Computer Networks (ComNet) 1/5 : **Introduction**

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Version 7.0

ComNet: course 1/5 outline

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Reinforce your understanding of networking

Deepen and extend beyond a first course in networking

- example: LI310/3I014 course from the UPMC Licence d'Informatique
- prerequisites, both theoretical and technical:
  - the vocabulary
  - introduction to signal processing
  - basic protocol mechanisms
  - classical protocols (HDLC, X25, IP, routing, UDP, TCP)
  - ISO layered model

Understand fundamental technologies

Study the principal current network architecture and its environment ➠ **TCP/IP** and **Internet**

- standardized applications (web, DNS, e-mail, ...)
- dynamic mechanisms (congestion control, ...)
- IPv4/v6 adressing (multicast, DHCP, NAT, tunnels, ...)
- advanced routing (AS hierarchy, OSPF, BGP, ...)
- media architectures (Ethernet, ADSL, FTTH, ...)

Basis for further courses in networking

Prerequisite for **advanced networking courses**

- In M1-S2: for required courses for students in the networking speciality, and for elective courses for other students
  - mobility, autonomous, wireless ➠ U.E. **MOB**
  - advanced routing ➠ U.E. **ROUT**
- In M2-S3: for students in the networking speciality
  - content networks ➠ U.E. **CONT**
  - traffic engineering and quality of service ➠ U.E. **ITQoS**
  - Internet metrology ➠ U.E. **METRO**
  - operator networks and data centers ➠ U.E. **REOP**
  - network security ➠ U.E. **SECRES**
  - smart mobility systems ➠ U.E. **SMS**

Course content

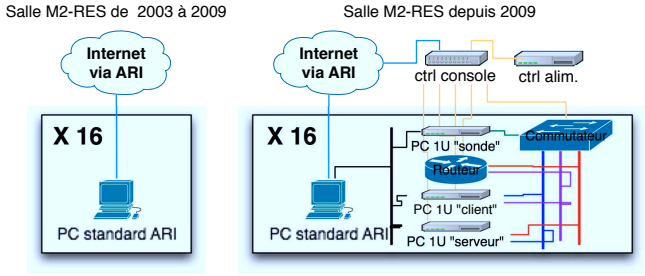
Top down approach:

Part 1/5	Introduction
Part 2/5	Application: Telnet, FTP, SMTP, HTTP, ... DNS, SNMP.
Part 3/5	Transport: services, UDP and TCP examples, ... congestion control.
Part 4/5	Network: IPv4, multicast, NAT... ... hierarchical routing, OSPF and BGP.
Part 5/5	Link: Switched Ethernet, ... point-to-point, local loop.

Labs

Four-hour **labs** consisting of written exerices (TDs) and practical ones (TMEs):

- interlacing of theoretical and practical aspects
- illustrated by concrete examples on a networking testbed using real hardware:



Lab schedule (tentative)

week	content	lab
1	Introduction to the networking testbed	n°1
2	Applications (1): Telnet, FTP, and web analysis	n°2
3	Applications (2): SMTP, DNS, and SNMP analysis	n°3
4	Completion of previous weeks' labs	
5	Transport (1): analysis of mechanisms	n°4
6	Transport (2): congestion control (planetlab)	n°5
7	Review/completion of previous weeks' labs	
8	Network (1): IP/ICMP (begin)	n°6
9	Network (2): IP/ICMP (end)	n°6
10	Review/completion of previous weeks' labs	

Course organization

13 weeks, within which...

Lectures: 10 × 2 hrs.
- O. Fourmaux, T. Friedman

Labs: 10 × 4 hrs.
- O. Fourmaux, T. Friedman, S. Imadali, T. M. T. Nguyen, K. Thai

Course website:
- Information and updates:
  `http://www-rp.lip6.fr/~fourmaux/index-cours.html`

Networking testbed for the labs

The testbed hardware rack, located in the M2-RES computer lab, room 31-208

Each pair of students has access to:
- a classical ARI host machine
- dedicated hardware for configuring networks, and capturing and analyzing traffic:
  - 1 Cisco switch
  - 1 Cisco router
  - 3 VMs in on 1U rackable server

Supporting traces and documents

- Network traffic traces, on which to test your knowledge
  - generated on the networking testbed during the labs
  - generated by the students (on the testbed or elsewhere)
  - pre-recorded (to use in case the testbed is down, or you wish to work elsewhere), available here:
    `http://www-rp.lip6.fr/~fourmaux/Traces/labV6.html`
- Documents available on the course website:
  - course slides
  - lab handouts (including optional exercises)
  - past exams
- Textbooks
  - available in the Math/Info libraries

Bibliography

- James F. Kurose, Keith W. Ross
  - **Computer Networking: A Top-down Approach Featuring the Internet**, 6th edition (Pearson, 2012)
- Andrew S. Tanenbaum, David J. Wetherall
  - **Computer Networks**, 5th edition (Prentice Hall, 2011)
- Douglas Comer
  - **Internetworking with TCP/IP** Vol 1: Principles, Protocols and Architectures, 6th edition (Prentice Hall, 2013)
- Olivier Bonaventure
  - **Computer Networking: Principles, Protocols and Practice**, `http://inl.info.ucl.ac.be/CNP3`

ComNet: course 1/5 outline

Tentative schedule for 2014-2015

dates	lecture	lab	comments
15-19/9	1	1	
22-26/9	2	2	
29/9-3/10	3	3	
6-10/10	4	4	
13-17/10	5	5	
20-24/10	6	6	
27-31/10	7	7	
3-7/11	–	–	midterm exam
12-14+17-18/11	8	8	
24-28/11	9	9	
1-5/12	10	10	
5-9/1	–	–	final exam
10-16/6	–	–	makeup exam

Warning : labs week = lecture week

Weekly schedule

	Lundi	Mardi	Mercredi	Jeudi	Vendredi
08:30–09:15		TME1 ARES (ITESCIA) 31-208	TME3 ARES 31-208	TME5 ARES 31-208	
09:15–10:45	**Cours ARES Amphi 45B**	TME1 ARES (ITESCIA) 31-208	TME3 ARES 31-208	TME5 ARES 31-208	Cours COMNET (english) 23-34-202
13:30–15:00		TME2 ARES (AFTI) 31-208	TME4 ARES 31-208	TME6 ARES 31-208	TME1 COMNET (english) 31-208
15:45–17:15		TME2 ARES (AFTI) 31-208	TME4 ARES 31-208	TME6 ARES 31-208	TME1 COMNET (english) 31-208

Exam details

Three exams:

- **Midterm exam** (application and transport layers only)
- **Final exam** (the whole course)
- **Makeup** (the whole course)

Exam rules

- **no electronic equipment** (mobile phone, calculator, etc.)
- **no documents** except **one** handwritten **A4** page

Definition

handwritten: entirely written by hand (no photocopies)

Calculating the grade for the course

1st session: *midterm* and *final* exams

$$N_{\mathrm{ARES}_1} = 0.4 N_{\mathrm{midterm}} + 0.6 N_{\mathrm{final}}$$

Note: If you pass the course in the first session ($N_{\mathrm{ARES}_1} \geqslant 50$), **you may not take the makeup exam**.

2nd session: makeup (you didn't pass the course in the 1st session)

- If your grade is officially compensated for by passing grades in other courses: by default, you keep your grade $N_{\mathrm{ARES}_1} < 50$
  - You may sit the makeup exam **iff** you **explicitly** sign up to do so with the RES secretariat
- If your grade is not compensated for, you **must** take the makeup exam (if you do not, $N_{\mathrm{ARES}_2} = 0$)

$$N_{\mathrm{ARES}_2} = N_{\mathrm{makeup}}$$

Final grade adjustments

The week after the final exam (**1st session**) or the makeup exam (**2nd session**):

- exams graded and a curve is applied
- grades posted **on DBUFR**
- students consult their graded exams
- juries
  - course jury (determines passing or failing)
  - Networking speciality jury (grade compensation)
  - Masters program jury (final decision)

ComNet: course 1/5 outline

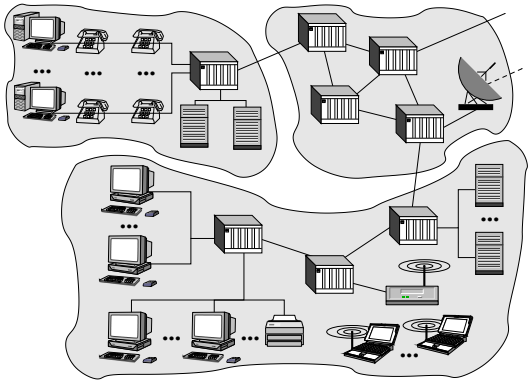
The environment we discuss in this lecture

The Internet

- omnipresent
- heterogeneous
- evolving
- complex...

➠ difficult to characterize!

Let's look at an example:

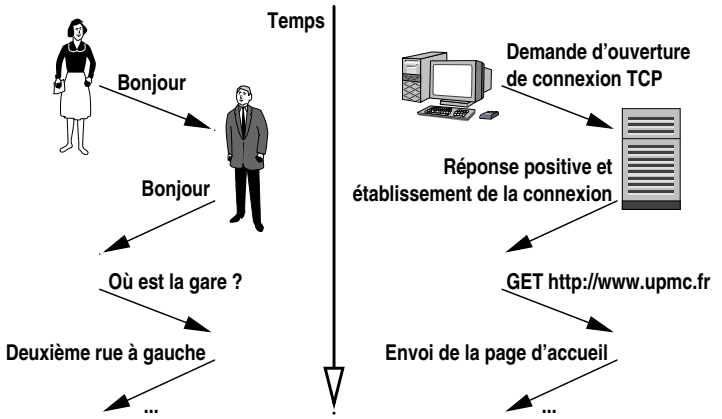


Internet components

What are the basic elements of the **Internet**?

- communications links
- routers (packet forwarding)
- hosts (end systems):
  - Unix workstations
  - classical PCs
  - mobile phones
  - an Internet toaster...
- networked applications
  - communication protocols...

Protocols: analogy



Protocol: definition

Definition

Protocol: protocols define format, order of messages sent and received among network entities, and actions taken upon message transmission and receipt.

- Remark
  - **any interaction between entities over the Internet is based on protocols**
    - this course focuses mainly on protocols
- Examples
  - web request
  - resolving name queries into IP addresses
  - route computation
  - congestion control...

Application services

Internet users use **distributed applications**:

- World Wide Web
- electronic mail
- peer-to-peer file sharing
- distributed games
- audio and video streaming
- real-time audio and video...

Network services

Applications are based on two types of services:

connectionless

analogy with the postal service

connection oriented

analogy with telephone service

and have correspondingly different characteristics:

- reliability
- ordering
- flow control
- congestion control...

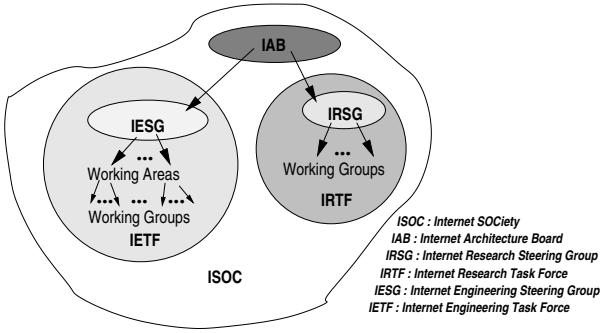
Quality of service

Qualité de Service (*QoS*) in the Internet

- The Internet offers a *best effort* service
  - no guarantees; the main concern is connectivity!
  - how many end-systems?
    - many of the 1.510^9 PCs + 1.510^9 smartphones...
    - 2.510^9 users active in 2012
    - Internet traffic >>> telephone traffic
- multimedia applications must adapt to the uncertain conditions...

➠ U.E. **CONT** / U.E. **ITQoS** (M2-S3)

Internet standardisation



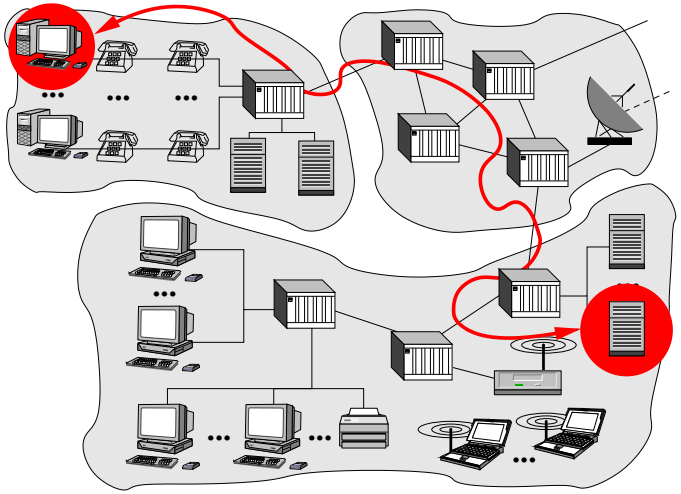
- IETF (*Internet Engineering Task Force*) working groups
- over 7300 RFCs (*Requests For Comments*)
- mostly *de facto* rather than *de jure standards*
  - IP, TCP, SMTP, SNMP, HTTP...
  - `http://www.rfc-editor.org/`

Some websites

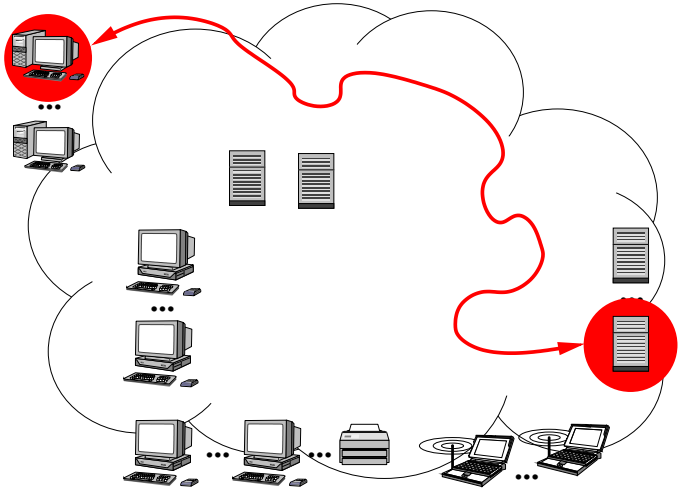
- IETF (*Internet Engineering Task Force*), `http://www.ietf.org/`
- W3C (*World Wide Web Consortium*), `http://www.w3.org/`
- ACM SIGCOMM (*Association for Computing Machinery – Special Interest Group in Data Communication*), `http://www.sigcomm.org/`
- *IEEE Communications Society*, `http://www.comsoc.org/`
- *IEEE Computer Society*, `http://www.computer.org/`
- `http://www-npa.lip6.fr/~fourmaux`

ComNet: course 1/5 outline

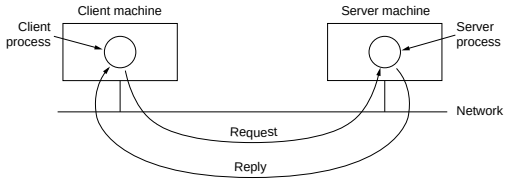
Network edge



Network edge (abstraction)



Distributed applications



client/server model

- the client sends requests
- receives service from an always-on server
  - web
  - e-mail
  - DNS...

peer-to-peer model

- minimal use of dedicated servers
- symmetrical communication

Application protocols

Heterogeneous environment ➠ standardised interactions

- web: **HTTP**, **HTML**
- e-mail: **SMTP**, **MIME**, **POP**, **IMAP**
- remote access: **Telnet**, **NVT**
- file transfer: **FTP**
- directory: **DNS**
- management: **SNMP**, **MIB**

➠ **Part 2/5**: Applications

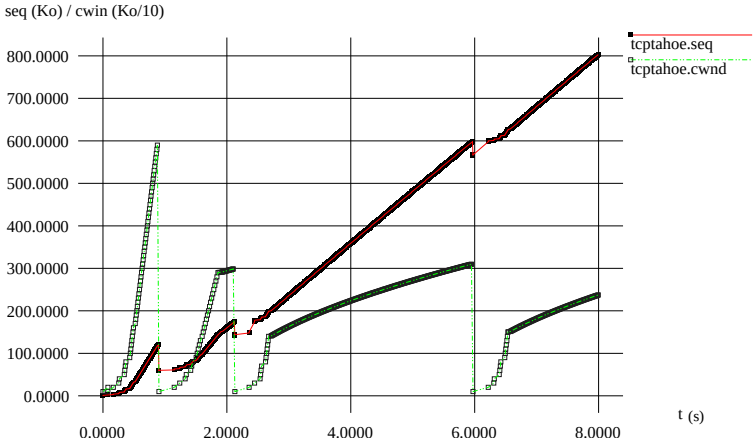
End-to-end services

Types of service that the network offers to end-hosts:

- **connection oriented** service
  - reliability
  - ordering
  - flow control
  - congestion control...
    - **TCP**
- **connectionless** service
  - simple
  - basis for other protocols
    - **UDP**

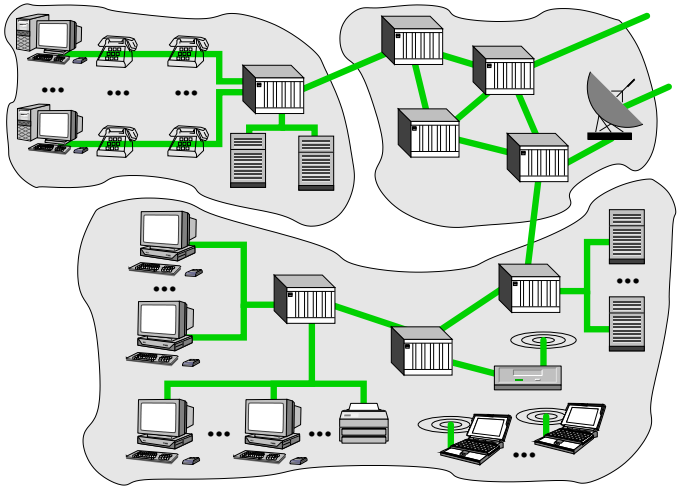
Impact of end-to-end control

What is the shape of traffic generated by TCP?



➠ **Part 3/5**: Transport

Inside the network



Communication links

Physical media

- media with waveguide
  - twisted pair (UTP5+, UTP6,...)
  - coaxial cables (baseband, broadband,...)
  - optical fibers (multimode, monomode,...)
- media without waveguide
  - satellite links (geostationary, constellation, ...)
  - terrestrial links (radio-waves, micro-waves, infrared, optical,...)

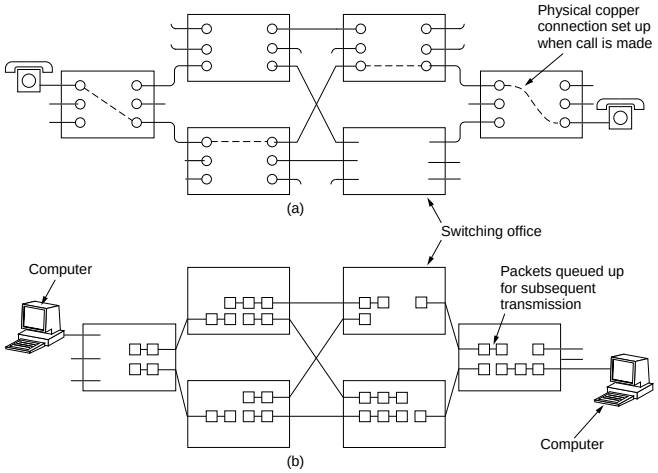
Access technology

- shared medium
- framing

Intermediate elements...

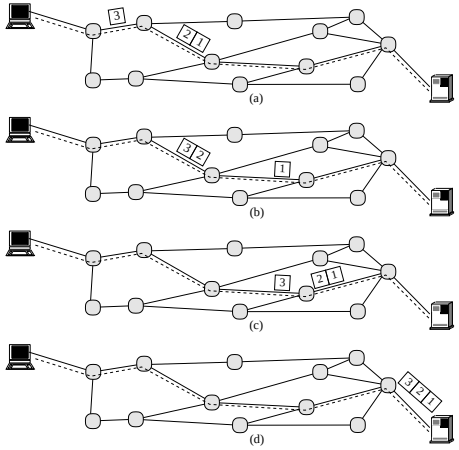
Data forwarding

Circuit switching or packet switching?



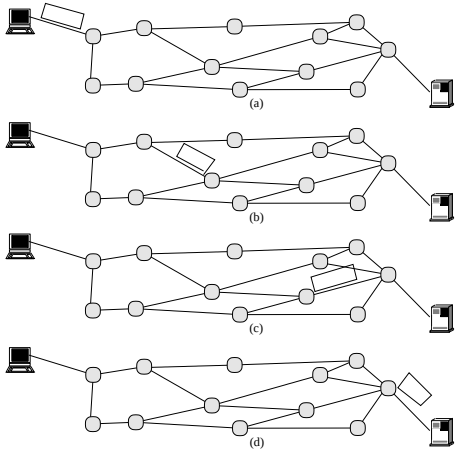
pictures from Tanenbaum A. S. *Computer Networks 3rd edition*

Virtual circuit transmission



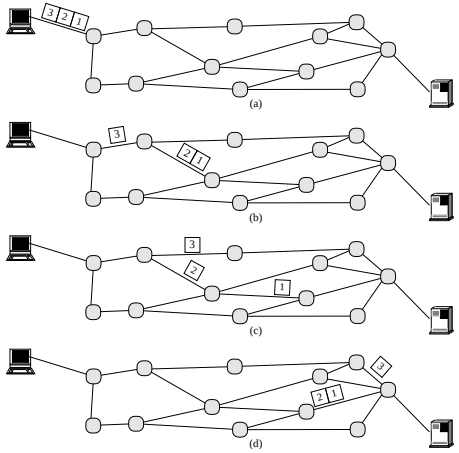
pictures from Stallings W. *High Speed Networks*

Message transmission



pictures from Stallings W. *High Speed Networks*

Datagram transmission



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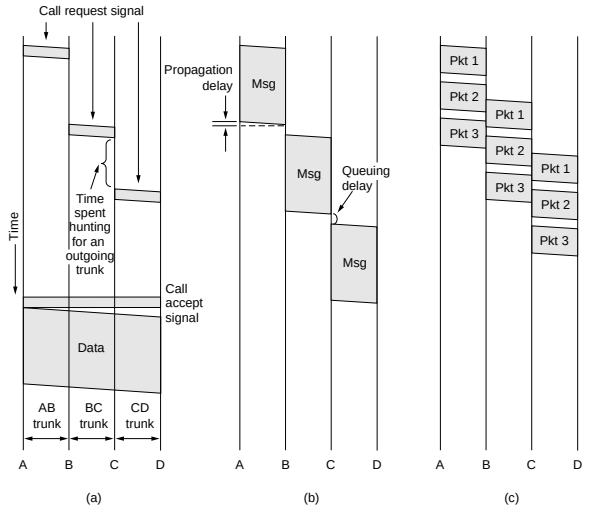
Comparing the three types of transmission



pictures from Tanenbaum A. S. *Computer Networks 3rd edition*

Delay recap

Types of delays in packet switching:

- nodal processing delay
  - uncompressible (D_n)
- queuing delay
  - depends on congestion ($D_q = 0$ if no congestion)
- transmission delay
  - depends on the size of the packet ($D_t = L/R$)
- propagation delay
  - $v = 2.10^8 m/s$ to $3.10^8 m/s$ ($D_p = d/v$)

Formula for **end-to-end delay**?

Internet addressing

Packets travel from source to destination hop-by-hop, with an address-based forwarding decision made at each intermediate node (**router**).

IPv4/v6 protocol

- universal
- virtual addressing
- **abstracts out the lower layer technologies**
  - each technology provides encapsulation
  - address conversion

Protocols have evolved to adapt to the present network

- classless addressing (**CIDR**), multicast, **IPv6**
- address translation (**NAT**)
- auto-configuration (**DHCP**)
- filtering...

Routing mechanisms

When and how to determine the **route** taken by data?

- the type of path followed depends upon the type of network:
  - **initially**
    - circuit switching
    - virtual circuits
  - **for each packet**
    - datagram
- calculating the information
  - routing **algorithms**
  - routing tables
    - local or centralized
    - static or dynamic
- information exchange
  - routing **protocols**...

Routing in the **Internet**

Datagram network

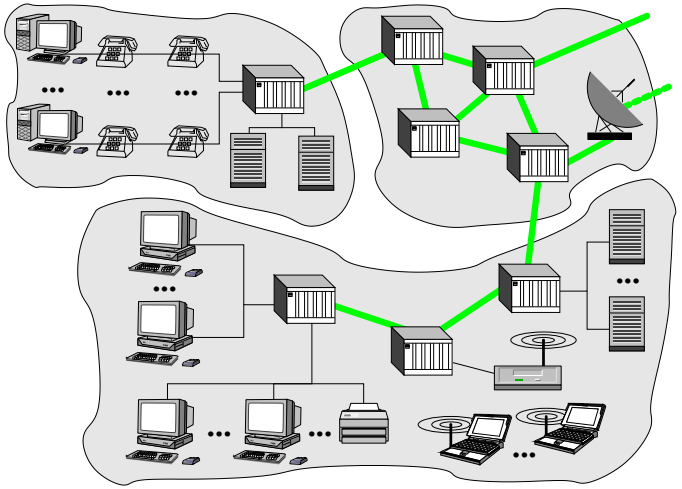
- routing of **each packet**

Hierarchical structure of the network (**ASes**)

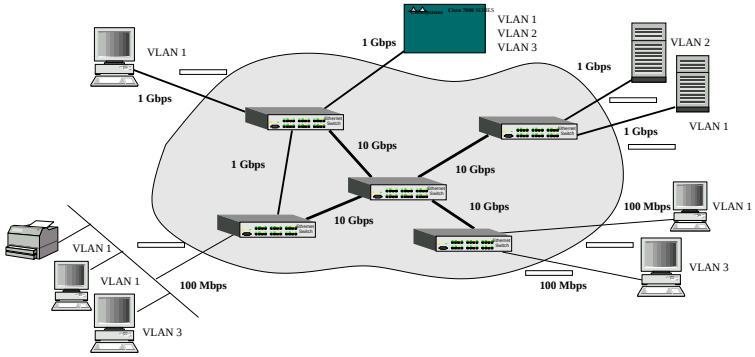
- internal routing: **OSPF**
- external routing: **BGP**

➠ **Part 4/5**: Network

Network core

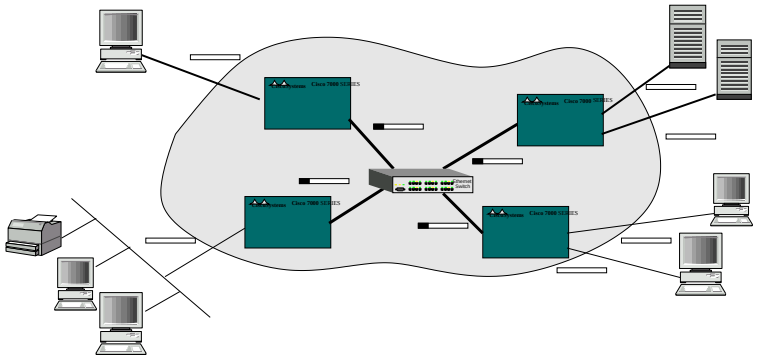


Ethernet technology



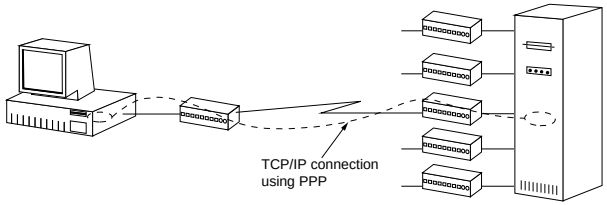
LAN evolution towards the WAN with **Fast Ethernet**, **Gigabit Ethernet**, **10Gigabit Ethernet** and **100Gigabit Ethernet**.
Integrating **switching** and structuring through **VLANs**...
➠ **Part 5/5 (1)**: Ethernet

MPLS technology



Integrating **switching** mechanisms at the network level (ATM, MPLS,...).
➠ U.E. **RTEL** (M1-S1)

Point-to-point technology

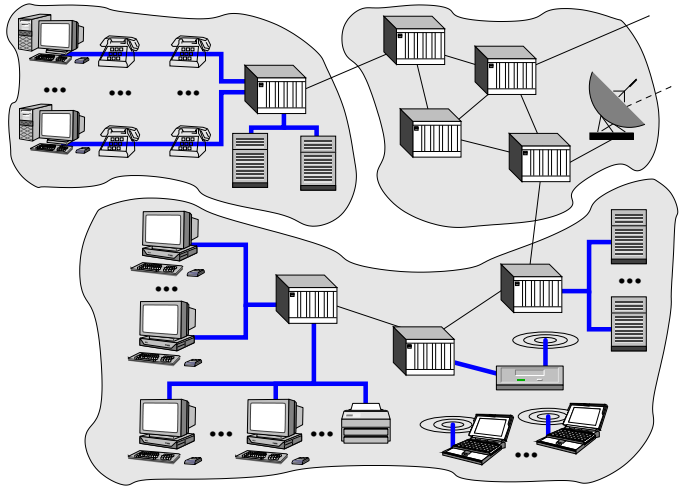


PPP only for old serial connections?

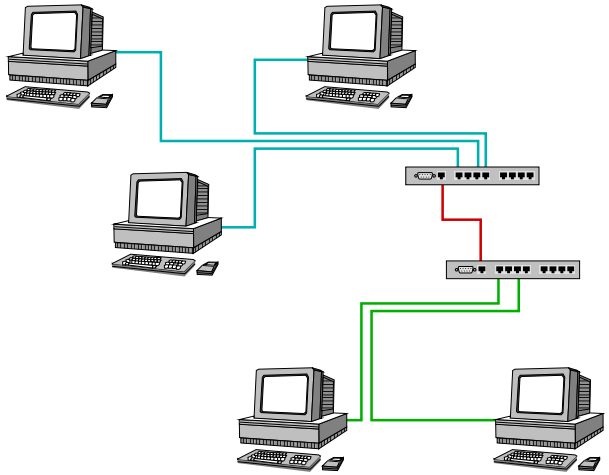
- PPP over SONET: **POS**
- PPP over Ethernet: **PPPoE**
- PPP over ATM: **PPPoA**
- PPP over IP: **L2TP** ...

➠ **Part 5/5 (2)**: Point-to-point

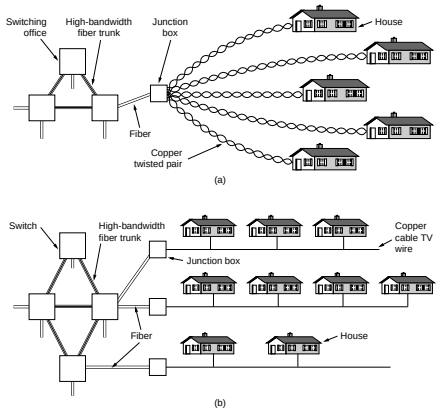
Access networks



Entreprise networks



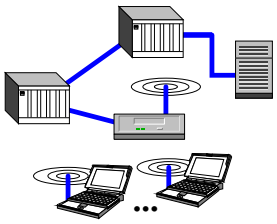
Wired residential



Residential (PSTN/ADSL, cable, optical fiber,. . .)

➠ **Part 5/5 (3)**: Local loop

Wireless access and mobility



Depending upon the degree of mobility:

- micro-mobility
  - Bluetooth/**WPAN** (IEEE 802.15)
- wireless local network
  - Wi-Fi/**WLAN** (IEEE 802.11)
- wireless local network
  - BLR/**WMAN** (IEEE 802.16)
- mobile phone
  - GSM, GPRS, i-mode,. . .
  - UMTS

➠ U.E. **MOB** (M1-S2)

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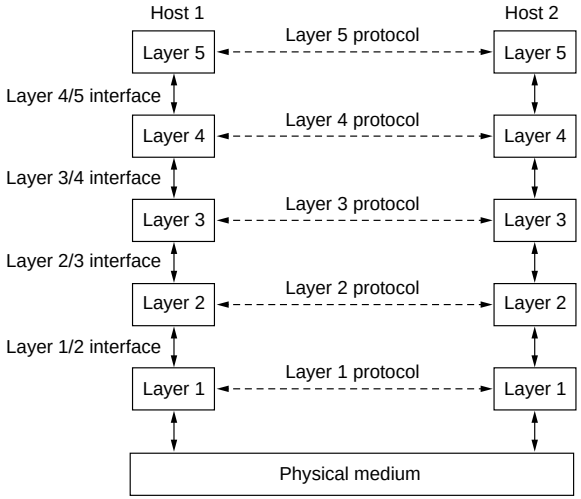
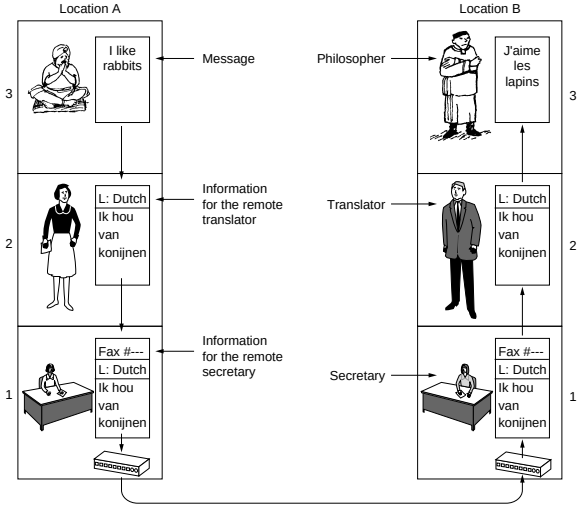
Protocols, layers, and interfaces



picture from Tanenbaum A. S. *Computer Networks 3rd edition*

Anthropological analogy



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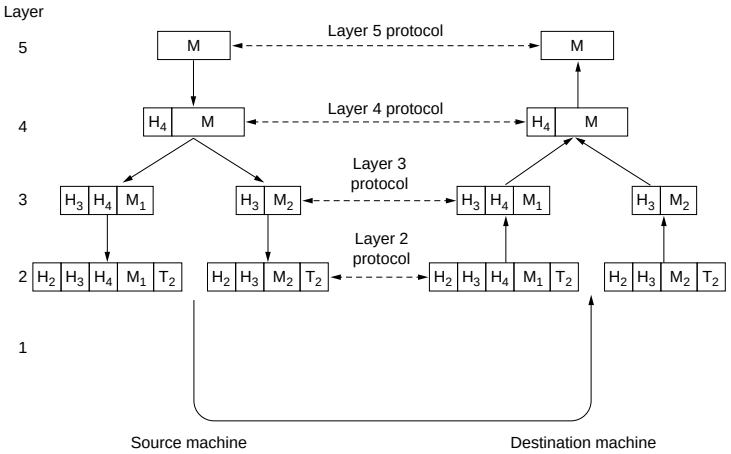
Repeated encapsulation



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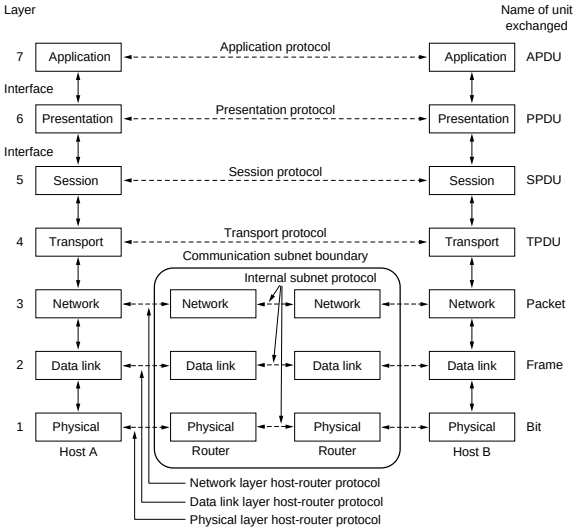
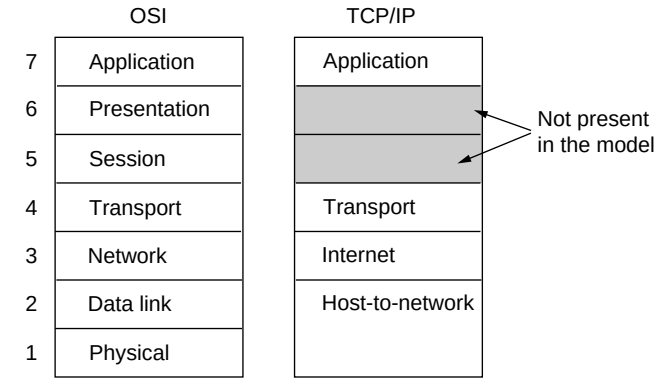
OSI (*Open Systems Intercon.* Reference Model – 1983)



TCP/IP reference model (1974)



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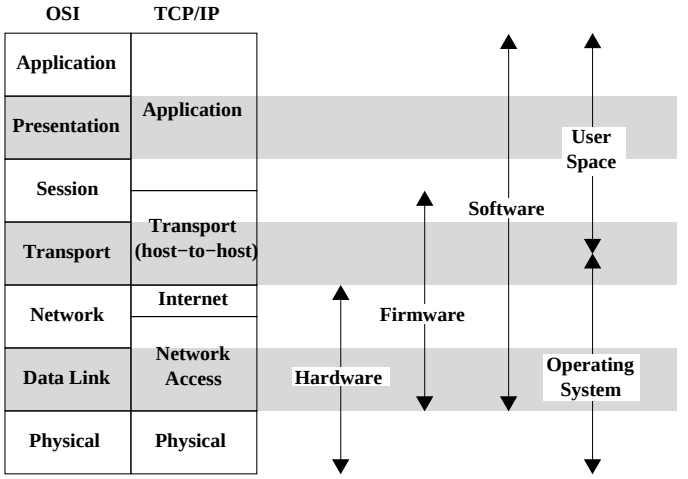
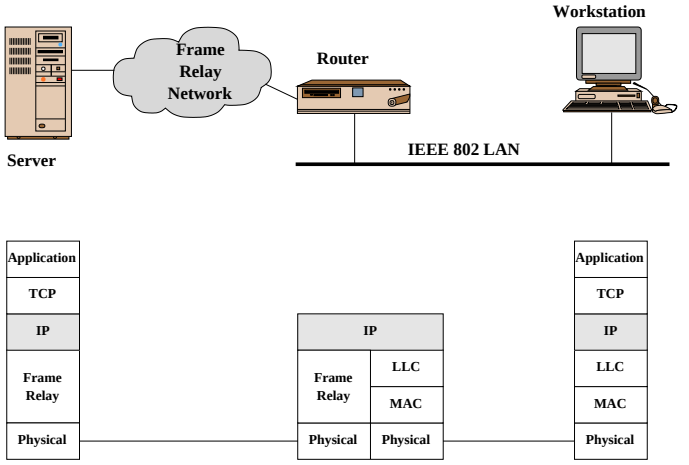
TCP/IP: comparison



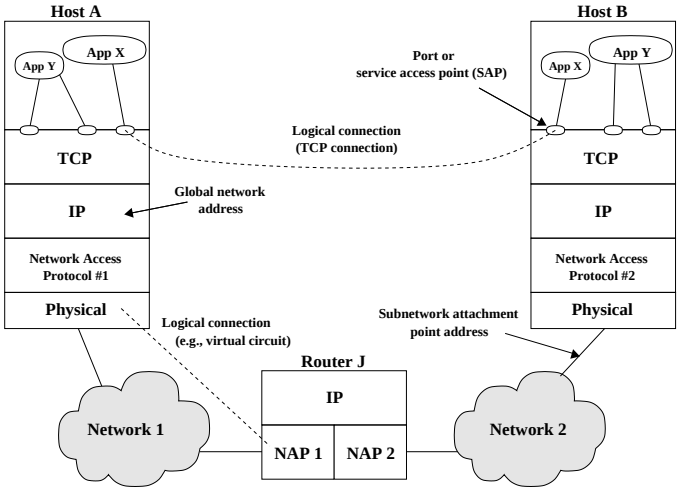
these pictures and to the end are from Stallings W. *High Speed Networks*

ComNet: course 1/5 outline

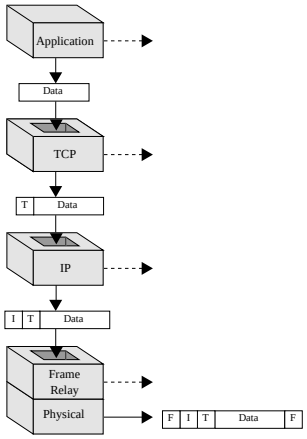
TCP/IP: example



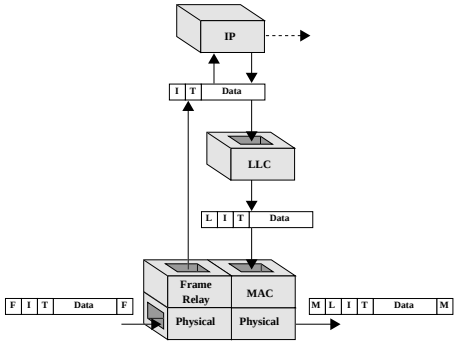
TCP/IP: concept



TCP/IP: sender actions



TCP/IP: router actions



TCP/IP: receiver actions