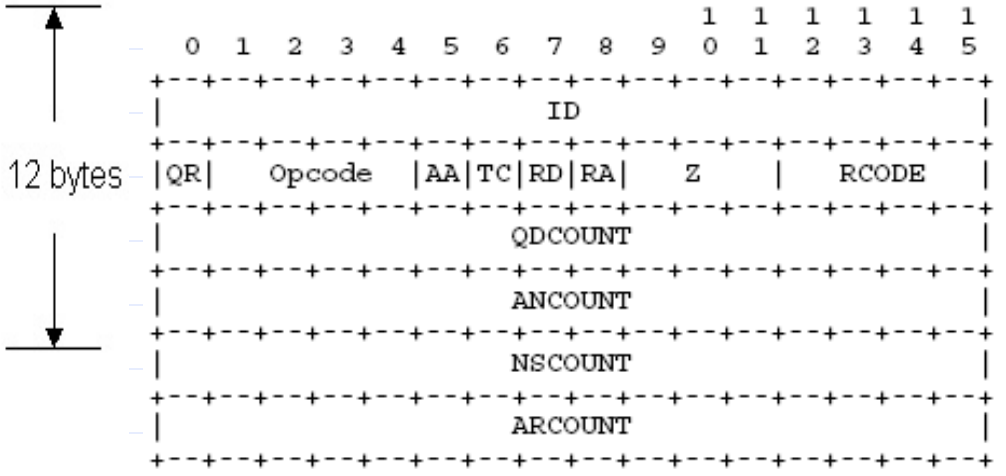
DNS Database

Linux BIND DNS implements it in a file, Windows in Registry:

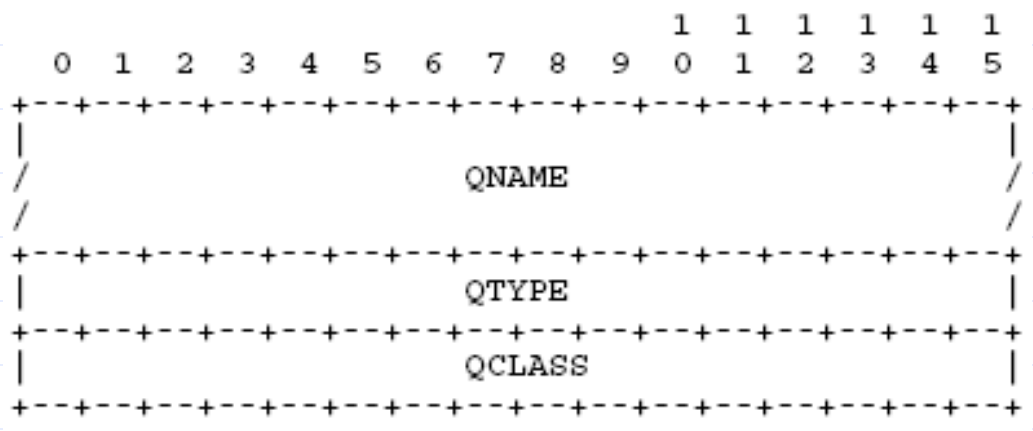
```
utcluj.ro SOA hercule.utcluj.ro. root.hercule.utcluj.ro.
2004101451  ; serial no
36000       ; refresh
3600        ; update retry
2390400     ; expiry
360000      ; minimum or TTL
utcluj.ro NS ns.edu.ro.
utcluj.ro NS ns.roedu.net.
utcluj.ro NS ns-a.rnc.ro.
utcluj.ro NS hercule.utcluj.ro.
utcluj.ro 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)	



Query DNS Packet Structure

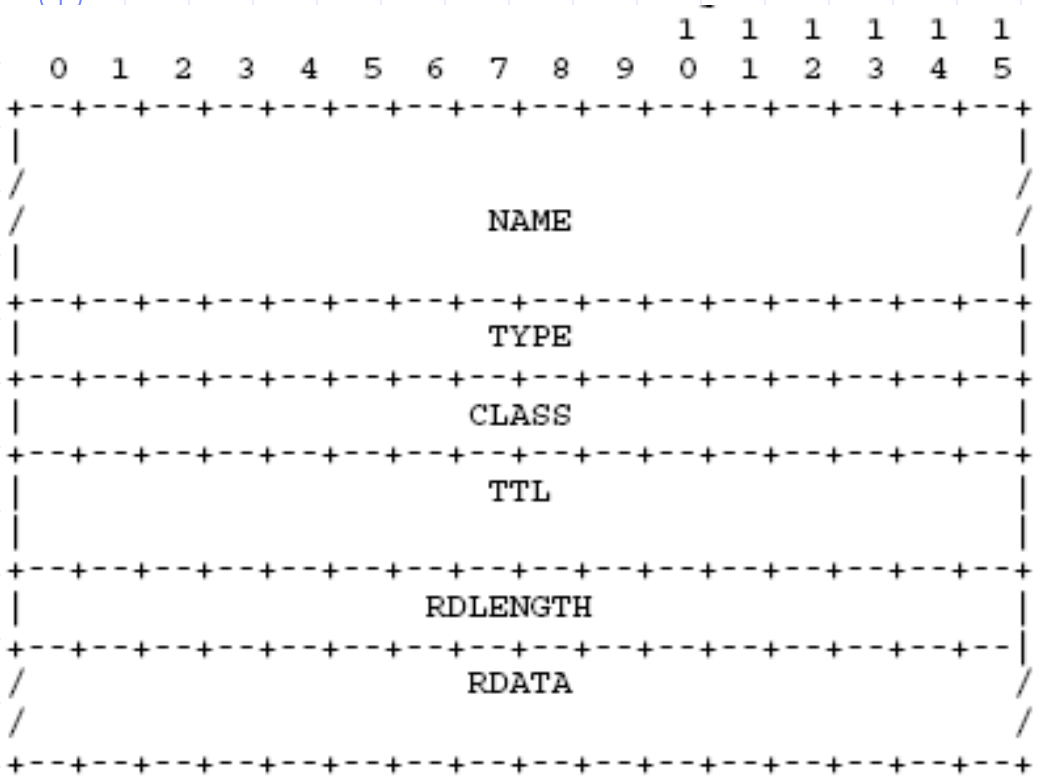


QName – host name or query data (www.cs.ubbcluj.ro)

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

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

Answer - (RR) DNS Packet Structure



NAME – the domain name to which this RR pertains

TYPE – RR Type

TTL- Time to Live (cache)

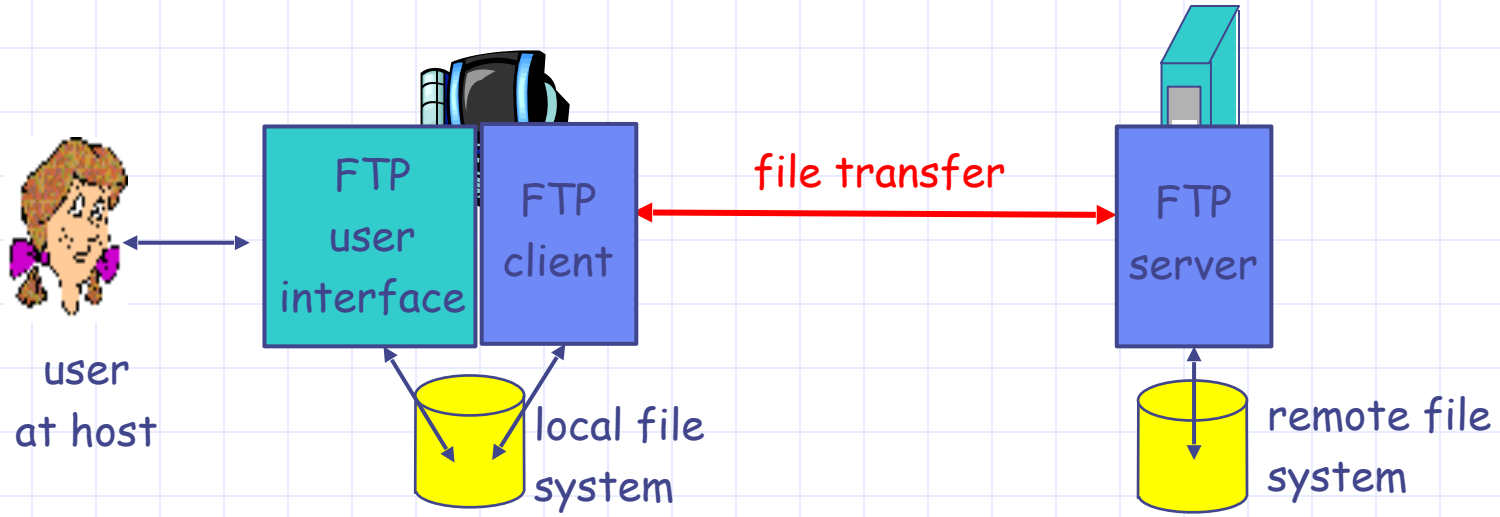
RDLENGTH – length of the RDATA (answer)

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



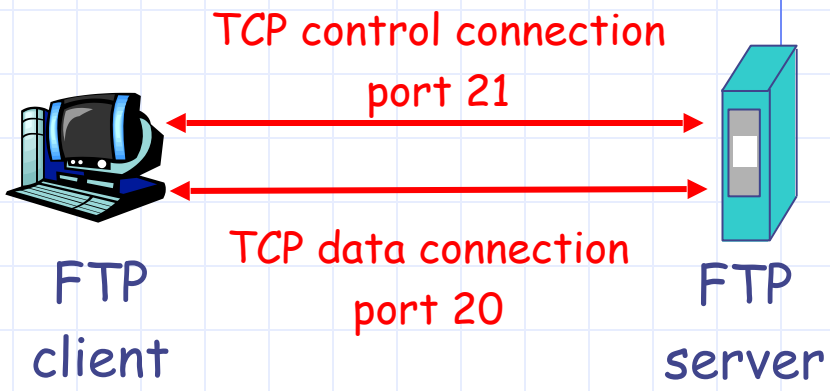
client: side that initiates transfer (either to/from remote)
server: remote host

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.

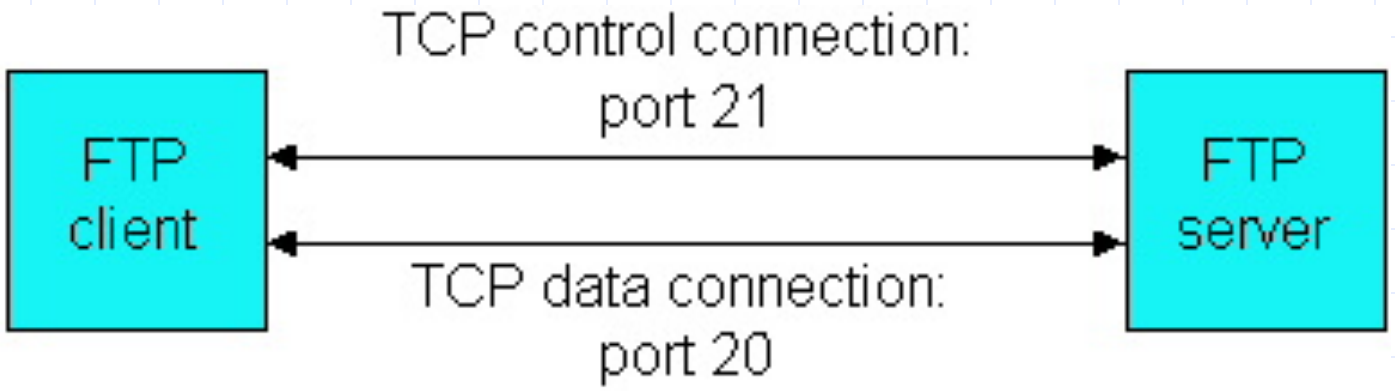


- Server opens a second TCP data connection to transfer another file.
- Control connection: "out of band"
- FTP server maintains "state": current directory, earlier authentication

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



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

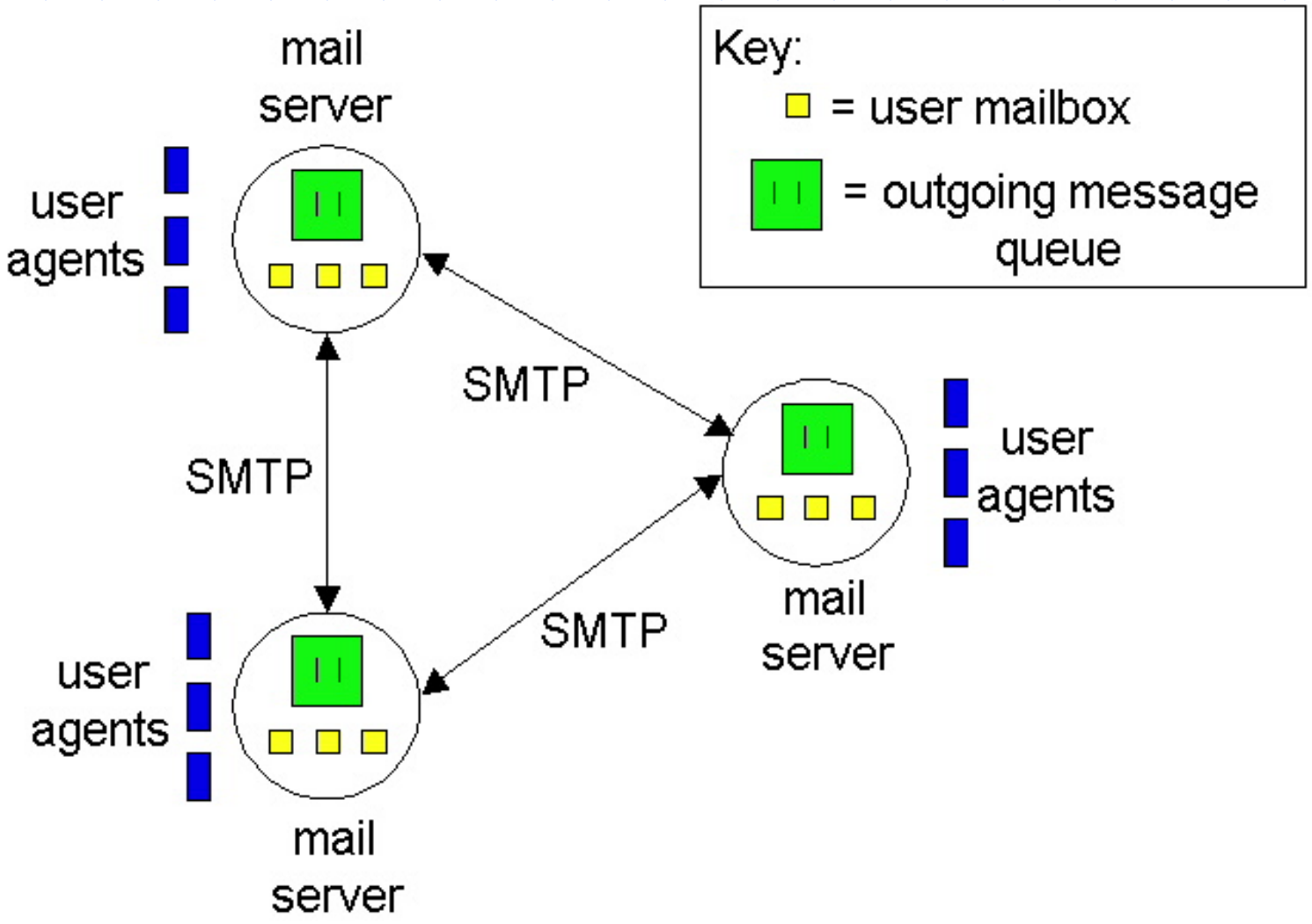
---> QUIT

221 Goodbye.

Passive connection

```
testbox1: {/home/p-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> 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.
```

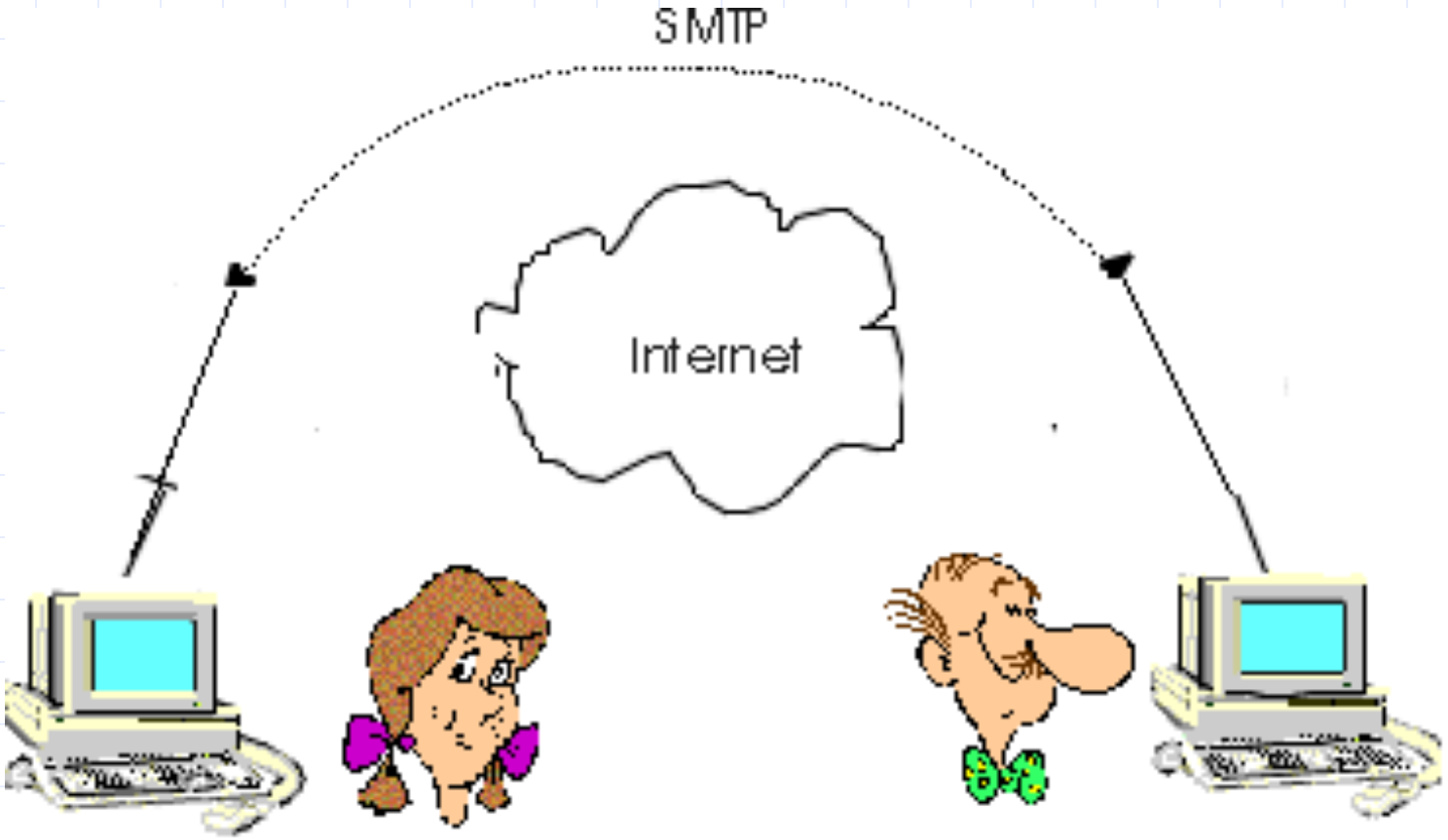
The SMTP Protocol



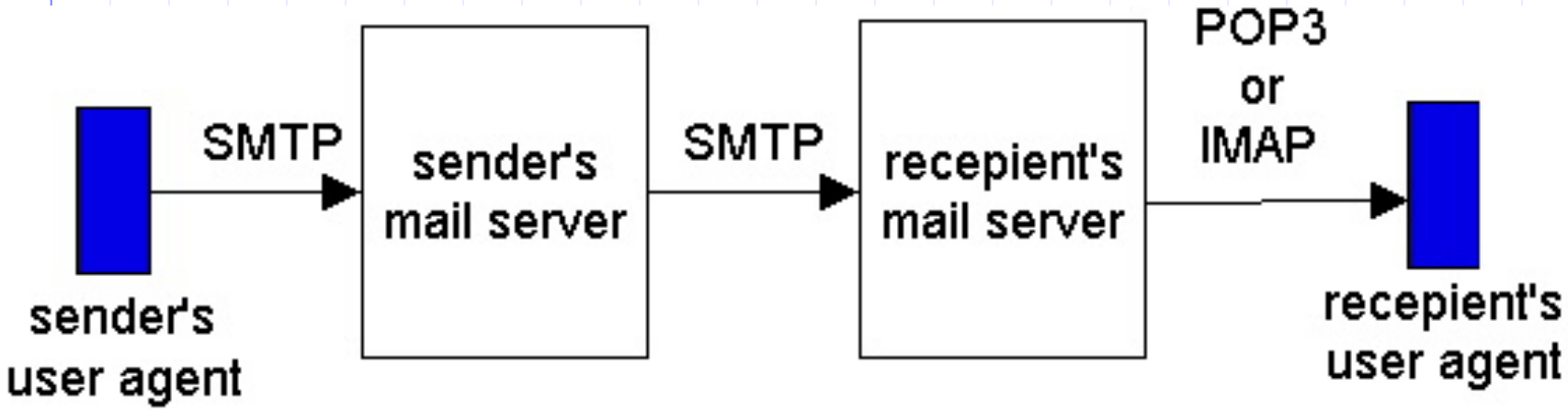
The SMTP protocol

- 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
```