UE PRIP
Principes des réseaux informatiques par la pratique
Application Layer

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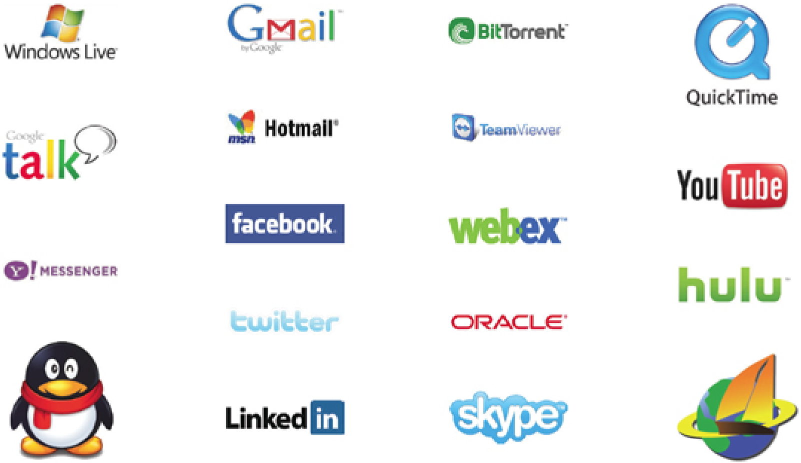
2022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Today's objective

- overview of the application layer
- understand the basics of app layer protocols
- app layer protocol example: HTTP (in this course)
- focus on the domain names system (in Lab DNS)

Approach:

- overview of the application layer, course and your questions (please!)
- analyze more in depth the functioning of the DNS (Lab session)

1. Network applications

Some network applications

you name them!

Creating a network app

write programs that:

- run on (different) end systems
- communicate over network
- e.g., web server software communicates with browser software

no need to write software for network-core devices

- network-core devices do not run user applications
- applications on end systems allows for rapid app development, propagation

Application architectures

possible structure of applications:

- client-server
- peer-to-peer (P2P)

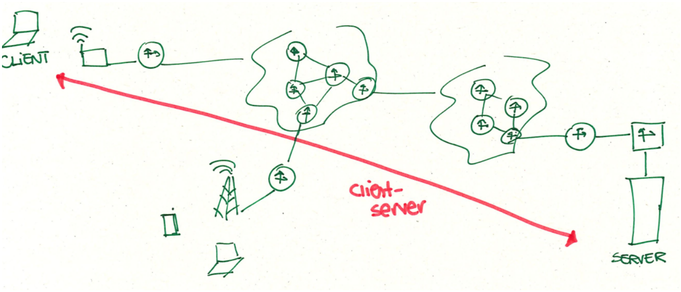
Client-server architecture

server:

- always-on host
- permanent IP address
- data centers for scaling

clients:

- communicate with server
- may be intermittently connected
- may have dynamic IP addresses
- do not communicate directly with each other

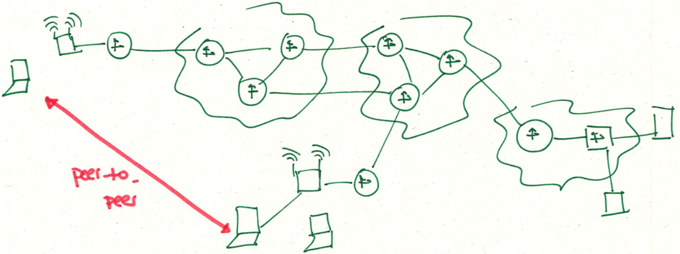


P2P architecture

- no always-on server
- arbitrary end systems directly communicate
- peers request service from other peers, provide service in return to other peers

  ! self scalability – new peers bring new service capacity, as well as new service demands
- peers are intermittently connected and change IP addresses

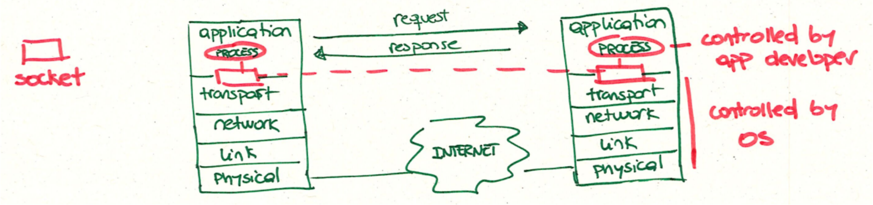
  ! complex management



Some vocabulary: process

process: program running within a host

- within same host, two processes communicate using inter-process communication (defined by OS)
- processes in different hosts communicate by exchanging *messages* (cf 1st course)

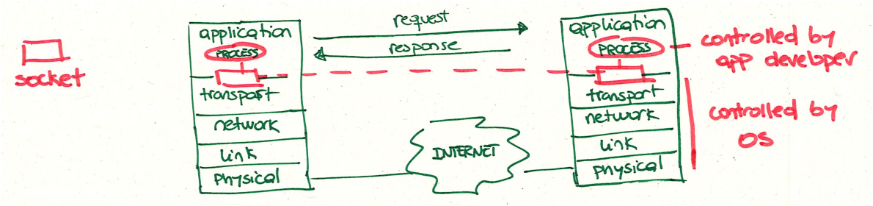


Some vocabulary: sockets

process sends/receives messages to/from its socket

- socket analogous to door
  - sending process pushes message out the door
  - sending process relies on transport infrastructure on other side of the door to deliver message to socket at receiving process

More about sockets in Transport layer course!



Addressing processes

Q Consider an incoming message to the host, how to know to which process is it destined?

Q Given that host is identified by an IP address, does an IP address suffice to identify a process?

! No, several process running on same host!

ports In the TCP/IP model, 16-bit numbers that are used along with IP addresses for identifying a process

Examples of well-known ports: HTTP server 80, mail server 25, DNS server 53

2. Application protocols

Application protocols are similar to a human conversation

Alice : Hello

Bob : Hello

Alice : What time is it ?

Bob : 11:55

Alice : Thank you

Bob : You're welcome

! Works if both speak same language!

Application protocols

A set of rules that specify:

- types of messages exchanged
  e.g. request, response
- message syntax
  what fields in messages and how fields are delineated
- message semantics
  meaning of information in fields
- message ordering
  rules for when and how processes send and respond to messages

Open protocols : defined by IETF, allow interoperability e.g. : HTTP, SMTP
Proprietary protocols: e.g. skype (no interoperability possible!)

Two types of messages

App protocols can be defined using either:

- Strings or lines of characters
- Bits

! But transport layer allows to transfer bits, not Strings ⇒ need of common representation e.g. usage of ASCII for characters

E.g. of characters defined on the ASCII table
A : 1000011b
0 : 0110000b
carriage return (CR) : 0001101b
line feed (LF) : 0001010b

An example of an open application layer protocol: HTTP

- HTTP: Hypertext transfer protocol
- Open protocol standardized by IETF

Q Do you use this protocol? What for?

Versions :

`HTTP`	$\sim$ 1989
`HTTP/1.1`	RFC 2068 (1997), RFC 2616 (1999), RFC 7230 (2014)
`HTTP/2`	RFC 7540 (2015), adds encryption (among other diffs)
`HTTP/3`	draft, implemented in some browsers (e.g. Chrome sep.19)

! More on RFCs soon!

(An RFC example)

https://tools.ietf.org/html/rfc7230

Some other application layer protocols

- DNS
- SMTP
- POP3
- IMAP
- SNMP
- FTP
- XMPP

… among many others

Q Is it really OK to consider the DNS as an application-layer protocol? to be discussed further after the DNS lab!

3. Services from lower layers

Application layer can rely on services from the transport layer

Which services are needed form an app point of view?

Data integrity

- 100% needed for e.g. file transfer
- Some loss tolerated for e.g. voice

Delay

- Low delay important for some apps (e.g. online gaming)
- Delay-tolerant apps also exist (e.g. file transfer)

Throughput

- Apps needing large bandwidth (e.g. video)
- "elastic" apps which use whatever "remaining" capacity

Q Can you think of any other?

Internet transport protocols services at a glance

TCP

- reliable transport between sending and receiving process: no losses, not disordered messages
- flow control: not overwhelming receiver
- congestion control: adapt sending rate when network overloaded
- connection-oriented: setup required between client and server processes
- no guarantees on delay, throughput, security (though security extension exists)

UDP

- unreliable data transfer between sending and receiving process
- connection-less
- does not provide guarantees on: reliability, flow control, congestion control, timing, throughput guarantee, security

Q Why using UDP then?

Q If an app is relying on UDP but needs some of the not provided guarantees, which solution?

4. Summary

Summary

Be sure you understand the following aspects:

- Application layer
- Application protocol
- Client-server architecture
- P2P architecture
- Services from the transport layer

Appendix: An example of an Internet application protocol: HTTP

HTTP overview I

- HTTP application protocol for distributed, collaborative, hypermedia information systems
- foundation of data communication for the World Wide Web
- request–response protocol in the client–server architecture

Q example of client and server?

- client submits HTTP request to server
- server:
  -provides resources (HTML files or other content) or
  -performs other functions on behalf of client
  -returns a response message to client.
- response contains:
  -completion status information about the request
  -requested content (if OK)

Recall: web pages

- 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*
  e.g. http://www.example.com/index.html, which indicates a protocol (http), a hostname (www.example.com), and a file name (index.html)

Uniform Resource Locator (URL) references a web resource by specifying its location on a computer network and a mechanism for retrieving it

HTTP overview II

Uses TCP:

1. client initiates TCP connection (creates socket) to server, port 80
2. server accepts TCP connection from client
3. HTTP messages (application-layer protocol messages) exchanged between browser (HTTP client) and Web server (HTTP server)
4. TCP connection closed

HTTP non-persistent and persistent

Non-persistent

- at most one object sent over TCP connection connection then closed
- downloading multiple objects required multiple connections

Persistent

- multiple objects can be sent over single TCP connection

Q Can you think of advantages and disadvantages of each one?

HTTP Request message

Text protocol, containing ASCII (human-readable format) characters, formated as follows:

- a request line (e.g., GET /images/logo.png HTTP/1.1)
- request header fields (e.g., Accept-Language: en).
- an empty line
- an optional message body

HTTP Request message example

```
GET / HTTP/1.1\r\n
Host: asdf.com\r\n
User-Agent: Mozilla/5.0 (X11; Linux x86_64; rv:68.0) Ge
Accept: text/html,application/xhtml+xml,application/xml
Accept-Language: fr,fr-FR;q=0.8,en-US;q=0.5,en;q=0.3\r\
Accept-Encoding: gzip, deflate\r\n
DNT: 1\r\n
Connection: keep-alive\r\n
Cookie: _ga=GA1.2.156074956.1559831863\r\n
Upgrade-Insecure-Requests: 1\r\n
\r\n
```

Response message

- status line: status code and reason (e.g., HTTP/1.1 200 OK)
- response header fields (e.g., Content-Type: text/html)
- an empty line
- an optional message body
- status line and header fields must end with $< CR >< LF >$

Response message example

```
HTTP/1.1 200 OK\r\n
Date: Thu, 23 Jan 2020 13:11:43 GMT\r\n
Server: Apache\r\n
Upgrade: h2\r\n
Connection: Upgrade, Keep-Alive\r\n
Last-Modified: Fri, 25 May 2018 14:29:40 GMT\r\n
ETag: "53f-56d089932ee03-gzip"\r\n
Accept-Ranges: bytes\r\n
Vary: Accept-Encoding\r\n
Content-Encoding: gzip\r\n
Content-Length: 683\r\n
Keep-Alive: timeout=2, max=100\r\n
Content-Type: text/html\r\n
\r\n
```

body follows

More on HTTP

Other important aspects we won't have time to discuss in class

- HTTP is a stateless protocol (server maintains no information about past client requests)
- cookies have been created to have some state
  - small piece of data sent from a website and stored on the user's computer by the user's web browser
  - designed for websites to remember stateful information
- web cashing or proxy
- security
  - **Q** Any security concern in the example messages we have seen?
  - alternatives HTTPS, HTTP/2

Acknowledgements

The contents of these slides are partially taken from Computer Networking a Top Down approach, J. KUROSE and K. ROSS and K. KUROSE's networking course http://www-net.cs.umass.edu/cs453_fall_2013/ and from e-book Computer Networking : Principles, Protocols and Practice, third edition http://beta.computer-networking.info/syllabus/default/index.html