Lecture 9: Application layer

Reading Chapter 7

Computer networks, Tanenbaum

ONE LOVE. ONE FUTURE.

Contents

- Application layer
  - Fundamental concepts
  - Case study: HTTP, Mail, FTP…

Fundamental concepts

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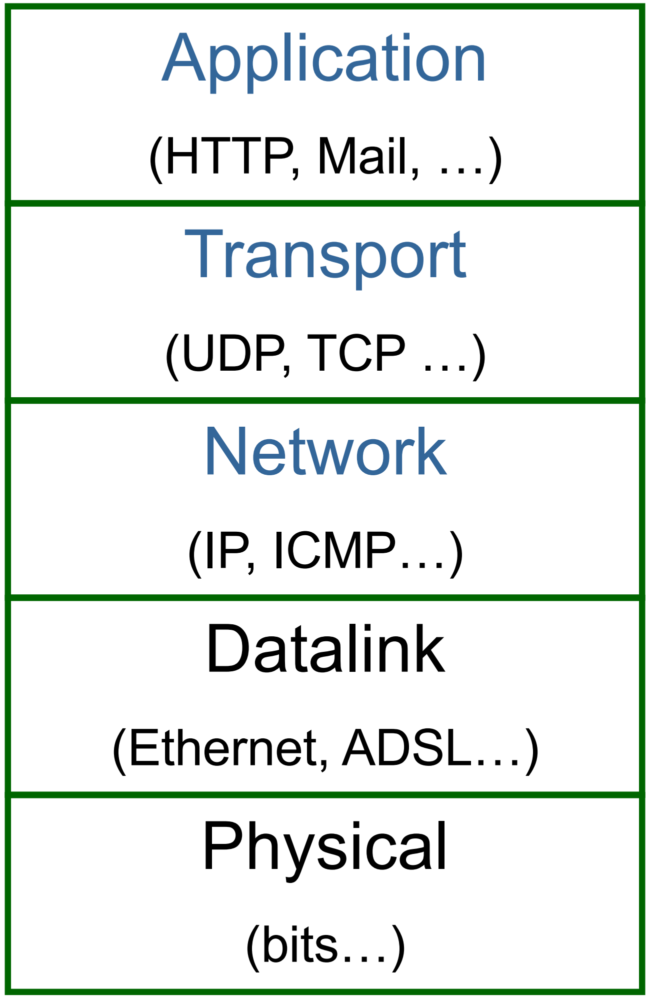
Application layer in OSI model



Application

(HTTP, Mail, …)

Transport

(UDP, TCP …)

Network

(IP, ICMP…)

Datalink

(Ethernet, ADSL…)

Physical

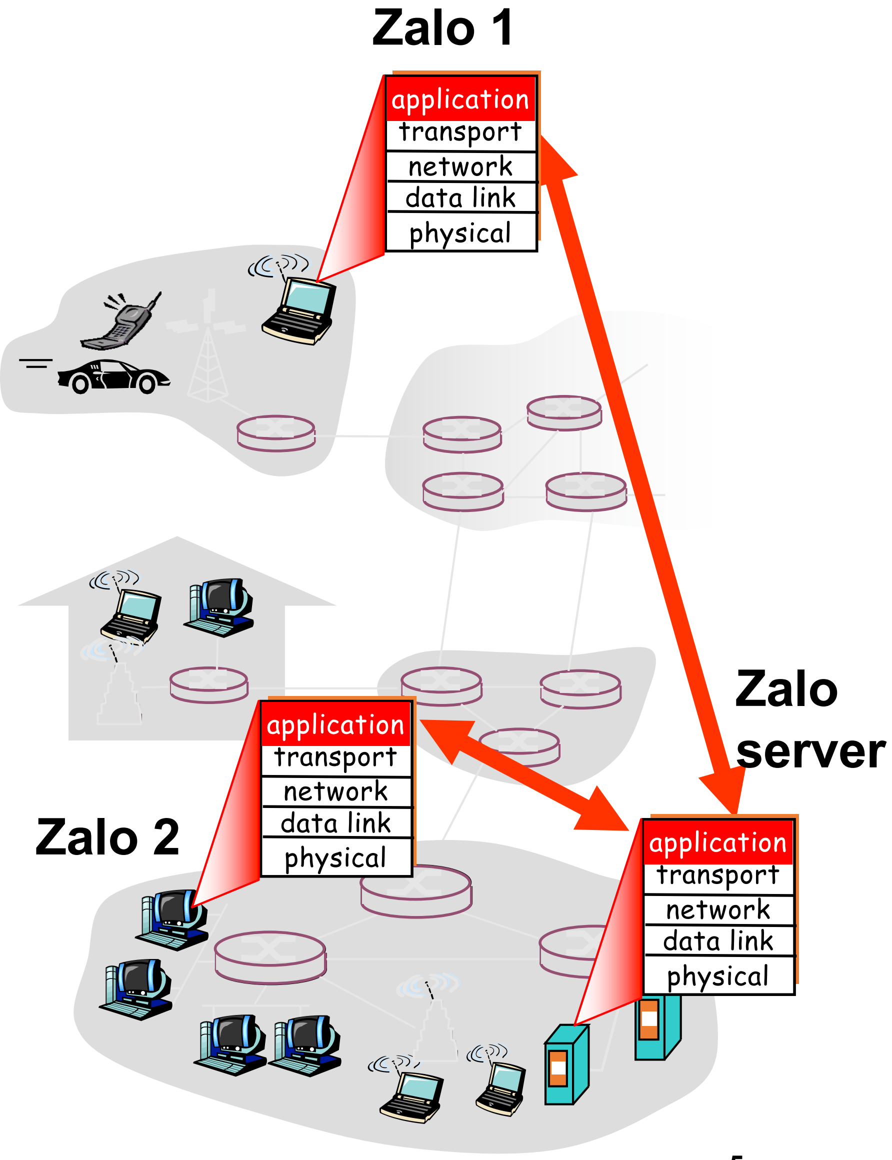
(bits…)

Protocols communication between parties of the application

Transmission data between application

Application and application protocol

- Application protocol
  - Define communication rule
  - Use service of transport layer (TCP/UDP…)
- Application:
  - Is a process on the internet. They communicate to each other by exchanging messages.
  - Runs on end systems
  - Use application protocol for providing service
- Example of application/protocol:
  - Web (HTTP)
  - Mail (SMTP/POP/IMAP) …

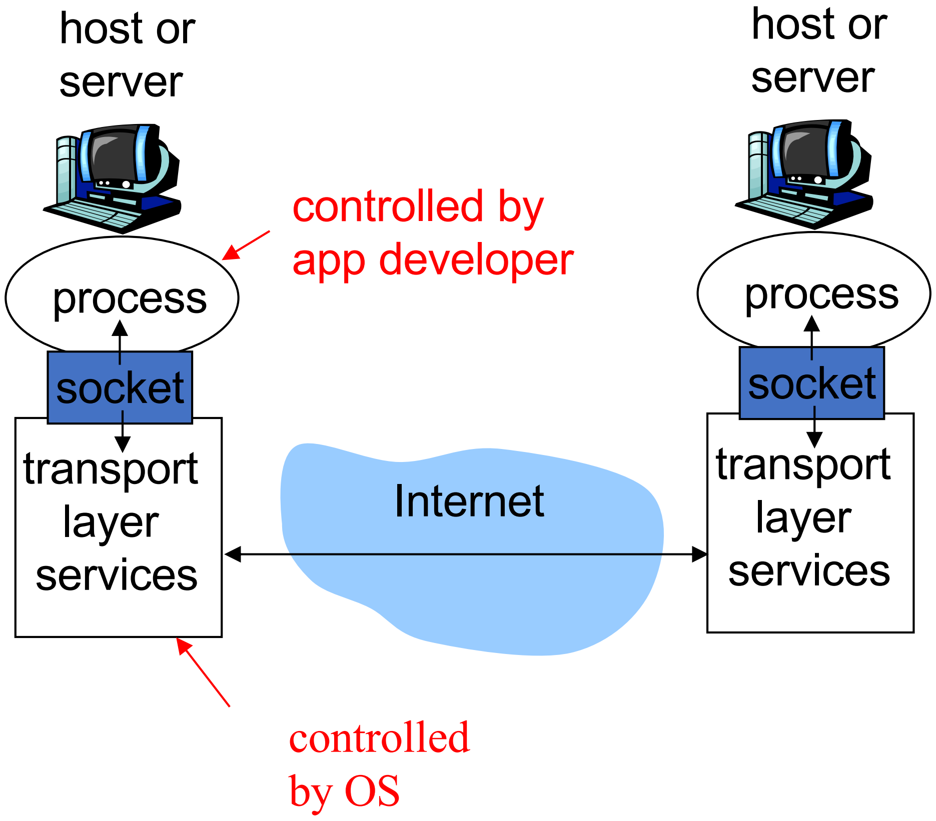


Components of an application

- Application software is compose of
  - User interface:
    - Interfacing with users,
    - e.g. Web browser (Firefox, IE), mail reader(Thunderbird, Outlook,..)
    - Implement one part of application protocol
  - Server program:
    - Responsible to provide service to users
- Application process: the application software running on an OS

Communication between process on the Internet

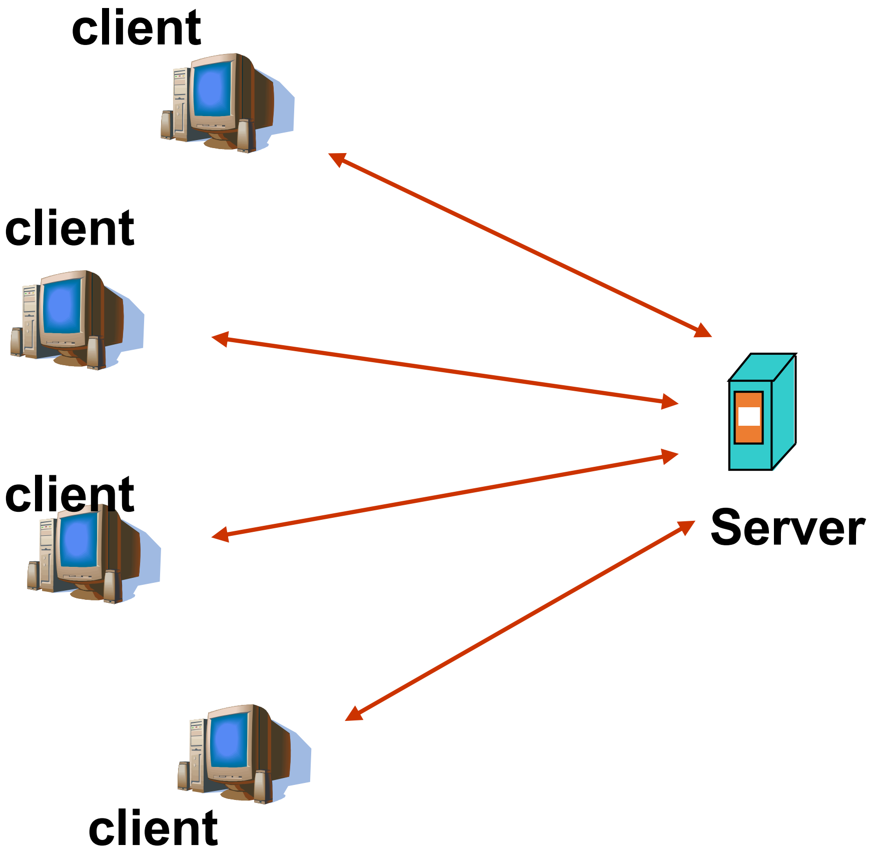
- Socket is an interface between an application process and transport layer
- Socket is defined by
  - Port
  - IP address
  - Transport protocol (TCP or UDP)
- Socket API (Application Programming Interface): Allow application to choose parameters for transport service
  - Choose transport protocol
  - Type of IO communication …



Application architecture

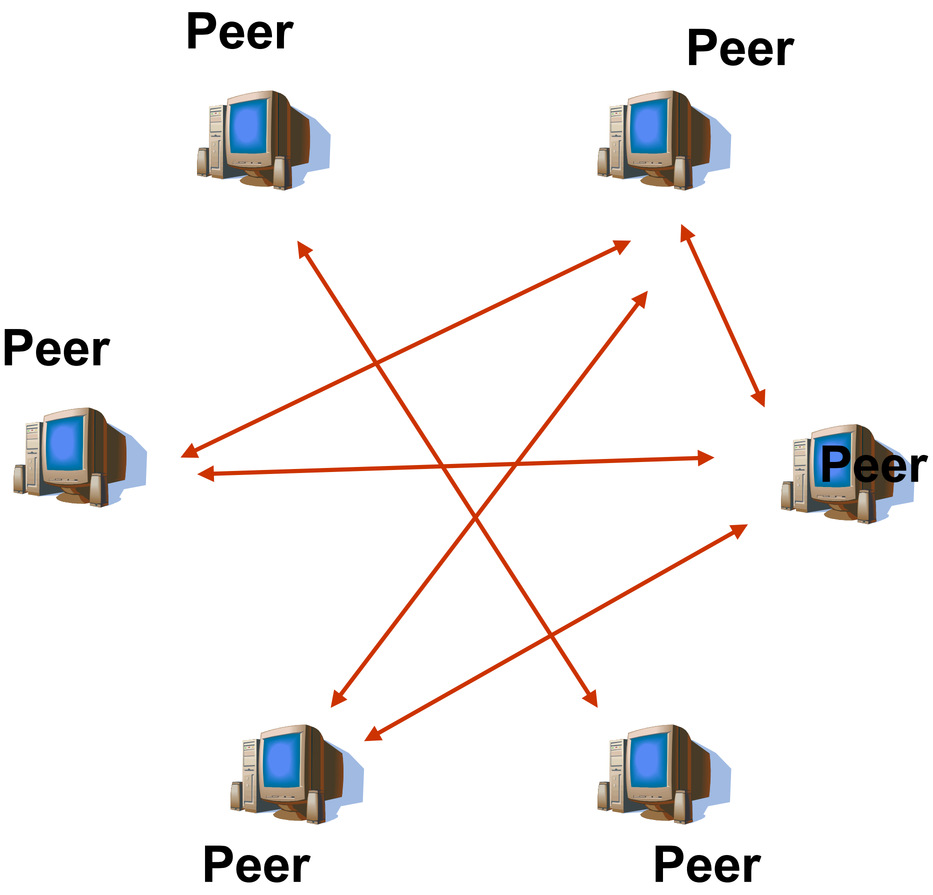
- Client-server:
  - There is a central communication point
- Peer-to-Peer (P2P)
  - No central communication point
- Hybrid
  - Combination of Client-server and P2P

Client-server



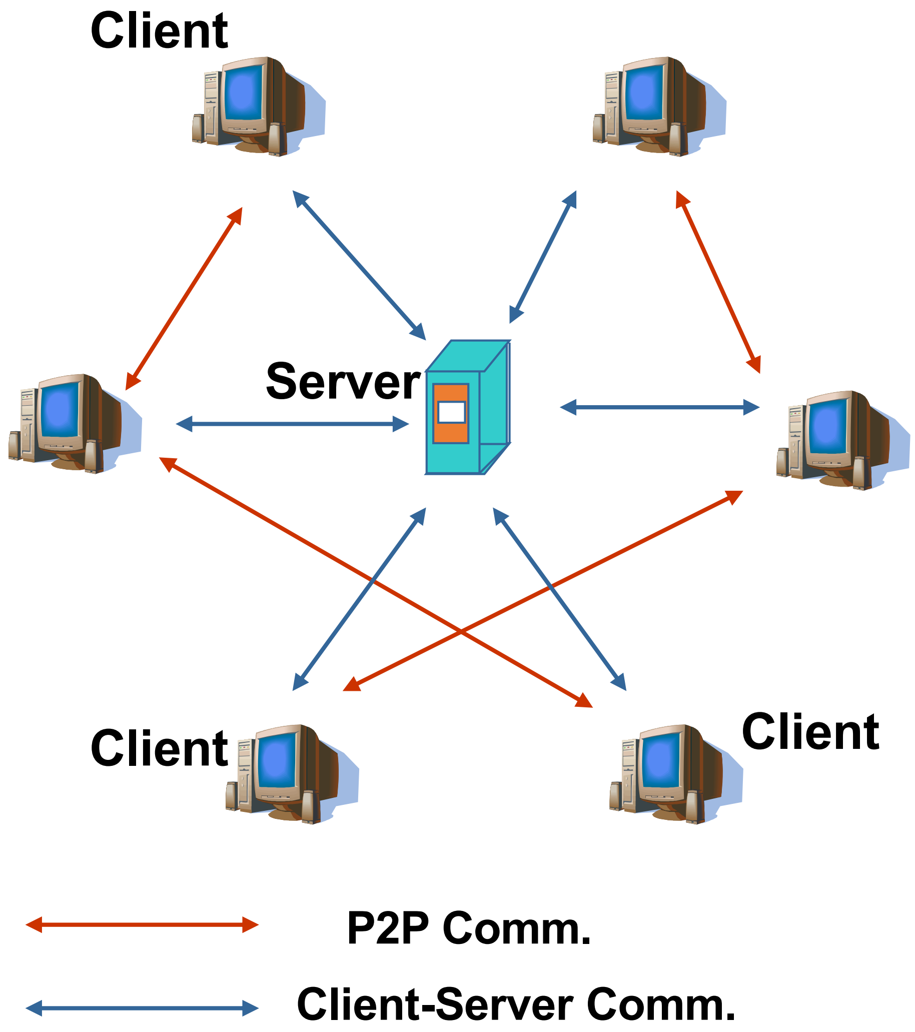
- Two kind of components: client and server
- Client
  - Client sends requests for service to server
  - Clients do not contact directly to each other
- Server
  - Always online waiting for service requests from clients
  - There may be backup servers for assuring high availability in failures
- e.g. Web, Mail, …

Pure Peer-to-peer architecture



- No center server, only peers as components
- Peers have equal role in the system
- Any two peers can communicate directly to each other but only when both are online.
- Peer does not need to be online all the time
- E.g. Gnutella, Bittorent

Hybrid architecture



- A center server for user management, indexing for search purpose.
- Clients communicate directly to each other after authentication process with server.
- E.g. Skype (before 2016)
  - Skype server manage user lists, authentication
  - After authentication users communicate directly to each other

Case study 1: HTTP and WWW

Reading 7.3

Computer Networks, Tanenbaum

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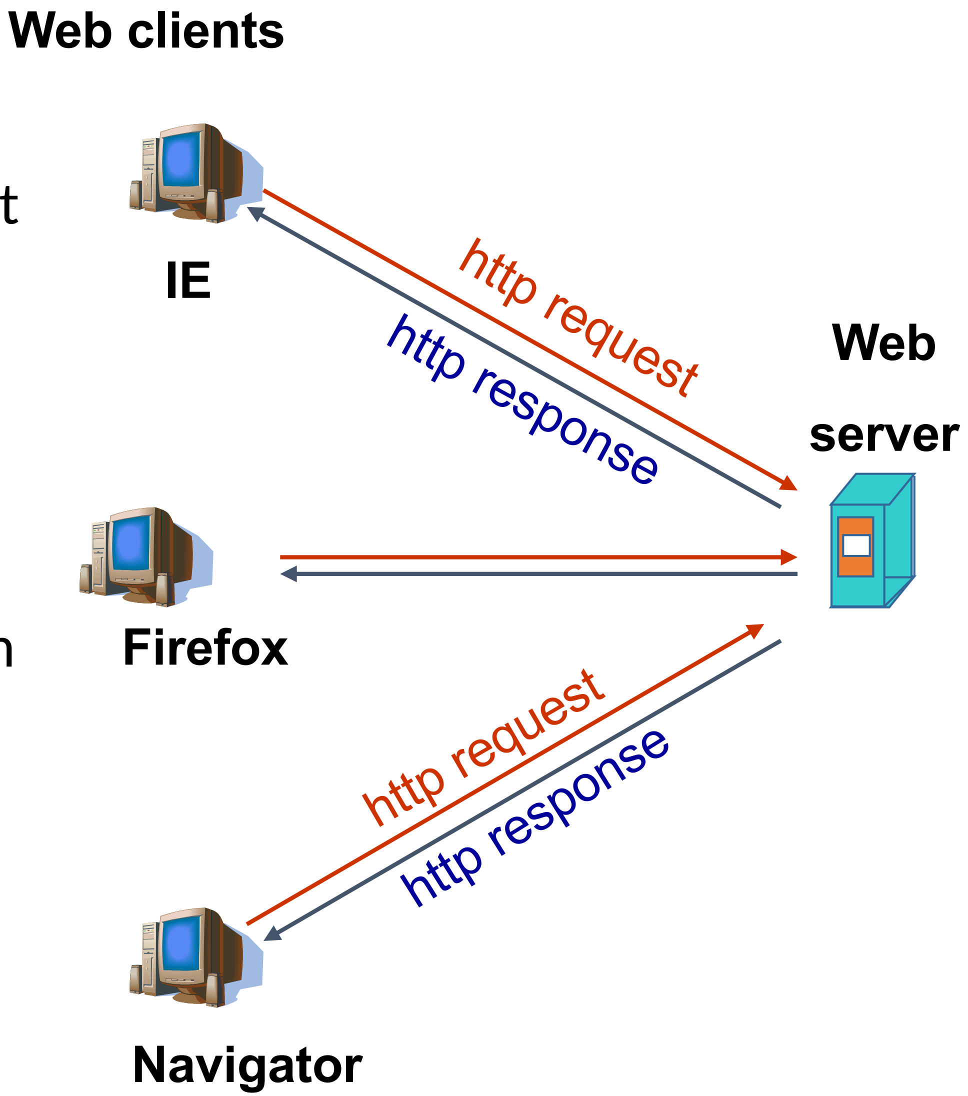
HTTP and Web

- WWW: World Wide Web
  - Application for exchanging the HTML documents (HyperText Markup Language) over Internet
  - WWW use HTTP protocol
- HTTP: HyperText Transfer Protocol
  - Client/Server model
  - Client (Web browser)requests for webpages and displays them on its interface
  - Server: Receive request from client and return results under the form of webpage.

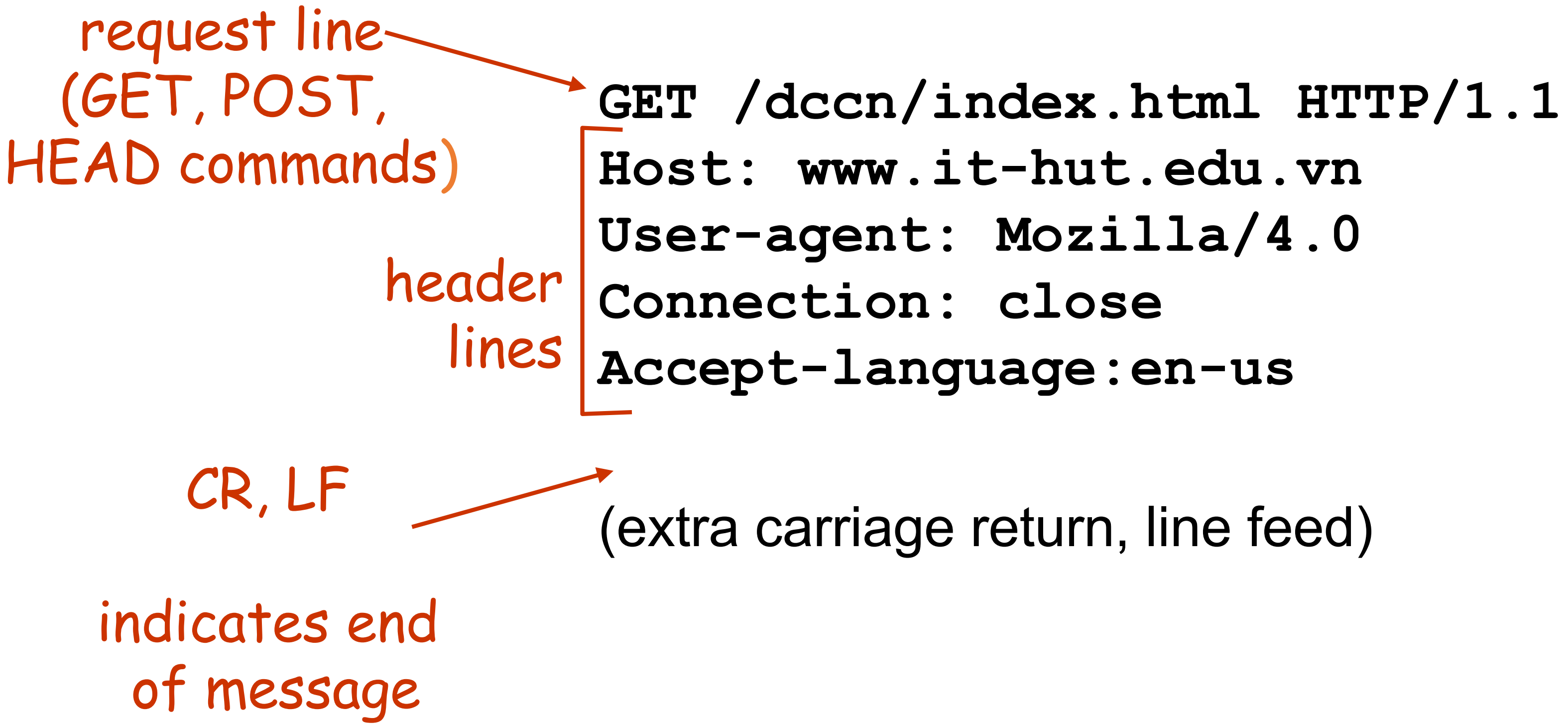


How HTTP works?

- Server open a TCP socket by default at port 80 waiting for
- Client initiates a TCP connection to server
- Server accept the connection request
- Exchange HTTP message
  - HTTP Request
  - HTTP Response
- Close connection TCP

Format of HTTP request

- ASCII encoding (readable using text editor)



request line (GET, POST, HEAD commands)

```
GET /dccn/index.html HTTP/1.1
Host: www.it-hut.edu.vn
User-agent: Mozilla/4.0
Connection: close
Accept-language:en-us
```

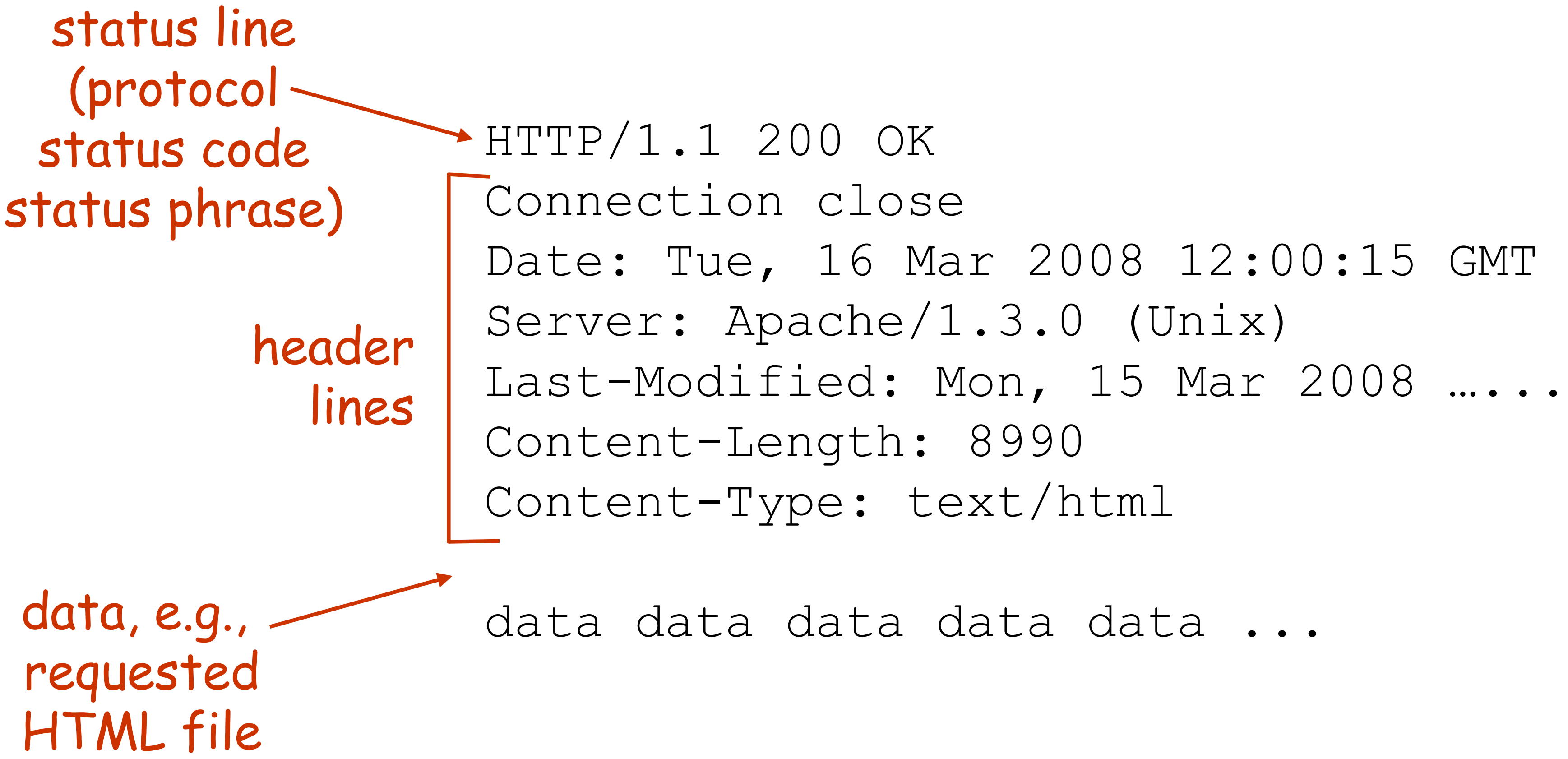
header lines

CR, LF

(extra carriage return, line feed)

indicates end of message

Format of HTTP response



status line (protocol status code status phrase)

header lines

data, e.g., requested HTML file

```
HTTP/1.1 200 OK
Connection close
Date: Tue, 16 Mar 2008 12:00:15 GMT
Server: Apache/1.3.0 (Unix)
Last-Modified: Mon, 15 Mar 2008 …...
Content-Length: 8990
Content-Type: text/html

data data data data data ...
```

Status code in Response message

Status code is in the first line of the Response message

200 OK

- request succeeded, requested object later in this message

301 Moved Permanently

- requested object moved, new location specified later in this message (Location:)

400 Bad Request

- request message not understood by server

404 Not Found

- requested document not found on this server

505 HTTP Version Not Supported

Types of HTTP connections

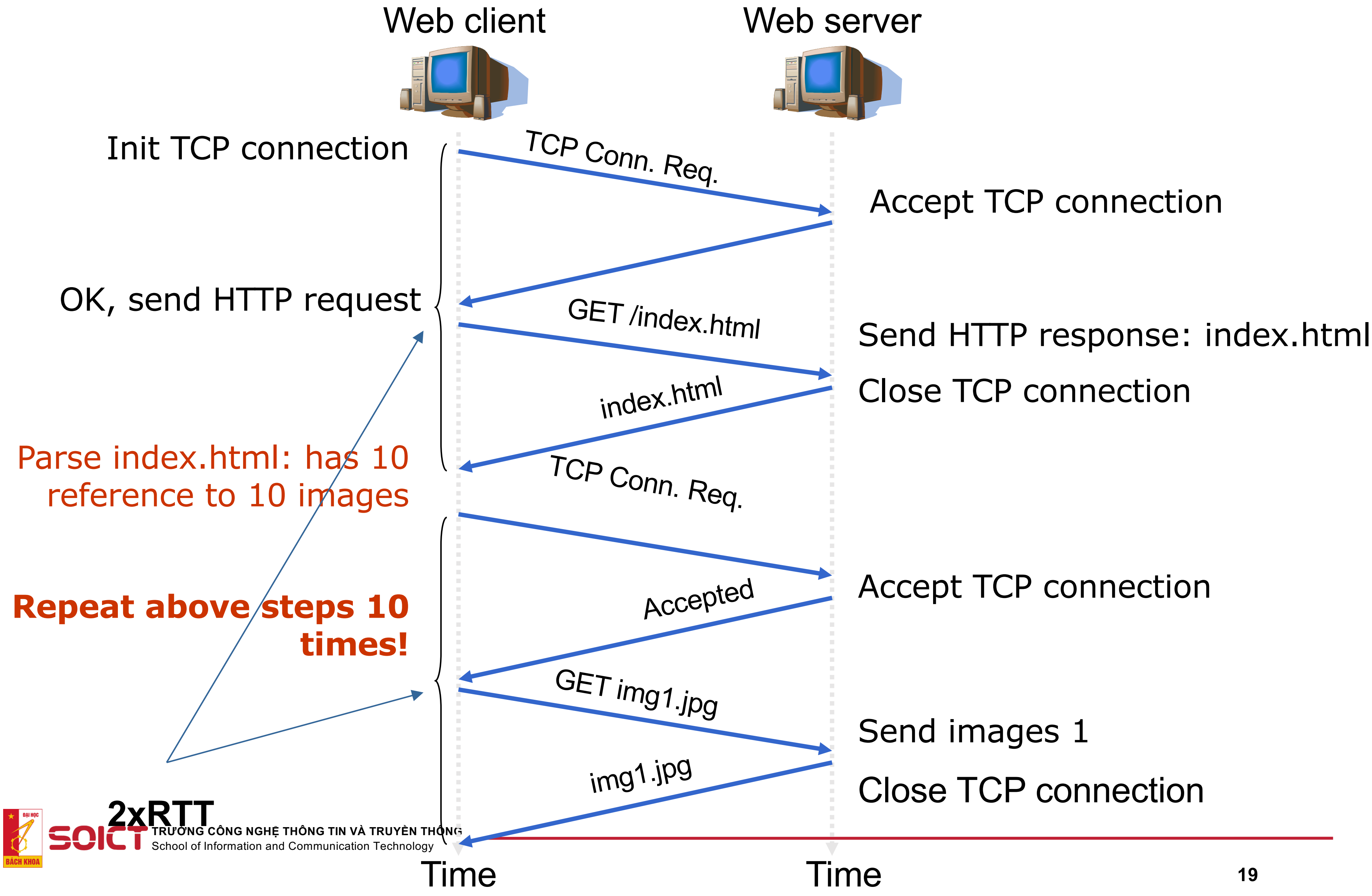
HTTP non-persistent

- Only one web object (text or image) is transferred over a connection TCP
- Option by default in HTTP/1.0
- HTTP 1.0: RFC 1945

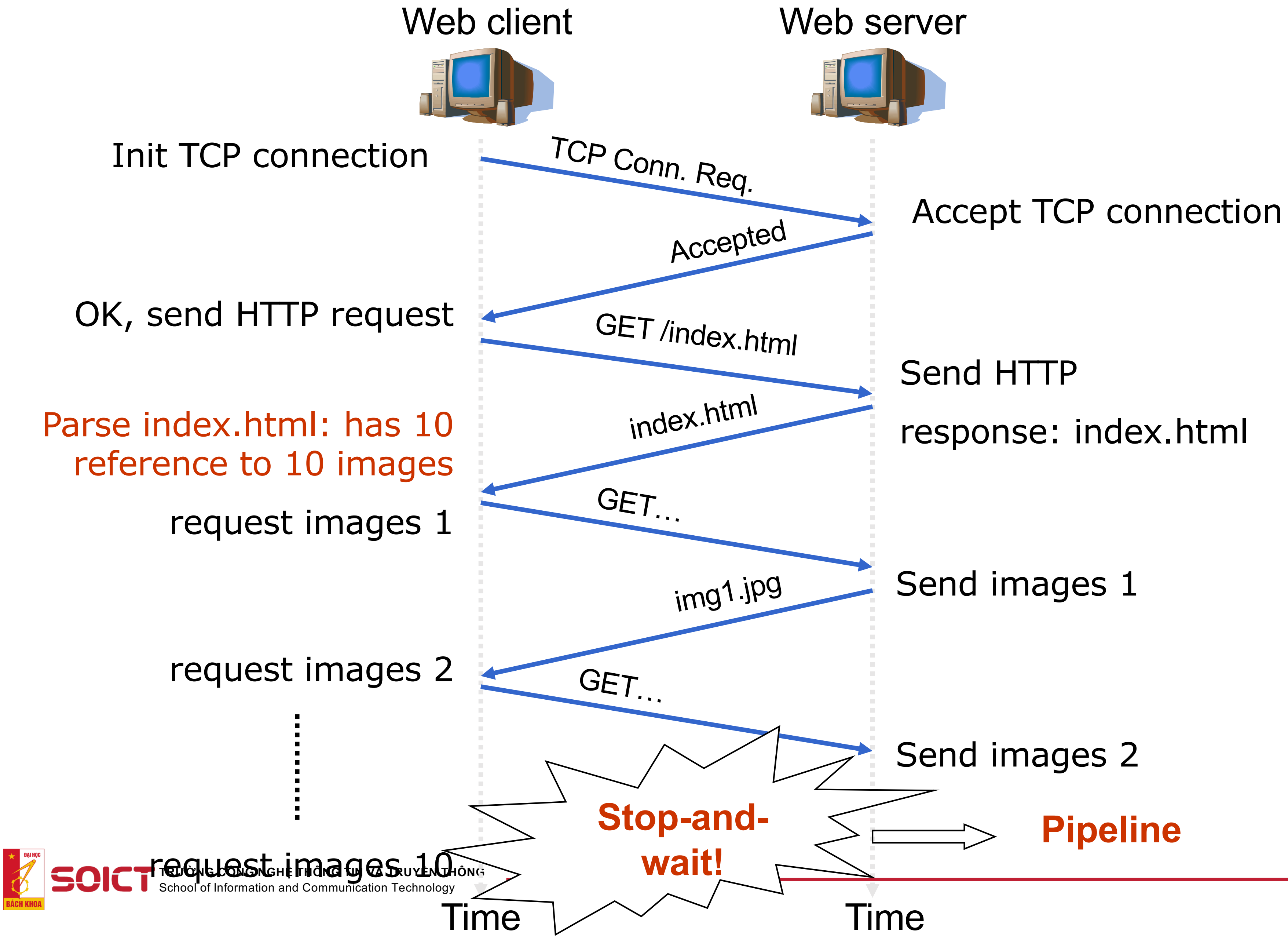
HTTP persistent

- Many web objects can be sent over a connection TCP.
- Option by default in HTTP/1.1
- HTTP 1.1: RFC 2068

Operation of HTTP/1.0



Operation of HTTP/1.1



Web client

Web server

Init TCP connection

TCP Conn. Req.

Accept TCP connection

Accepted

OK, send HTTP request

GET /index.html

Send HTTP

response: index.html

index.html

Parse index.html: has 10 reference to 10 images

request images 1

GET…

Send images 1

img1.jpg

request images 2

GET…

Send images 2

request images 10

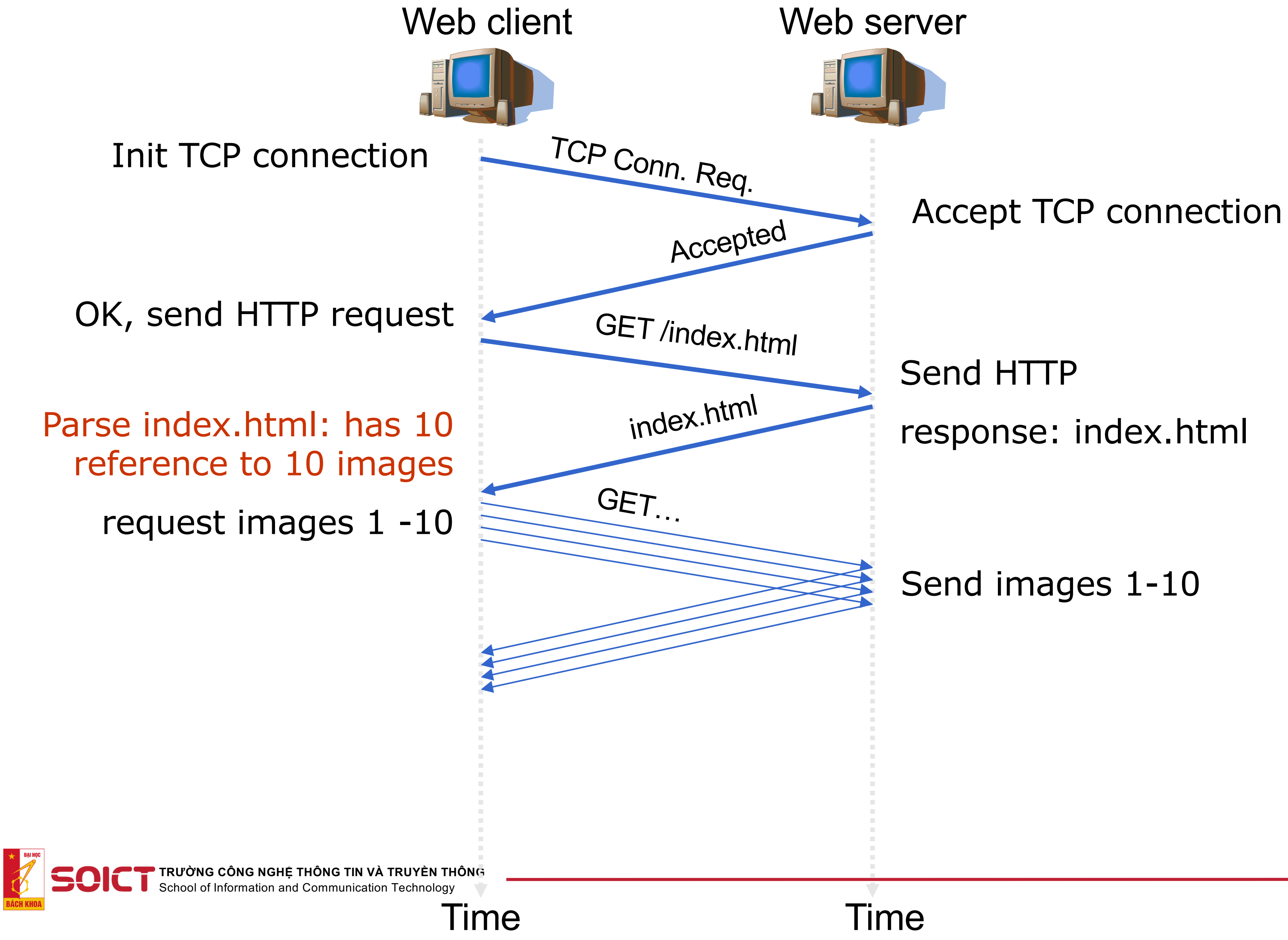
Stop-and-wait!

Pipeline

Time

Time

HTTP/1.1 with pipeline



Methods in HTTP request message

HTTP/1.0

- GET: get an webpage
- POST: submitting a form
- HEAD: ask for the header of an webpage

HTTP/1.1

- GET, POST, HEAD
- PUT
  - Upload an webpage to the server under address given in URI, file content is in the body of the message
- DELETE
  - Delete a file given in the URI

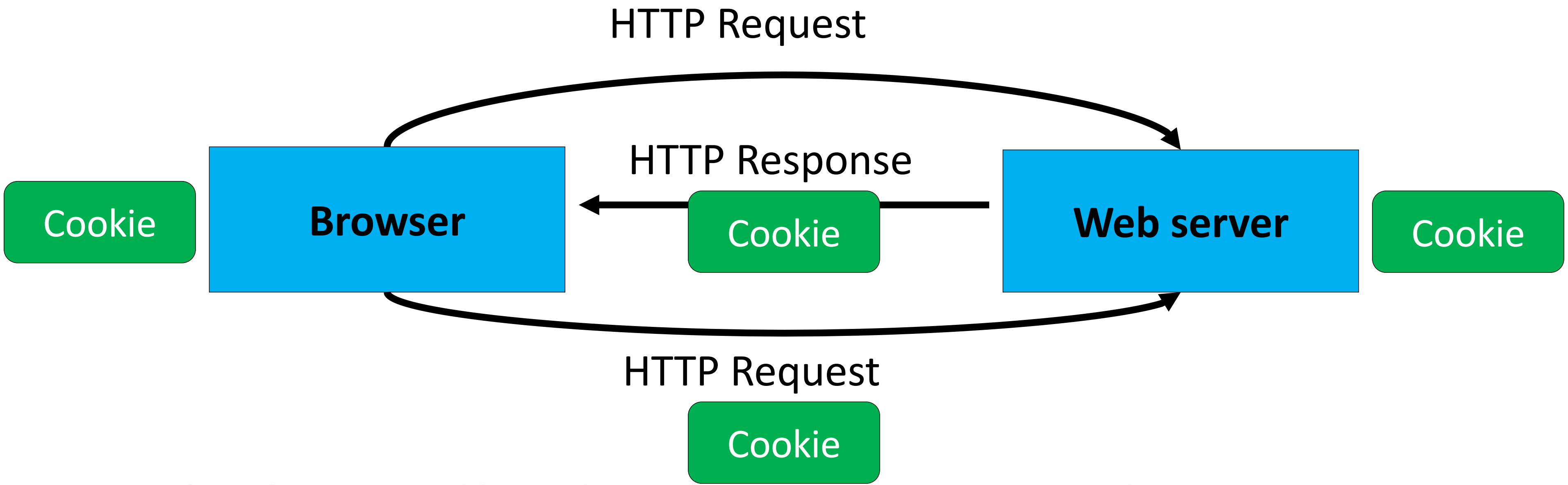
Attention: Even with GET, user can sends parameters to servers in URL. Ex:

http://www.google.com/search?q=computer+network&flags=68&num=10

HTTP is stateless protocol

- In a HTTP session:
  - Browser connects to Web server
  - Browser sends an HTTP Request
  - Web server replies with a HTTP Response
  - …repeat…
  - Browser disconnects
- HTTP Request are processed independantly
- Web server does not remember the state of HTTP request
  - If Web service requires that users must be authenticated, users must login at each HTTP Request ☹

HTTP Cookie

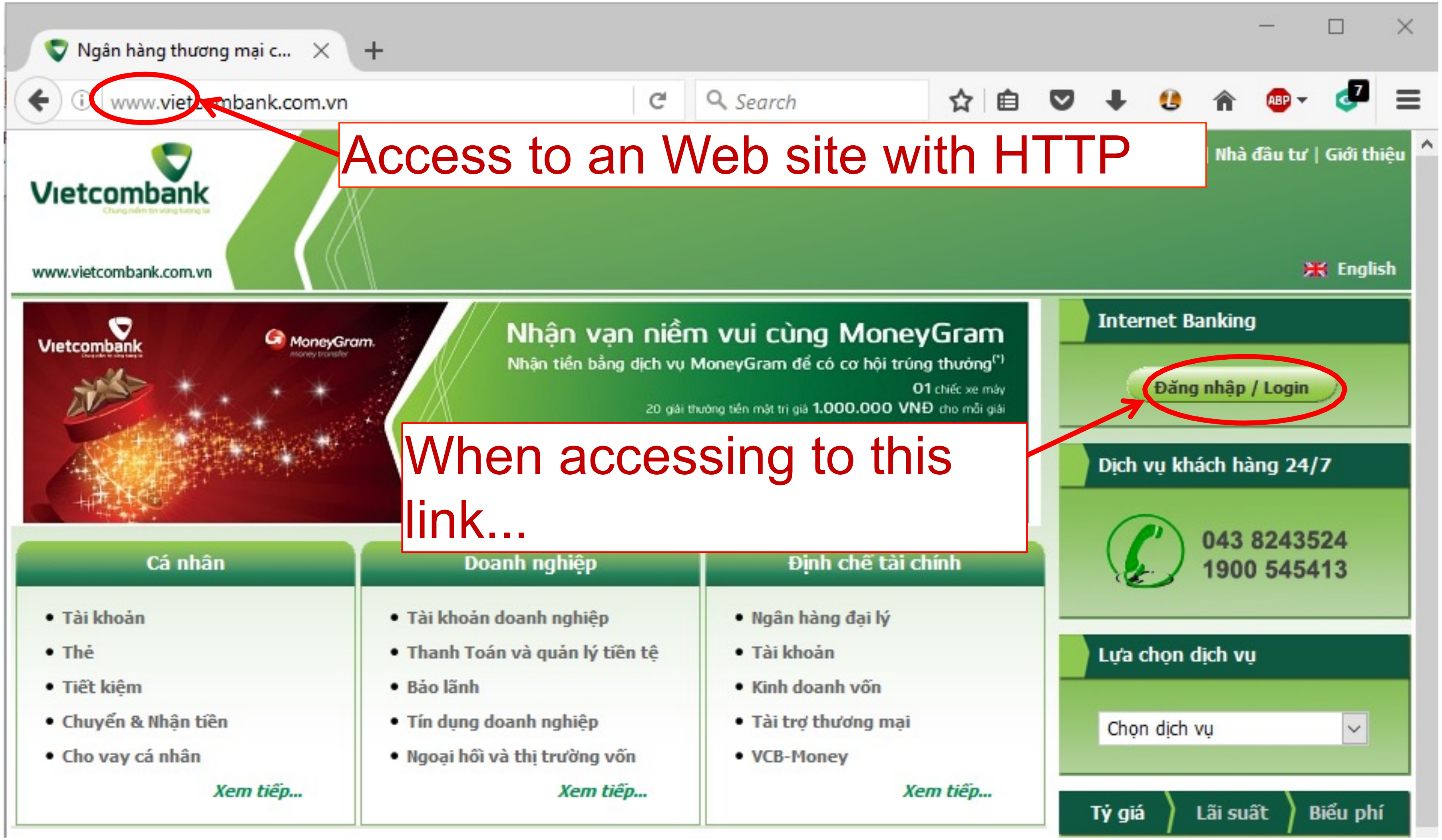


- Cookie: data created by web application, contains state of the communication
  - Server stores cookie (a part or all)
- After processing a request, Web server returns a HTTP Response with cookie attached
  - Set-Cookie: key = value; options;
- Browser saves cookie
- Browser sends next HTTP Requests with cookie to show the current state of the communication

HTTPS

- Limitation of HTTP:
  - Unable to verify the fiability of Web server → thief can fake an webpage to stole users' information.
    - Ex: fake an webpage of a bank and put it in a similar address.
      - Real webpage is: www.bidv.com.vn, Fake webpage may be at bidv.vn
  - Unable to avoid eavesdropping attack→ thief can stole sensible information by analysing eavesdropped HTTP messages
- Secure HTTP: use SSL/TLS instead of TCP to carry HTTP message
  - Authentication:
    - Website can prove its identify by providing Website certificate that was signed by a trusted party.
  - Encryption:
    - HTTP message are encrypted before transmission and decrypted at the receiver side → Thief can not read (understand) the HTTP message content.
- Service port: 443 (instead of 80)

HTTP on Web browser



Ngân hàng thương mại c...

www.vietcombank.com.vn

Search

Nhà đầu tư | Giới thiệu

Vietcombank

www.vietcombank.com.vn

English

Nhận vạn niềm vui cùng MoneyGram

Nhận tiền bằng dịch vụ MoneyGram để có cơ hội trúng thưởng(*)

01 chiếc xe máy

20 giải thưởng tiền mặt trị giá 1.000.000 VNĐ cho mỗi giải

Internet Banking

Đăng nhập / Login

Dịch vụ khách hàng 24/7

043 8243524
1900 545413

Cá nhân

- Tài khoản
- Thẻ
- Tiết kiệm
- Chuyển & Nhận tiền
- Cho vay cá nhân

Xem tiếp...

Doanh nghiệp

- Tài khoản doanh nghiệp
- Thanh Toán và quản lý tiền tệ
- Bảo lãnh
- Tín dụng doanh nghiệp
- Ngoại hối và thị trường vốn

Xem tiếp...

Định chế tài chính

- Ngân hàng đại lý
- Tài khoản
- Kinh doanh vốn
- Tài trợ thương mại
- VCB-Money

Xem tiếp...

Lựa chọn dịch vụ

Chọn dịch vụ

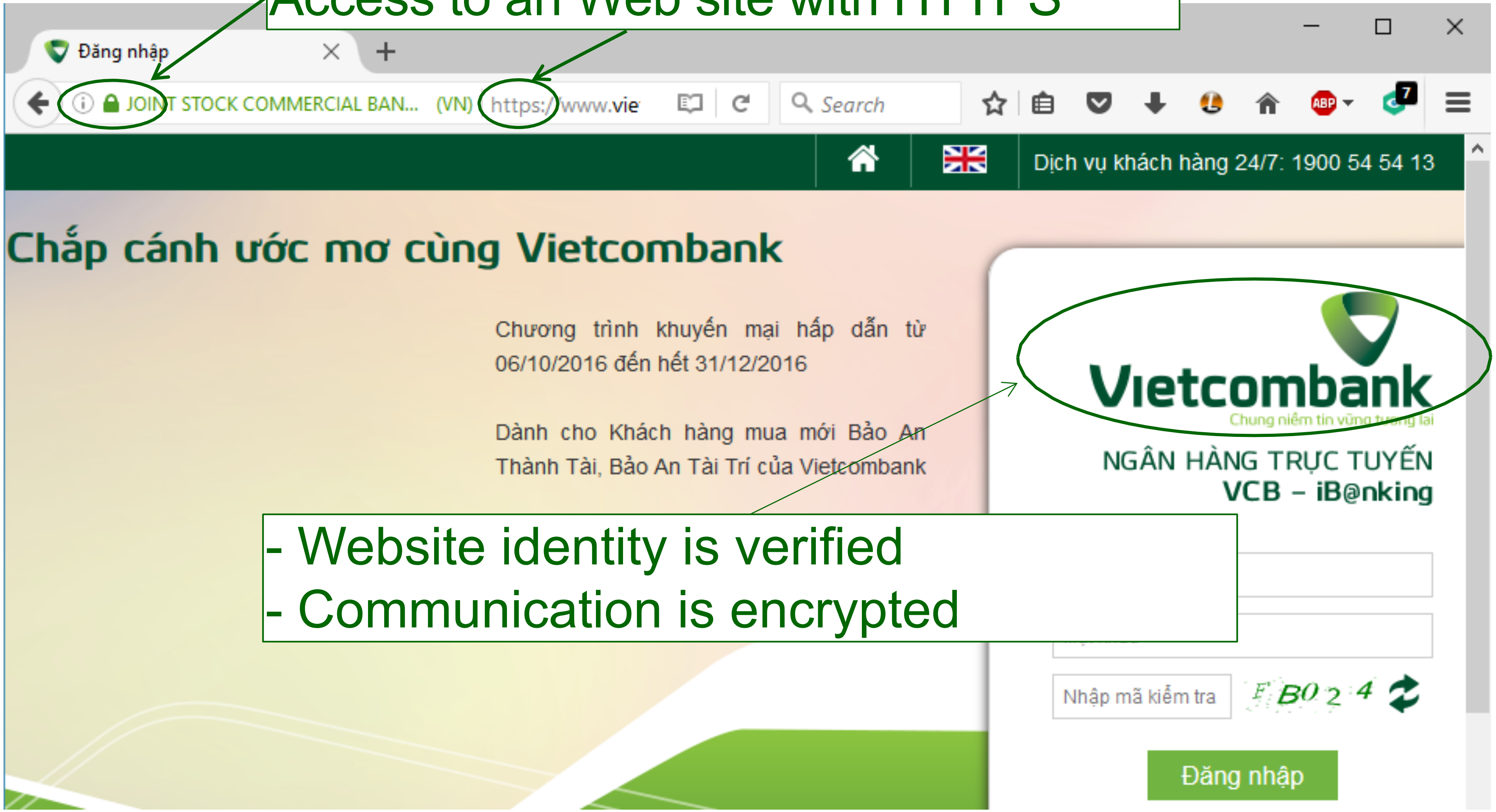
Tỷ giá | Lãi suất | Biểu phí

Access to an Web site with HTTP

When accessing to this link...

HTTPS on Web browser

Access to an Web site with HTTPS



Dịch vụ khách hàng 24/7: 1900 54 54 13

Chắp cánh ước mơ cùng Vietcombank

Chương trình khuyến mại hấp dẫn từ 06/10/2016 đến hết 31/12/2016

Dành cho Khách hàng mua mới Bảo An Thành Tài, Bảo An Tài Trí của Vietcombank

Vietcombank

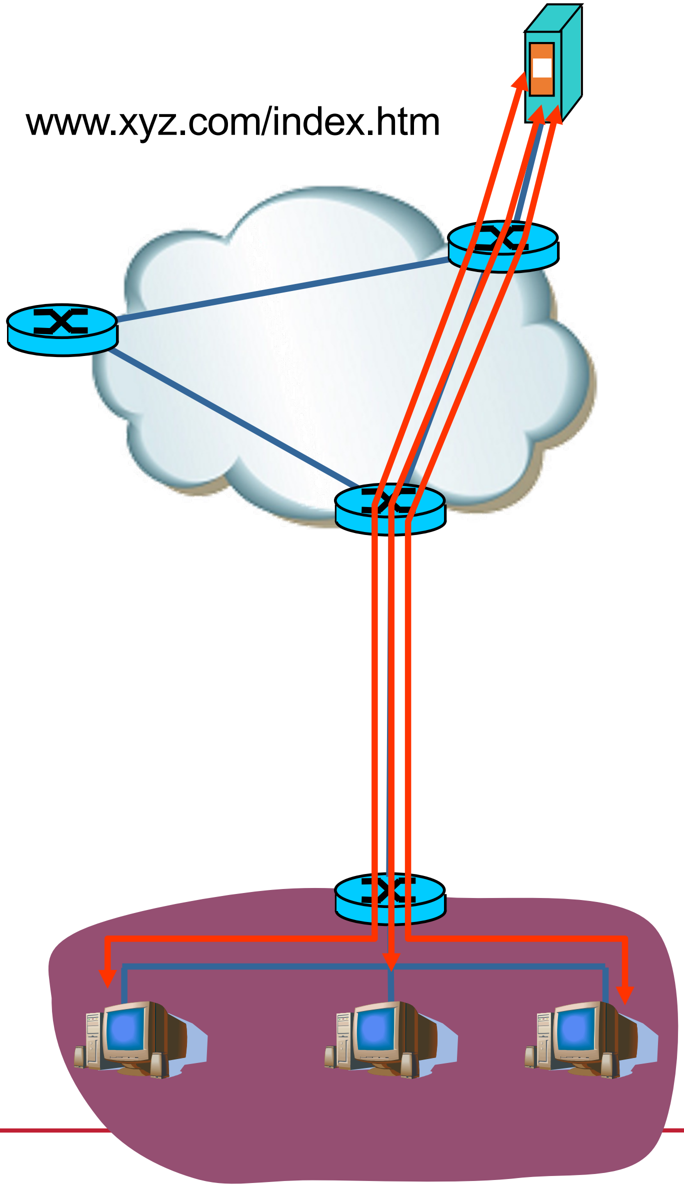
Chung niềm tin vững tương lai

NGÂN HÀNG TRỰC TUYẾN
VCB – iB@nking

- Website identity is verified
- Communication is encrypted

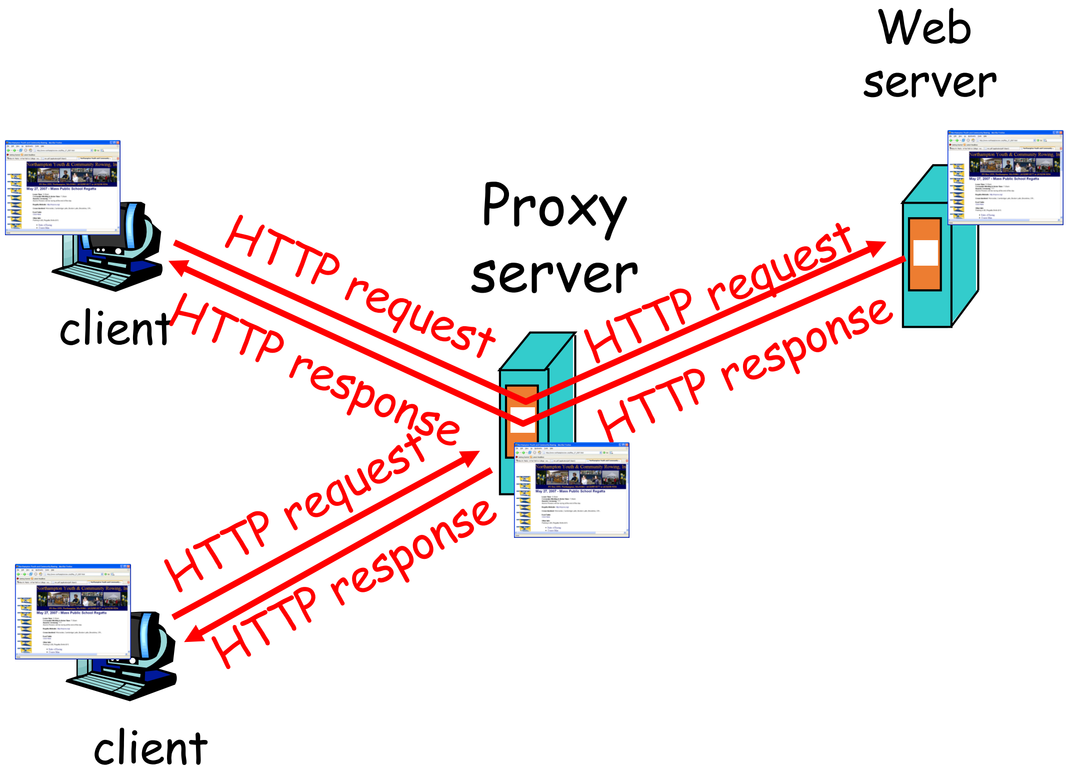
Web cache

- “Cache”: buffer memory
- Similar notion of computer cache
    - L1 cache, L2 cache
    - “cache miss”, “cache hit”
- Case study:
    - An organization has uniquely an Internet line.
    - Multiple users can access to the same webpages, ex: news pages
    - Solution for improving the performance?



Web cache - proxy

- Users connects to web server through a web proxy.
- Web browsers send a request to a web page to the proxy
  - Miss: The required web page is not found Proxy gửi yêu cầu tới máy chủ web, trả lời trình duyệt và lưu đệm đối tượng web
  - Hit: Proxy trả đối tượng web cho trình duyệt



Web caches

- Proxy: Vừa là client, vừa là server
- Sử dụng bởi các ISP nhỏ, các tổ chức như trường học, công ty…
- Ảnh hưởng của proxy
  - Làm giảm lưu lượng web trên đường ra Internet
  - Có thể làm giảm thời gian đáp ứng
  - Thử phân tích vài trường hợp
    - cache hit
    - cache miss
    - proxy bị quá tải
    - Trang web thay đổi/trang web động?

Local cache

- Web pages could be stored in local server (local cache)
- Using local cache for
  - Reading web offline
  - Improve performance in accessing web pages

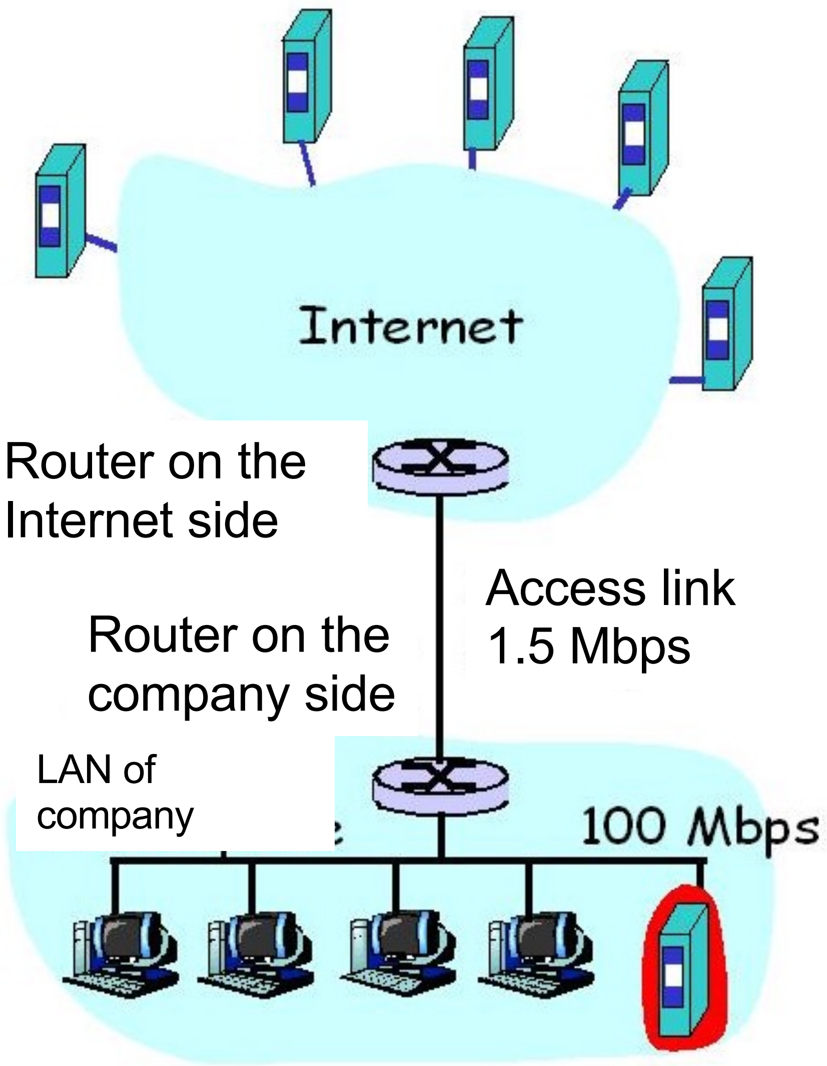
Exercise

- A company having an Internet connection from their LAN with data rate 1.5 Mbps.
- Webpage to be downloaded from the Internet has the average size 900 kbits
- The frequency of accessing files on the web is =1,5 times/s.
- Duration for sending an HTTP request from company router to the Internet is 2 (s)
- What is the average responding time in following cases?

Exercise (cont.)

- If all the links have already some load. Transmission time on a loaded link is calculated by the following formular:
  - $= W_m /(1 - \rho)$,
    - W_m: Transmission time without load
    - ρ: load (ratio of traffic/capacity)
- If there is a cache
  - Assume that ccache hit rate: p=0.4.
  - Hint:
    - Use the formular: $T_m = \Sigma\, p_i{}^*T_i$,
    - p_i probability having responding time T_i

Servers



Router on the Internet side

Access link 1.5 Mbps

Router on the company side

LAN of company

Cache of the company

Case study 2: Email

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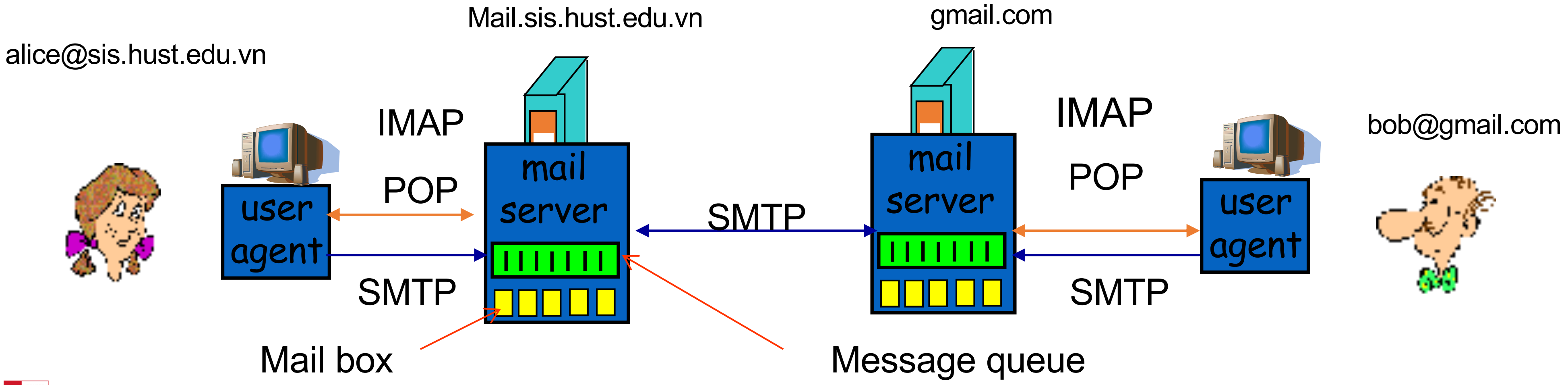
EMAIL

- MUA (Mail User Agent)
  - Get email from server and send email to server
  - e.g. Outlook, Thunderbird…
- MTA (Mail Transfer Agent): :
  - Contains users' mail boxes
  - Contains queue of emails to be sent out
  - e.g. Sendmail, MS Exchange…

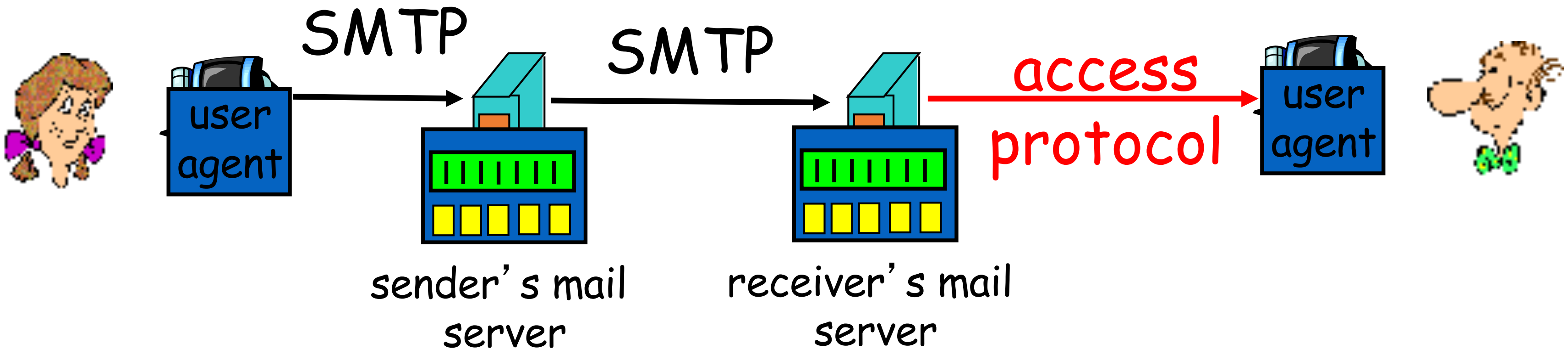
- Communication protocols:
  - Send email: SMTP-Simple Mail Transfer Protocol
  - Receiving email:
    - POP – Post Office Protocol
    - IMAP – Internet Mail Access Protocol



SMTP

- Described in RFC 2821
- Use TCP, port 25: Deliver emails from client to server and between servers
- Interaction in request/response style
    - Request: commands in ASCII
    - Response: response code + data

Protocol for retrieving email



- POP: Post Office Protocol [RFC 1939]
  - Authentication and retrieving emails
- IMAP: Internet Mail Access Protocol [RFC 1730]
  - More complex than POP
  - Emails are processed and stored in server
  - Quota?

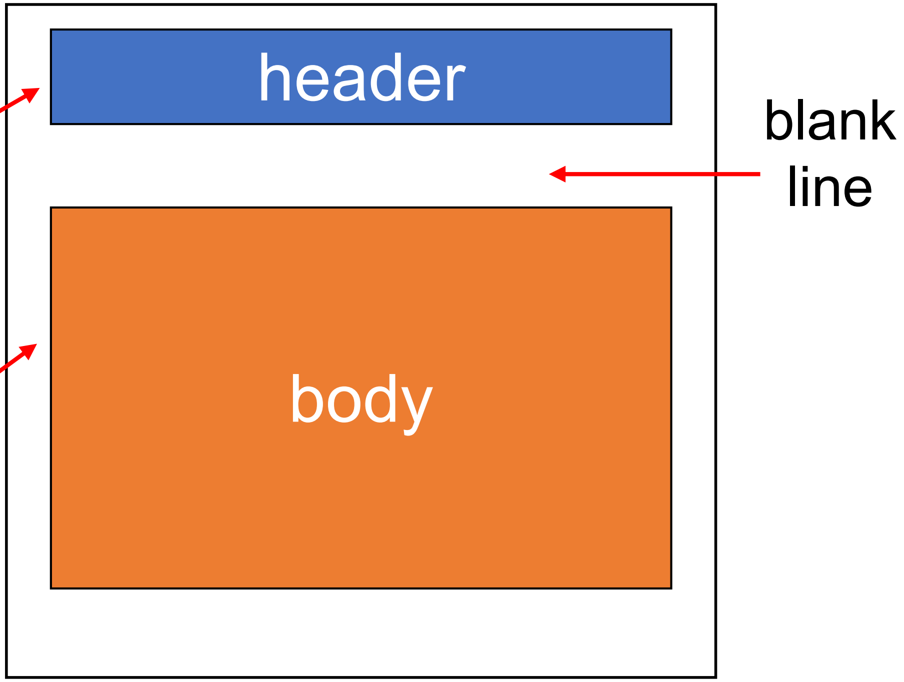
Web Mail

- Very popular nowadays
- Using Web browser as a MUA
- MUA and MTA communicate using HTTP
- Mails are stored in server
- E.g.
  - Gmail,
  - Hotmail,
  - Yahoo! Mail, etc.
  - http://mail.hust.edu.vn

Format of email message

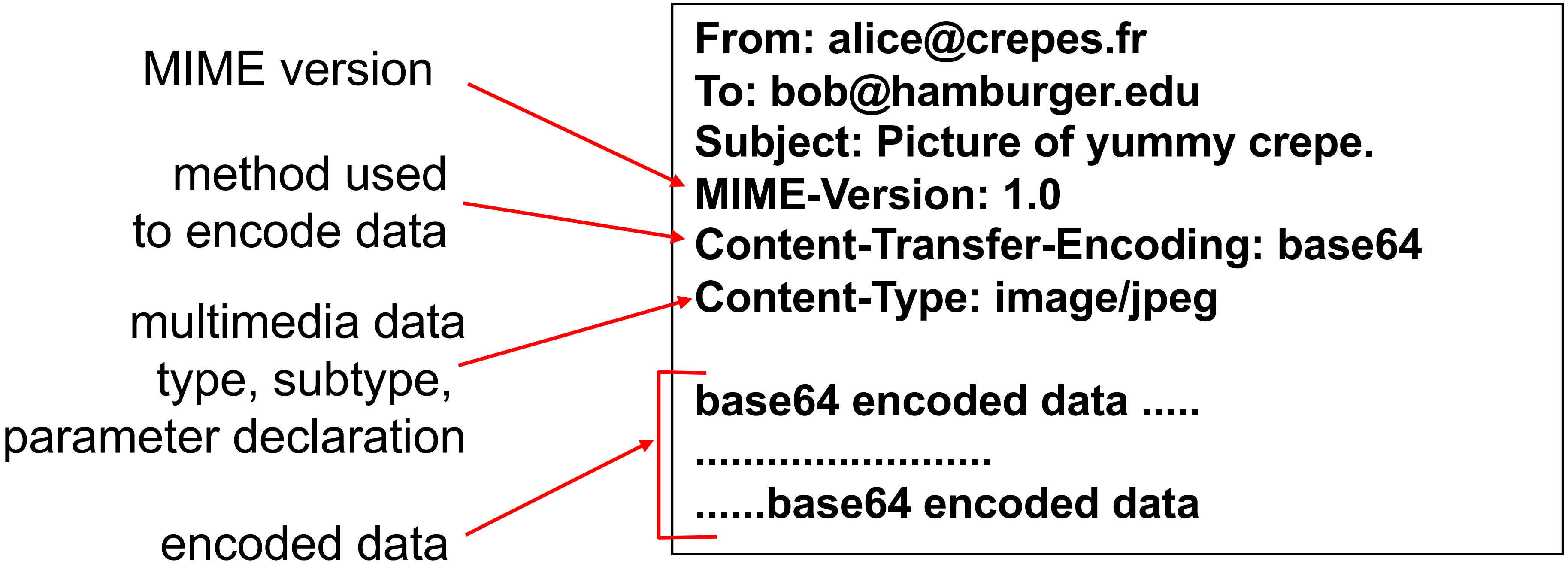
RFC 822 define the email message format that can be delivered with SMTP

- Header
  - To:
  - From:
  - Subject:
- Body
  - Content using ASCII characters



To transfer multimedia data: multimedia extensions

- MIME: multimedia mail extension, RFC 2045, 2056
- Information lines are added in the header to specify the format of sent data



MIME version

method used to encode data

multimedia data type, subtype, parameter declaration

encoded data

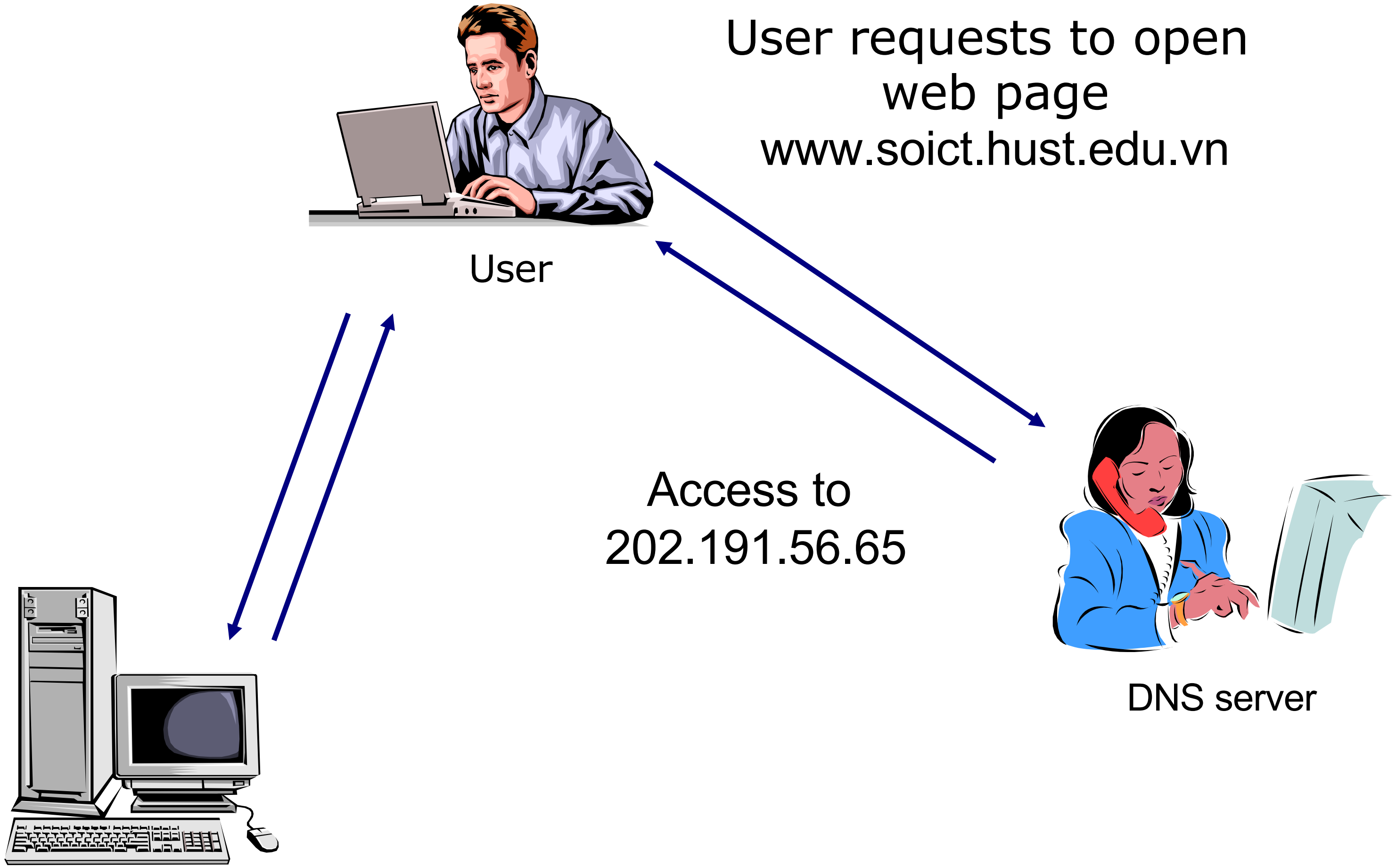
```
From: alice@crepes.fr
To: bob@hamburger.edu
Subject: Picture of yummy crepe.
MIME-Version: 1.0
Content-Transfer-Encoding: base64
Content-Type: image/jpeg

base64 encoded data .....
.........................
......base64 encoded data
```

Domain name service

Overview

- Domain name: ID of network nodes used in application layer
  - Domain names are managed centrally
  - International domain name is managed by ICANN, who delegate subdomains to other organization
    - Việt Nam: VNNIC
- DNS (Domain Name System): includes a system of domain name servers that manages domain names and provide domain name resolution service
- Necessity of resolving domain names to IP addresses
  - Human uses domain names to access services. Ex: accessing webpage by domain name, www.soict.hust.edu.vn.
  - Computers and network devices (router) perform their functionalities based on IP addresses
- How to convert domain names to IP addresses?

Converting domain name to IP address example



User requests to open web page www.soict.hust.edu.vn

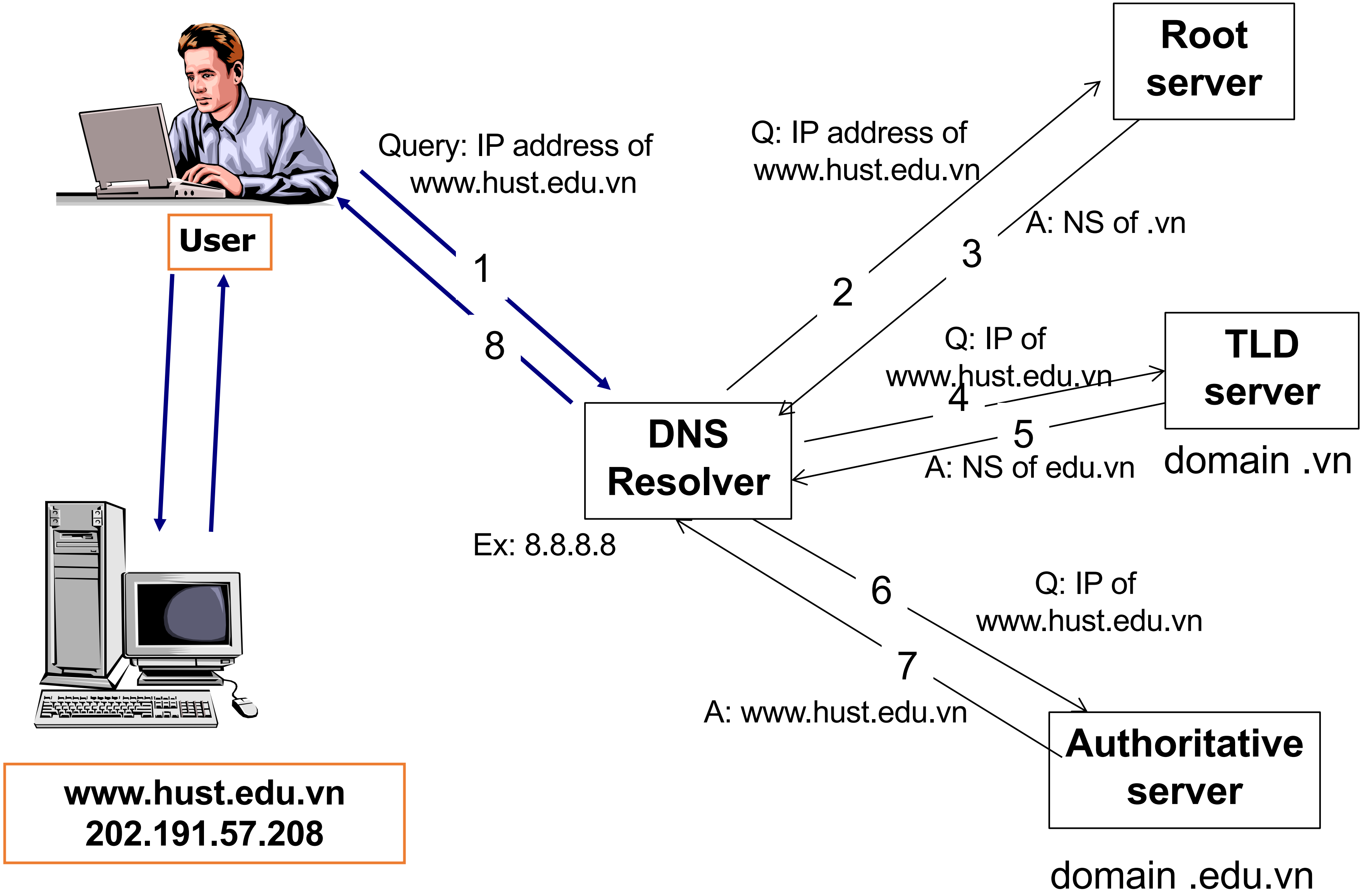
User

Access to 202.191.56.65

DNS server

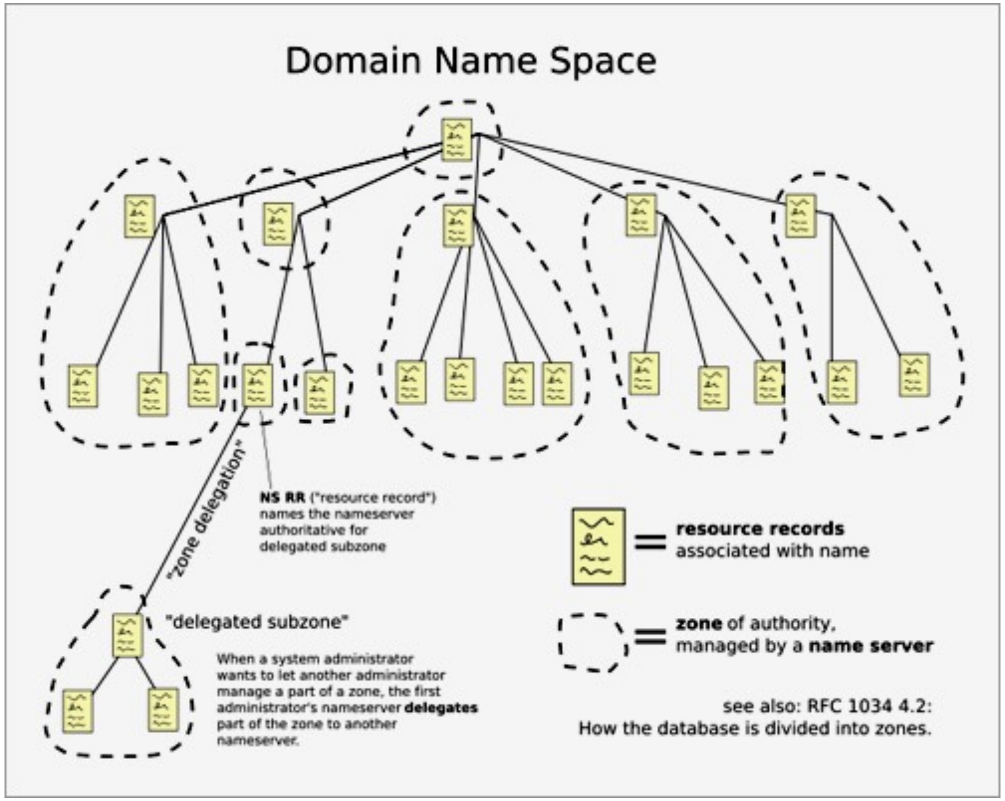
Web server
202.191.56.65

Domain Name resolution process



Domain name space

- Hierarchical architecture
  - Root: top node
  - Space bellow top are divided into zones
- Each node in the tree has records that describe the domain name corresponding to that node. For example:
  - SOA: Record describing a zone.
  - NS: Delegate a zone to a server
  - A: Record containing the mapping of a name to an IP address.


Domain Name Space
"zone delegation"
NS RR ("resource record") names the nameserver authoritative for delegated subzone
"delegated subzone"
When a system administrator wants to let another administrator manage a part of a zone, the first administrator's nameserver delegates part of the zone to another nameserver.
= resource records associated with name
= zone of authority, managed by a name server
see also: RFC 1034 4.2: How the database is divided into zones.

Hình ảnh từ: Wikipedia

Domain name service

- **Root server**:
  - Manage the list of TLD nameserver based on the extension of that domain (.com, .net, .org, etc.)
  - The root nameservers are overseen by a nonprofit called the Internet Corporation for Assigned Names and Numbers (ICANN).
  - There are 13 root server but there are mutiple copies of each one all over the world

Domain name service

- **Top Level Domain (TLD) nameserver**
  - maintains information for all the domain names that share a common domain extension
    - Generic top-level domains: .com, .org, .net, .edu, and .gov.
    - Country code top-level domains: .vn, .uk, .fr, .jp …
    - If a user searches for google.com, after receiving a response from a root nameserver, the recursive resolver then sends a query to a .com TLD nameserver.
- Management of TLD nameservers is handled by IANA, a branch of ICANN

Dmain name service

- **Authoritative domain name server**
  - Final holder of the DNS records
  - Possible records:
    - A: address, AAAA: IPv6 address
    - NS: name server
    - MX: mail exchange
    - CNAME: alias
    - PTR: address to name
    - SRV: generic service (used for SIP)
    - SOA: start of authority (gives various info. about zone)
    - TXT: text

Domain name resolution

- Domain name service works in client/server model
  - Work at application layer using DNS protocol
  - Use UDP/TCP as transport layer with port 53
  - Two resolution modes:
    - Recursive Query
    - Interactive Query

DNS message

- DNS Query and DNS Reply uses common format
- Identification: ID of the request
  - ID of the DNS reply message should fit with the ID of the corresponding DNS query message
- Flags: control fields
- #Question: number of requested domain names
- QUESTION: list of requested domain names

Identification	**Flags**
#Question	**#Answer RRs**
#Authority RRs	**#Additional RRs**
QUESTION	
ANSWER	
AUTHORITY	
ADDITIONAL	

DNS message

- #Answer RRs: number of answer records
- ANSWER: answer records
- # Authority RRs: the number of records received from authority servers
- AUTHORITY: Records received from authority servers
- #Additional RRs: Number of additional records
- ADDITIONAL: additional records

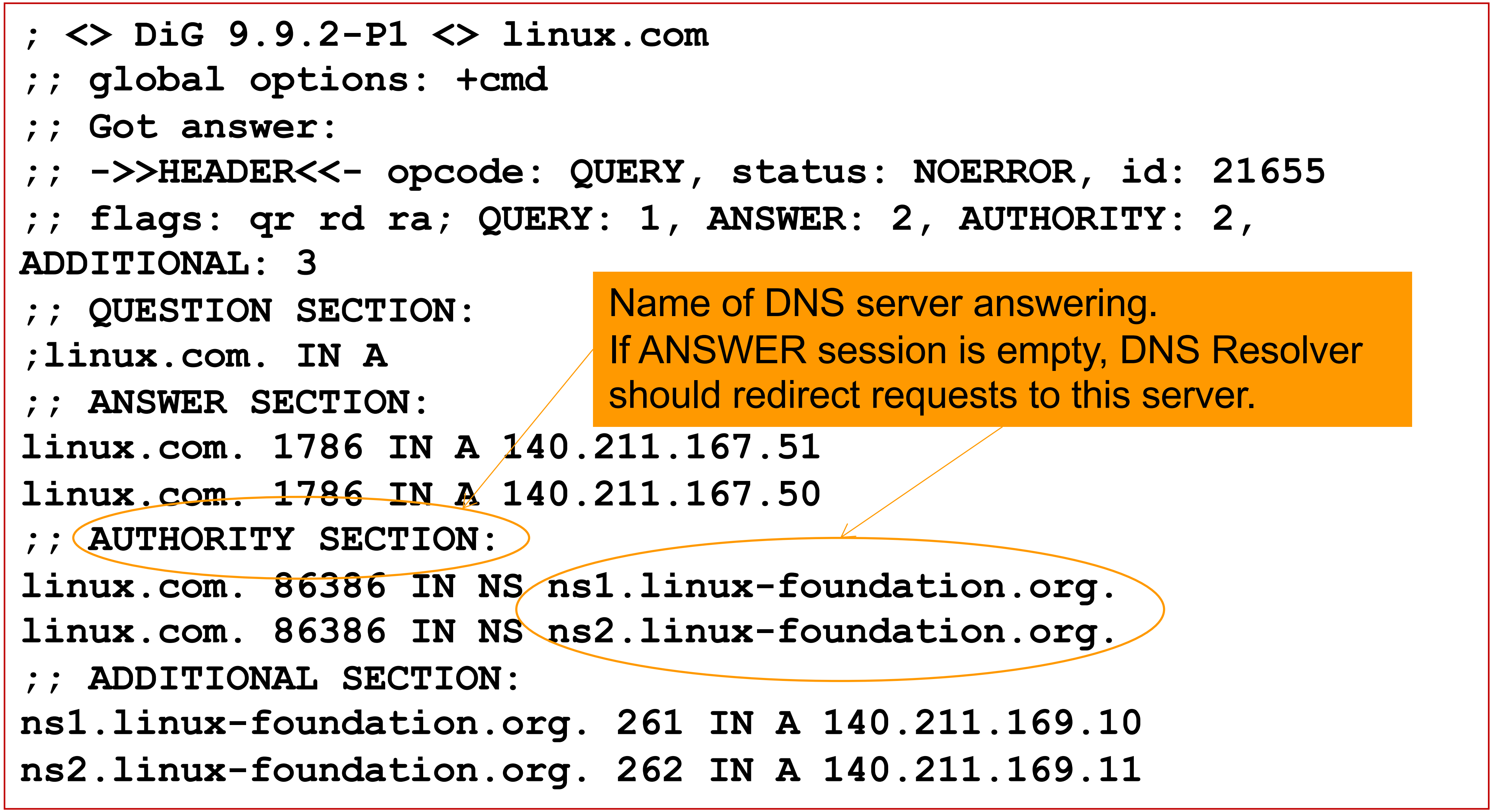
Identification	**Flags**
#Question	**#Answer RRs**
#Authority RRs	**#Additional RRs**
QUESTION	
ANSWER	
AUTHORITY	
ADDITIONAL	

Ex: dig linux.com

```
; <> DiG 9.9.2-P1 <> linux.com
;; global options: +cmd
;; Got answer:
;; ->>HEADER<<- opcode: QUERY, status: NOERROR, id: 21655
;; flags: qr rd ra; QUERY: 1, ANSWER: 2, AUTHORITY: 2,
ADDITIONAL: 3
;; QUESTION SECTION:
;linux.com. IN A
;; ANSWER SECTION:
linux.com. 1786 IN A 140.211.167.51
linux.com. 1786 IN A 140.211.167.50
;; AUTHORITY SECTION:
linux.com. 86386 IN NS ns1.linux-foundation.org.
linux.com. 86386 IN NS ns2.linux-foundation.org.
;; ADDITIONAL SECTION:
ns1.linux-foundation.org. 261 IN A 140.211.169.10
ns2.linux-foundation.org. 262 IN A 140.211.169.11
```

TTL: time to live of the information in cache

Ex: dig linux.com DNS



```
; <> DiG 9.9.2-P1 <> linux.com
;; global options: +cmd
;; Got answer:
;; ->>HEADER<<- opcode: QUERY, status: NOERROR, id: 21655
;; flags: qr rd ra; QUERY: 1, ANSWER: 2, AUTHORITY: 2,
ADDITIONAL: 3
;; QUESTION SECTION:
;linux.com. IN A
;; ANSWER SECTION:
linux.com. 1786 IN A 140.211.167.51
linux.com. 1786 IN A 140.211.167.50
;; AUTHORITY SECTION:
linux.com. 86386 IN NS ns1.linux-foundation.org.
linux.com. 86386 IN NS ns2.linux-foundation.org.
;; ADDITIONAL SECTION:
ns1.linux-foundation.org. 261 IN A 140.211.169.10
ns2.linux-foundation.org. 262 IN A 140.211.169.11
```

Name of DNS server answering.
If ANSWER session is empty, DNS Resolver should redirect requests to this server.

Ví dụ: dig linux.com

```
; <> DiG 9.9.2-P1 <> linux.com
;; global options: +cmd
;; Got answer:
;; ->>HEADER<<- opcode: QUERY, status: NOERROR, id: 21655
;; flags: qr rd ra; QUERY: 1, ANSWER: 2, AUTHORITY: 2,
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;; QUESTION SECTION:
;linux.com. IN A
;; ANSWER SECTION:
linux.com. 1786 IN A 140.211.167.51
linux.com. 1786 IN A 140.211.167.50
;; AUTHORITY SECTION:
linux.com. 86386 IN NS ns1.linux-foundation.org.
linux.com. 86386 IN NS ns2.linux-foundation.org.
;; ADDITIONAL SECTION:
ns1.linux-foundation.org. 261 IN A 140.211.169.10
ns2.linux-foundation.org. 262 IN A 140.211.169.11
```
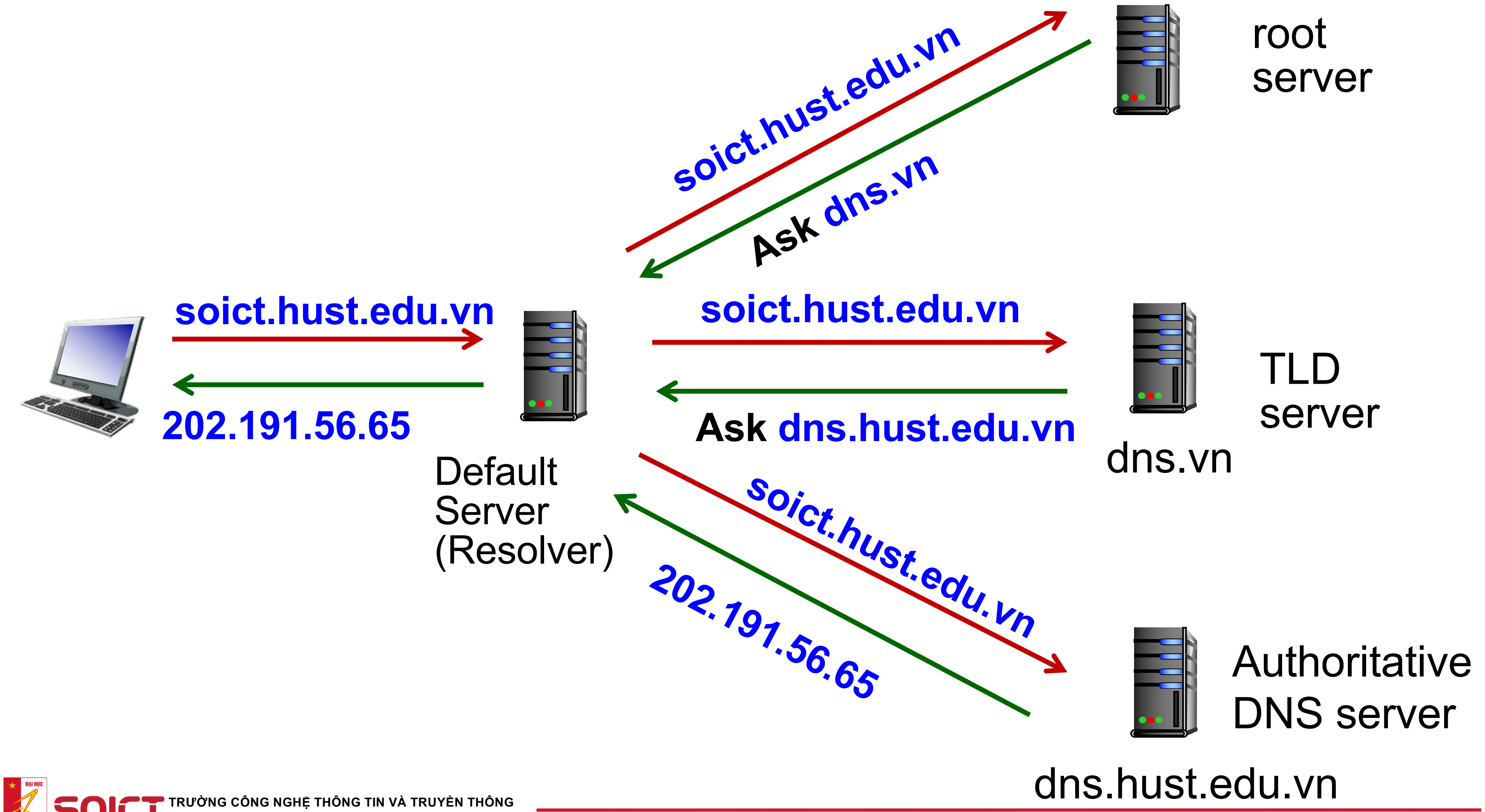

IP address of the server answering the request.
This information will be saved to cache

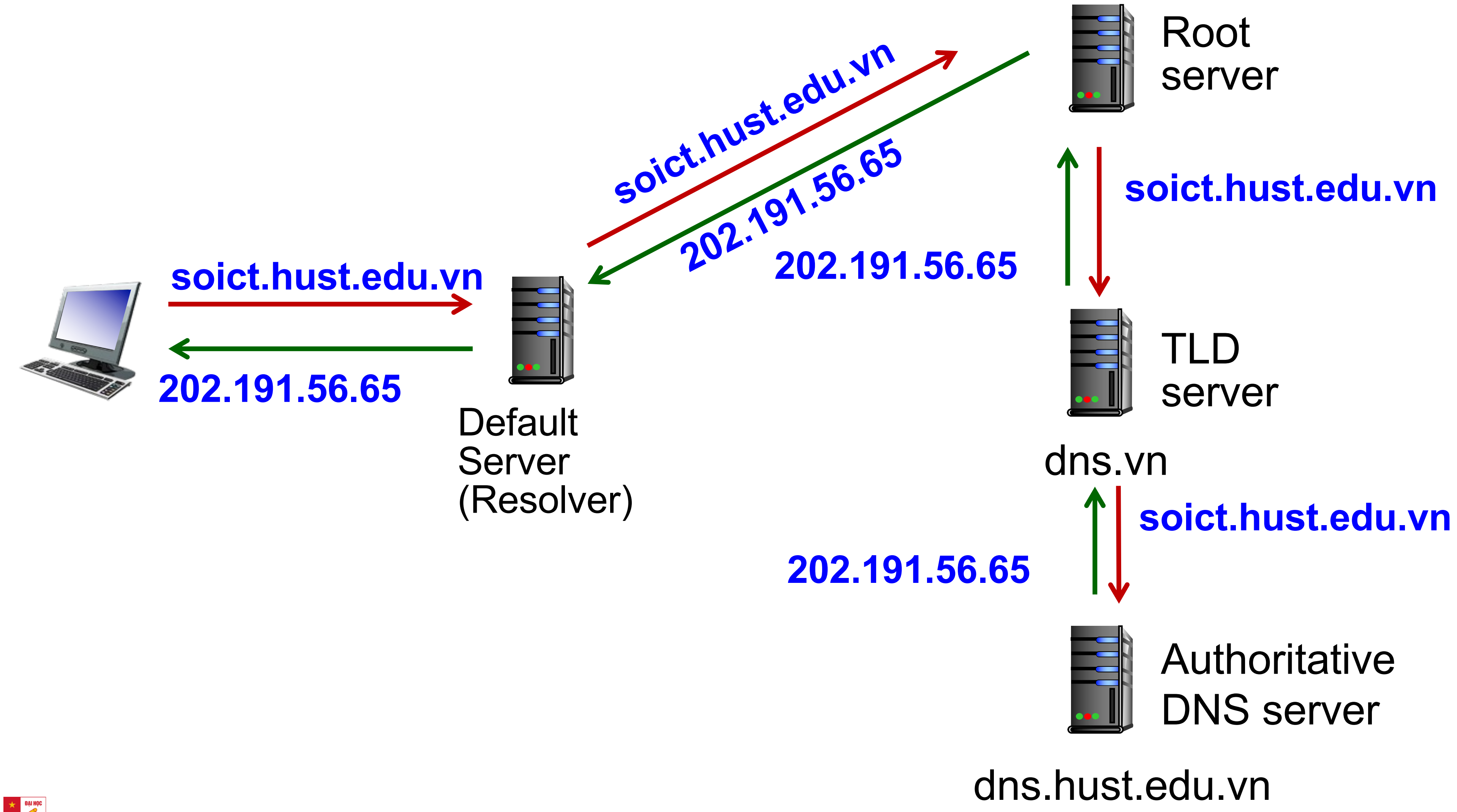
Interactive resolution

- Default mechanisms in DNS systems



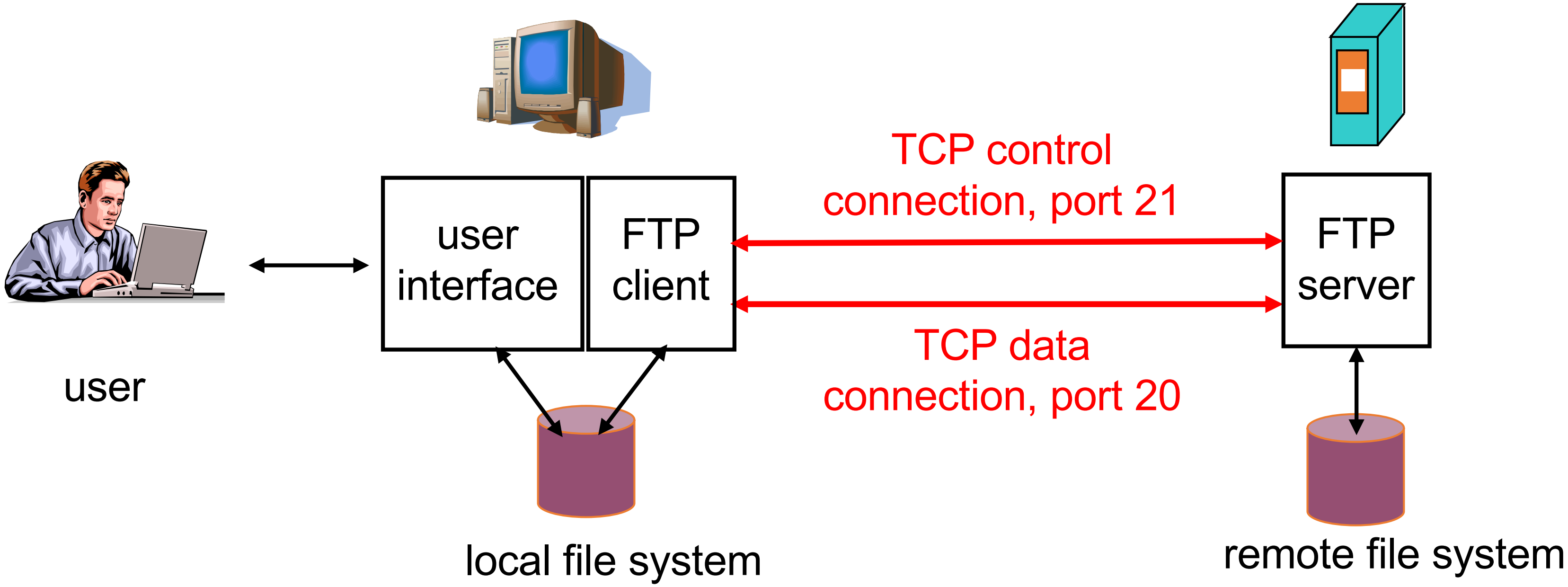
Recursive mechanism

- Optional extension



File transfer application

FTP: File Transfer Protocol



- Client-server model
- Objective: transferring files between machines
- RFC 959
- Use TCP, ports 20, 21

- Out-of-band control mechanism:
  - Port 21 is dedicated for FTP commands communication
  - Port 20 is dedicated for data communication
- User authentication before file transferring

FTP commands and answer codes

Ex of commands

- **USER *username***
- **PASS *password***
- **LIST** : request listing files
- **RETR filename** download a file from server
- **STOR filename** upload a file from server

Ex of answer codes

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

Example of an ftp client

Command line

```
C:\Documents and Settings\hongson>ftp
ftp> ?
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
```

GUI FTP clients: IE, Firefox, GFTP, File zilla

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