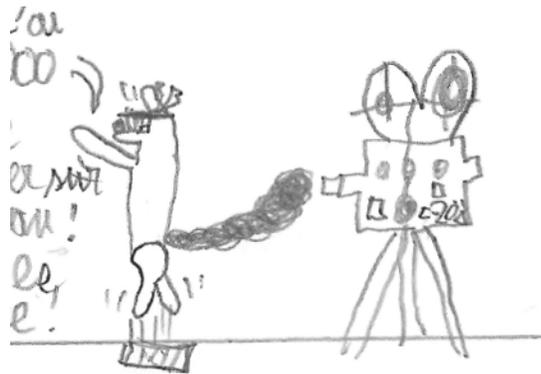




ÉCOLE POLYTECHNIQUE
FÉDÉRALE DE LAUSANNE

Application Layer

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Fall 2009

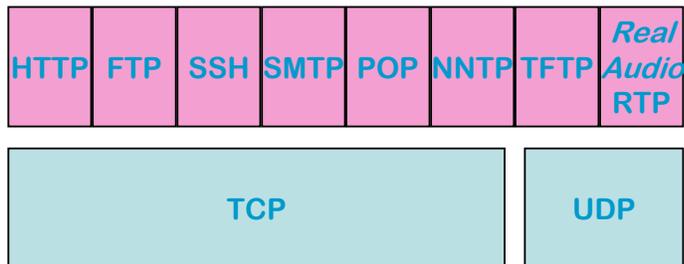


About This Module

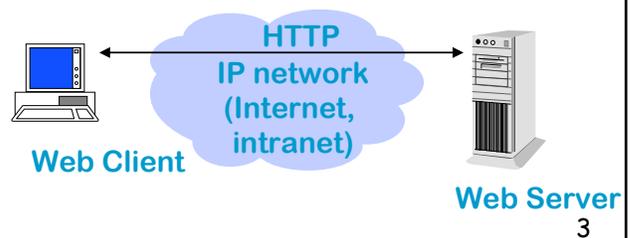
- The application layer of TCP/IP consists of the distributed applications themselves – it is the topic of the courses on information systems and distributed systems
- In this module, we focus on the relationship between the application layer and the lower layers.
- We review
 1. Examples of application layers
 2. The “End-to-end Principle” and Application Layer Gateways

1. Examples of Application Layer: DNS; Web; Email

- Application **programs** (ex. netscape) use a set of well defined application layer **protocols** (ex. HTTP) and **formats** (ex: HTML)
- A given Application Layer protocol uses TCP or UDP

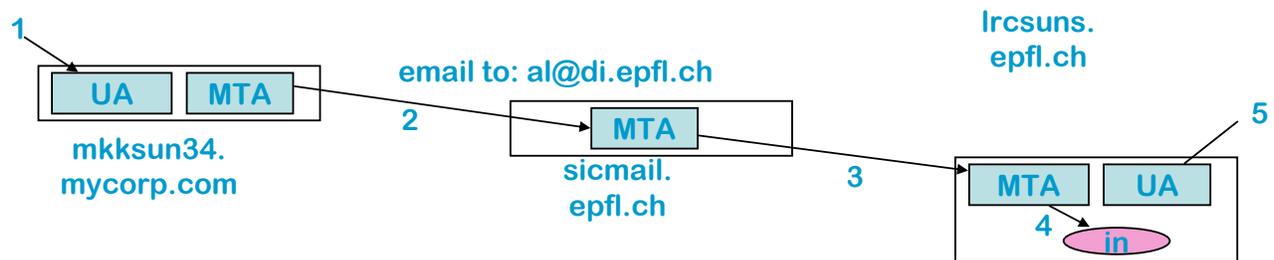


- Application layer runs on hosts
 - ▶ does not involve routers



Example: Email

- email address: identifier human user
 - ▶ format: user@domainName
 - ▶ domainName is a name according to DNS



1. user creates mail with UA; UA triggers MTA to send it
2. MTA sends to destination or mail exchanger, using SMTP (simple mail transport protocol). SMTP uses TCP
3. mail exchanger sends to destination MTA using SMTP
4. destination MTA delivers to user mailbox
5. user reads mailbox with UA

SMTP Session Example

- use telnet <destMachine> <serverPort> to communicate manually with a server

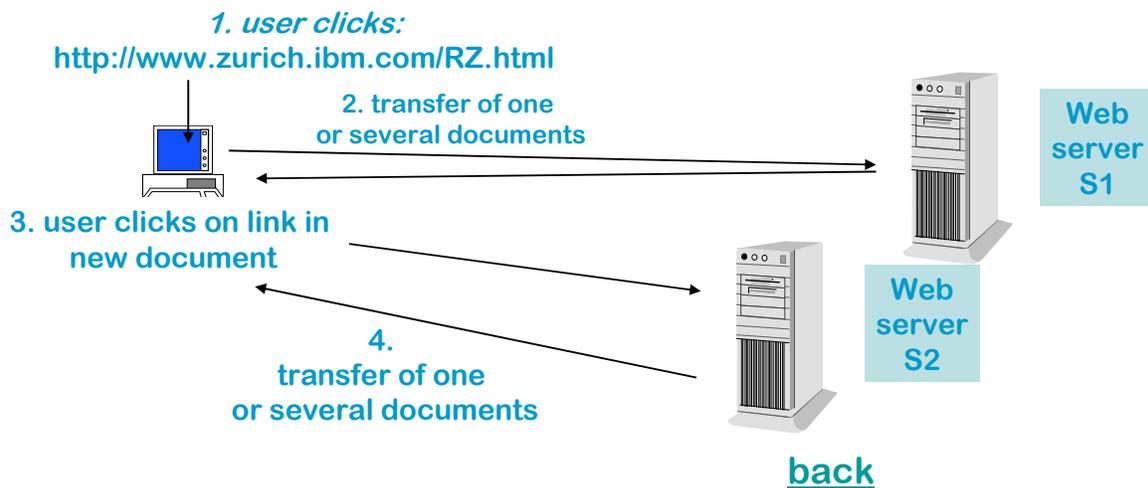
- example

```
lrcsuns:/export/home1/leboudec$ telnet localhost 25
Trying 127.0.0.1 ...
Connected to localhost.
Escape character is '^]'.
220-lrcsuns.epfl.ch Sendmail/LRC ready at Mon, 23 Jun 1997 16:47:26 +0200
220 ESMTMP spoken here
HELO lrcmac45.epfl.ch
250 lrcsuns.epfl.ch Hello localhost [127.0.0.1], pleased to meet you
MAIL FROM: leConcombreMasque
250 leConcombreMasque... Sender ok
RCPT TO: leboudec@di.epfl.ch
250 leboudec@di.epfl.ch... Recipient ok
DATA
354 Enter mail, end with "." on a line by itself
ceci est un essaiiii
.
250 QAA15185 Message accepted for delivery
QUIT
221 lrcsuns.epfl.ch closing connection
Connection closed by foreign host.
```

Example: World Wide Web (WWW)

■ three components

- ▶ file transfer protocol: HTTP (hyper text transfer protocol); uses TCP
- ▶ format for documents with links (“hyperdocuments”): HTML (hyper text markup language)
- ▶ URLs (universal resource locators)



URLs

- identify documents to be transferred and application layer protocol to use



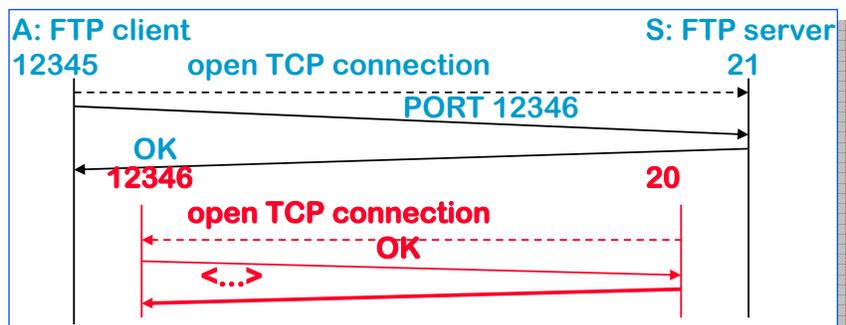
- examples

- ▶ `ftp://lrcftp.epfl.ch/meinix.ps.gz`
- ▶ `http://lrscsun.epfl.ch:12345`
- ▶ `news://comp.infosystems.www`

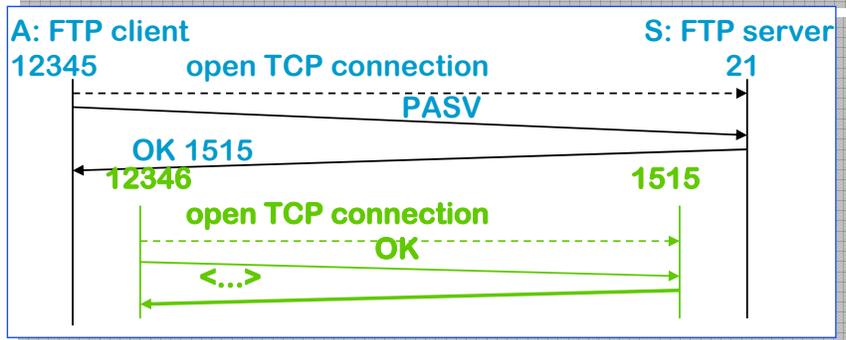
Q. What does 12345 represent ?
solution

Example: File Transfer Protocol (FTP)

- “active mode”: uses two TCP connections; ports 20 and 21 are reserved (first version)



- “passive-mode” only port 20 is reserved (second version)



Q1. What are the TCP server ports in each case ?

[solution](#)

Example: Domain Name System: DNS

■ *Why* invented ?

- ▶ support user friendly naming of resources: computers, printers, mailboxes,...
- ▶ hide IP address changes on servers

Q. Why would an IP address change ?

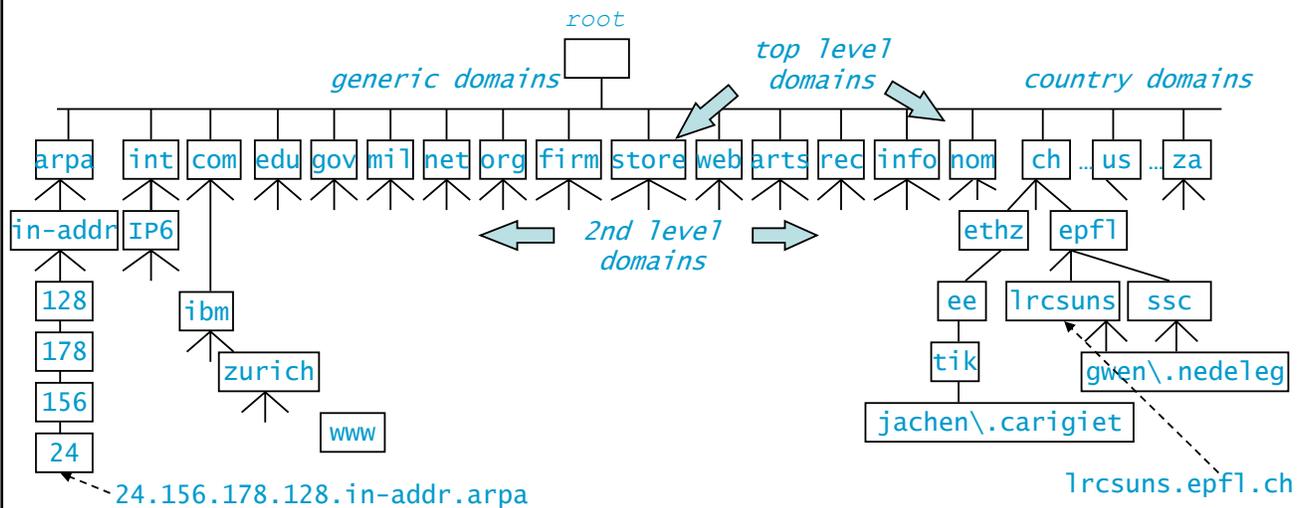
[solution](#)

■ *What* does it do ?

- ▶ map DNS names (ex: ssc.epfl.ch) to IP addresses

■ *How* does it work ?

DNS Names



- ▶ every node on the tree represents one or a set of resources
- ▶ every node on the tree has a label(lrcsuns) and a domain name (lrcsuns.epfl.ch)
- ▶ domain name = sequence of labels, ≤ 64 bytes per label
 - ▶ examples: www.zurich.ibm.com, lrcsuns.epfl.ch, ezinfo.ethz.ch, ee.ethz.ch
 - ▶ names have same syntax for subdomains or individual resources

How Does DNS Work ?

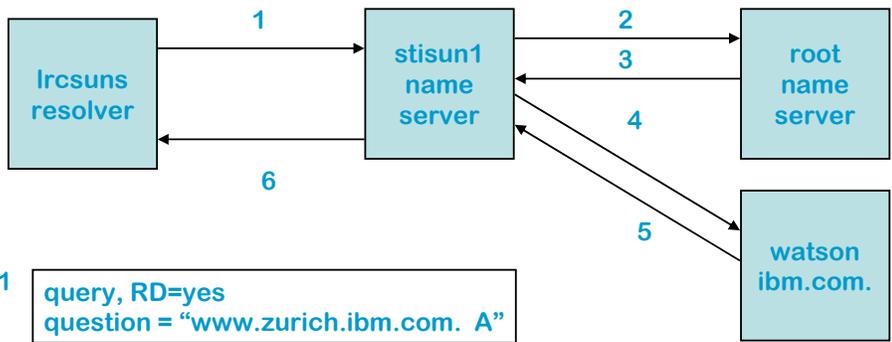
- When machine needs to map name to IP address
 - ▶ DNS resolver contacts a DNS server
 - ▶ IP address of DNS server is known to machine at configuration time
 - ▶ DNS server may not know answer: in such a case, DNS server needs to do several iterations, as shown next on an example.
 - ▶ A cache is used at DNS resolver and at DNS server to avoid repeating the same requests frequently.

- DNS uses UDP for queries and responses.

The next slide shows an example of name resolution.

1. an application on lrcsuns requests a name resolution (find the IP address of www.zurich.ibm.com), a request is sent to the name server configured at lrcsuns
2. the epfl name server does not know the answer, but, as any name server, knows the IP address of root name servers.
3. a root name server knows the IP addresses of all level-2 domains. Thus, it informs lrcsuns of the IP address of the name servers responsible for the ibm.com domain
4. the epfl name server sends the same request now to the ibm name server
- 5 the ibm name server gives the IP address of www.zurich.ibm.com back to the epfl name server. The epfl name server keeps the address in its cache, this will be used if the same request comes again
- 6 the epfl name server gives the IP address of www.zurich.ibm.com back to lrcsuns. End of the resolution !

The request sent by lrcsuns is *recursive* (RD=yes): lrcsuns will receive only the final answer. In contrast, the request sent by the epfl name server is *iterative* (RD=no): it receives only partial answers that help towards the solution.



- 1 query, RD=yes
question = "www.zurich.ibm.com. A"
- 2,4 query, RD=no
question = "www.zurich.ibm.com. A"
- 3 answer
question = "www.zurich.ibm.com. A"
answer = ""
authority= "ibm.com. NS watson.ibm.com.
 NS ns.austin.ibm.com.
 NS ns.almaden.ibm.com."
additional="watson.ibm.com. A 192.35.232.34
 ns.austin.ibm.com. A 129.34.139.4
 ns.almaden.ibm.com A 198.4.83.134"
- 5,6 answer
question = "www.zurich.ibm.com. A"
answer = "www.zurich.ibm.com. A 193.5.61.131"

2. Application Layer Gateways

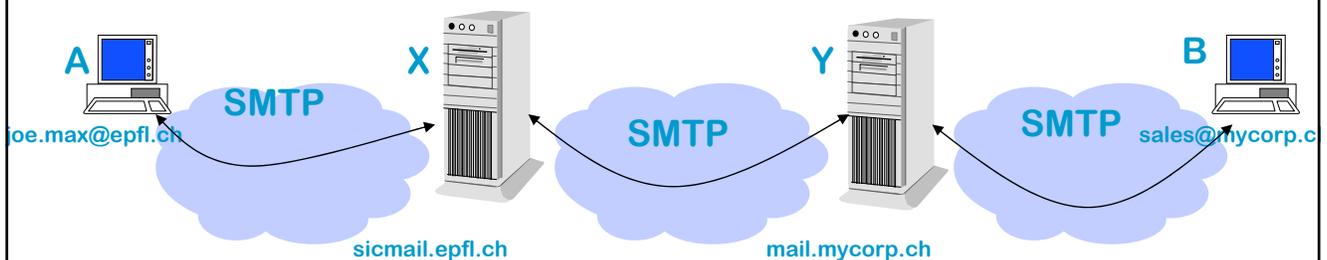
- Reminder: a layer- n *intermediate system* acts on data of protocol n for which it is neither source nor destination. The opposite is *end-system*

Q1. What is the name for an IP layer intermediate system ? MAC layer?
Physical layer ?

[solution](#)

- An *application layer gateway* is the name for an application layer intermediate system.
 - ▶ It terminates the TCP connections (if the application layer uses TCP)
 - ▶ We have called this in the introduction “store and forward”

Examples of Application Layer Gateways



- For example, a mail server acts as application layer gateway when it relays an email from one machine to another.

Q. SMTP uses TCP; how many TCP connections are there on the figure ?

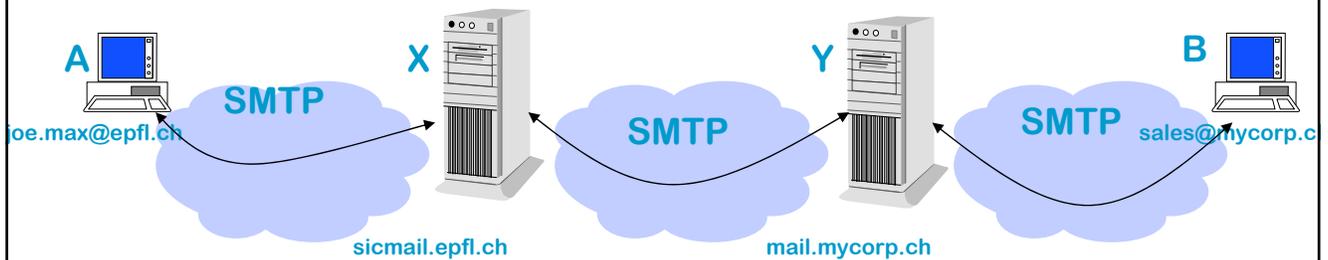
solution

The “End-to-end” Principle

- The “end-to-end” principle of the Internet says that the application layer should avoid intermediate systems, as much as possible.
 - ▶ Example: the [web](#)

- *Why* this principle ?
 - ▶ Simplify the network. The network is independent of applications and can be run more safely.
 - ▶ Allow easy deployment of applications. Ex: the web was deployed in 1994 in a few months. Before that, TCP/IP existed, but not HTTP.
 - ▶ Performance is better – see [archi.ppt](#)

The “End-to-end” Principle for Email



■ Q. what would a strict application of the end-to-end principle on the figure give ?

[solution](#)

The End-to-end Principle is not always Applicable

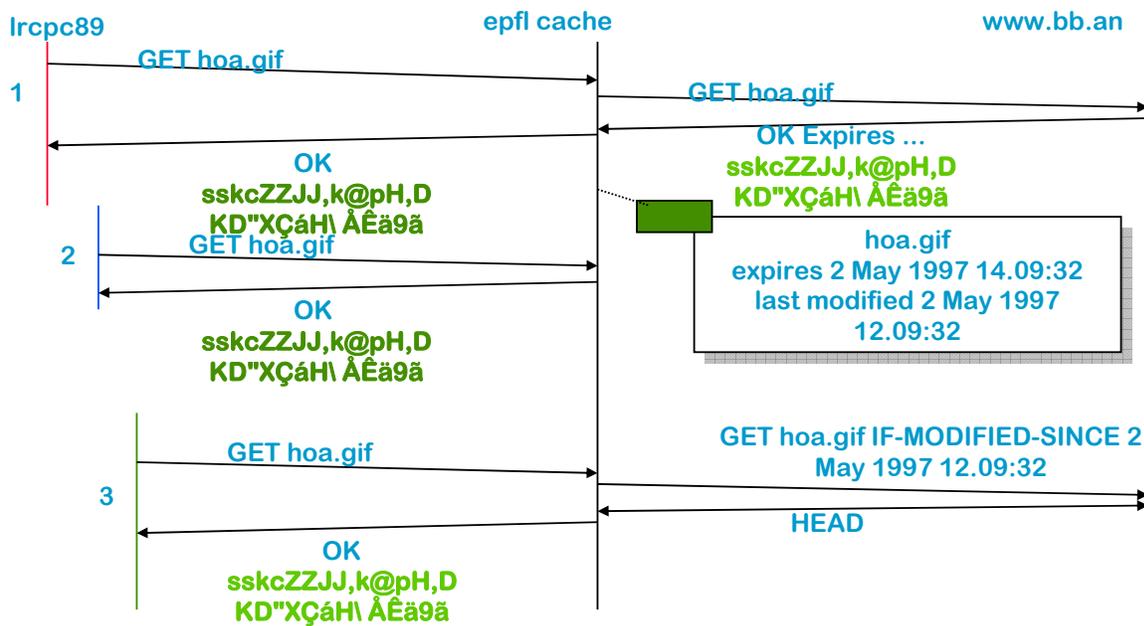
- Application layer gateways are still desirable in some cases.

Q. Can you mention three good reasons for desiring an application layer gateway ?

solution

Web Caches

- These are HTTP Intermediate Systems, deployed for performance. The idea is: keep frequently asked documents close to user
 - cache can reduce traffic due to responses or to requests
 - similar system deployed by content distribution networks



Facts to Remember (5)

- There are many TCP/IP application layer standards
 - ▶ protocol, data format, programs
- Application layer runs on hosts, not routers
- Application layer programs use clear text commands
- DNS is a world wide distributed data base used for mapping names to IP addresses (and vice versa)

Q. Give three examples of application layer intermediate systems and say why they are justified ?

[solution](#)

Solutions

URLs

- identify documents to be transferred and application layer protocol to use

`http://www.zurich.ibm.com/RZ.html`

*protocol
to be
used*

target host

path for document on target host

- examples

- ▶ `ftp://lrcftp.epfl.ch/meinix.ps.gz`
- ▶ `http://lrcsuns.epfl.ch:12345`
- ▶ `news://comp.infosystems.www`

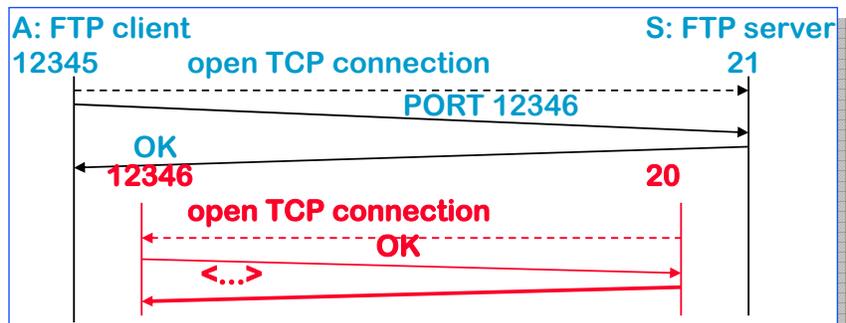
Q. What does 12345 represent ?

A. The TCP port number on which the server listens.

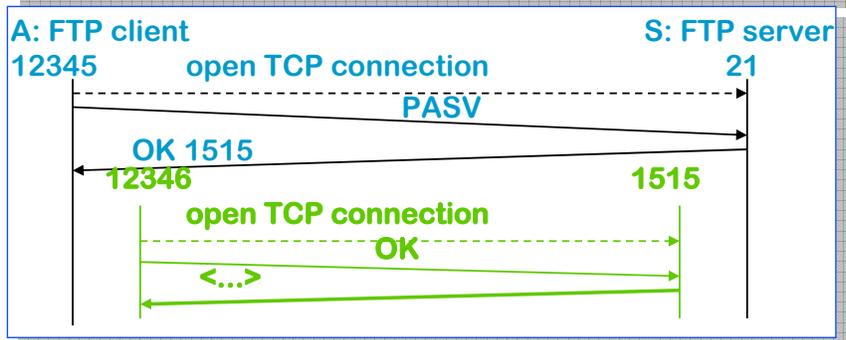
[back](#)

Example: File Transfer Protocol: FTP

- “active mode”: uses two TCP connections; ports 20 and 21 are reserved (first version)



- “passive-mode” only port 21 is reserved (second version)



Q1. What are the TCP server ports in each case ?

A1. Active mode: port 21 on S; port 12346 on A; Passive mode: port 21 on S. [back](#)

Example: Domain Name System: DNS

■ *Why* invented ?

- ▶ support user friendly naming of resources: computers, printers, mailboxes,...
- ▶ hide IP address changes on servers

Q. Why would an IP address change ?a

A. For example: you migrate a web server to a new machine. During the migration, you have both machines running, so you need to keep both IP addresses in operation.

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■ *What* does it do ?

- ▶ map DNS names (ex: ssc.epfl.ch) to IP addresses

■ *How* does it work ?

2. Application Layer Gateways

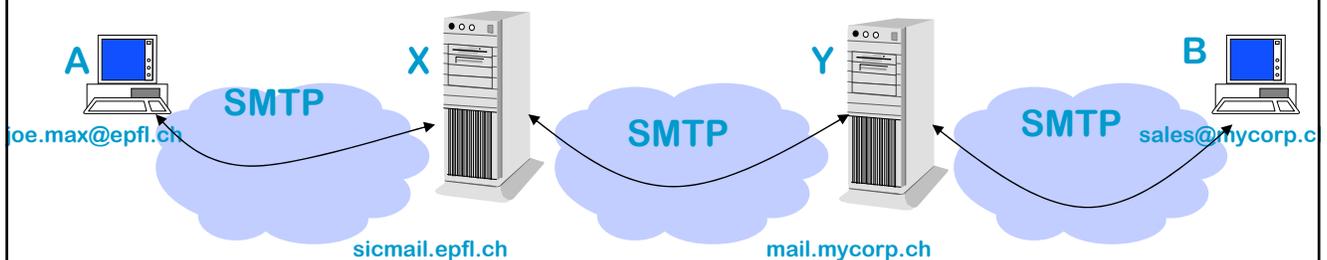
- Reminder: a layer- n *intermediate system* acts on data of protocol n for which it is not source nor destination. The opposite is *end-system*

Q1. What is the name for an IP layer intermediate system ? MAC layer? Physical layer ?

A2. router; bridge; repeater [back](#)

- An *application layer gateway* is the name for an application layer intermediate system.
 - ▶ It terminates the TCP connections (if the application layer uses TCP) and
 - ▶ We have called this in the introduction “store and forward”

Examples of Application Layer Gateways



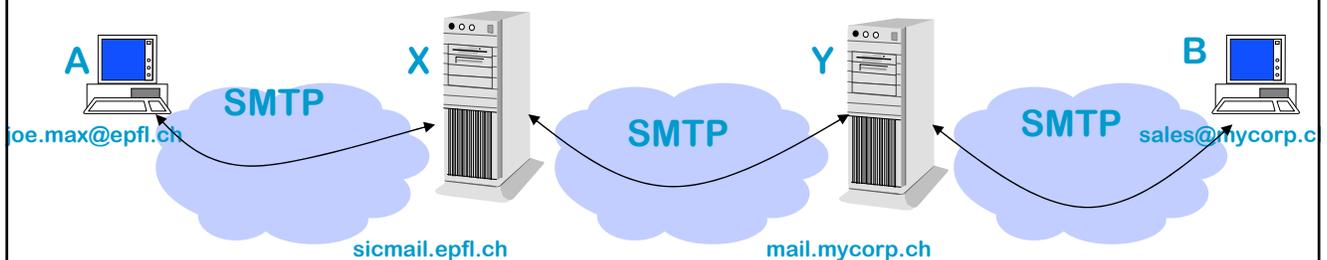
- For example, a mail server acts as application layer gateway when it relays an email from one machine to another.

Q. SMTP uses TCP; how many TCP connections are there on the figure ?

A. 3

[back](#)

The “End-to-end” Principle for Email



■ Q. what would a strict application of the end-to-end principle on the previous figure give ?

A. PC A should open a TCP connection directly to B and transfer the email over the connection. This is not possible here as PCs are not expected to be always available for service, as an email server is. However, one could require that A directly opens a TCP connection to email server Y instead of going through email server X.

[back](#)

The End-to-end Principle is not always Applicable

- Application layer gateways are still desirable in some cases.

Q. Can you mention three good reasons for desiring an application layer gateway ?

A. Here are ≥ 3 reasons:

1. **Mobility** (or partial connectivity). On the previous figure, this is why we send email to Y and not to B.
2. **Security**. X knows A and accepts email from A, but Y does not know A and does not accept email from A. X knows Y and accepts email from Y. This is why A has to go through X to send email. Similarly, see the module on firewalls
3. **Interworking**. We have seen such a case in the interworking between IPv4 and IPv6.
4. **Performance**. See web proxies

[back](#)

Facts to Remember (5)

- There are many TCP/IP application layer standards
 - ▶ protocol, data format, programs
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- Application layer programs use clear text commands
- DNS is a world wide distributed data base used for mapping names to IP addresses (and vice versa)

Q. Give three examples of application layer intermediate systems and say why they are justified ?

A.

1. email relay: justified by nomadic users or by authentication
2. web proxies: reduce request rates on hot spot servers; may reduce bandwidth consumption
3. DNS server acting as proxy: reduce amounts of queries by caching