Course presentation

Course objectives
- Pedagogical approach
- Instructional methodology

Administrative questions
- Schedule
- Evaluation

Course introduction
- Network components
- Protocol hierarchy
- TCP/IP example

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 addressing (multicast, DHCP, NAT, tunnels, ...)
- advanced routing (AS hierarchy, OSPF, BGP, ...)
- media architectures (Ethernet, ADSL, FTTH, ...)

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: remote login, file transfert... ... multimedia, DNS, SNMP. |
| Part 3/5 | Transport: services, UDP and TCP examples, ... congestion control, DCCP, SCTP. |
| Part 4/5 | Network: IPv4/v6, multicast, NAT... ... hierarchical routing, OSPF and BGP. |
| Part 5/5 | Link: Switched Ethernet, ... point-to-point, local loop. |

Basis for further courses in networking

Labs

Four-hour labs consisting of written exercises (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)

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

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 Mathematics & Computer Science libraries
    - see: http://www.jubil.upmc.fr/fr/campus/acces_jussieu.html
Bibliography

- James F. Kurose, Keith W. Ross
- Andrew S. Tanenbaum, David J. Wetherall
- Douglas Comer
- Olivier Bonaventure

Olivier Bonaventure - T. Friedman (olivier.fourmaux@upmc.fr)

Computer Networks (ComNet) 1/5: Introduction

Tentative schedule for 2014-2015

<table>
<thead>
<tr>
<th>dates</th>
<th>lecture</th>
<th>lab</th>
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<td>6-10/10</td>
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<td>3-7/11</td>
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<td>makeup exam</td>
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Warning: labs week = lecture week

Weekly schedule

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<th>Jeudi</th>
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<td>TME5 ARES (APRT) 31-208</td>
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Olivier Bonaventure - T. Friedman (olivier.fourmaux@upmc.fr)
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

\[ N_{ARES_1} = 0.4N_{\text{midterm}} + 0.6N_{\text{final}} \]

Note: If you pass the course in the first session \( N_{ARES_1} \geq 50 \), 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 \( N_{ARES_1} < 50 \)
  - 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, \( N_{ARES_2} = 0 \))

\[ N_{ARES_2} = N_{\text{makeup}} \]

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

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3. Course introduction
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   - Protocol hierarchy
   - TCP/IP example
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 links)
- 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
- 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 1.5×10⁹ PCs + 1.5×10⁹ smartphones...
    - 2.5×10⁹ 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/

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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?

![Graph showing TCP traffic shape](image)
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...

Virtual circuit transmission

Circuit switching or packet switching?

Physical copper connection set up when call is made

Packets queued up for subsequent transmission

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

pictures from Stallings W. High Speed Networks
Message transmission

Datagram transmission

Comparing the three types of transmission

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 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
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

Integrating switching mechanisms at the network level (ATM, MPLS, ...).

⇒ U.E. RTEL (M1-S1)

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
Entreprise networks

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)

Residential (PSTN/ADSL, cable, optical fiber, ...)
⇒ Part 5/5 (3): Local loop

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⇒ U.E. MOB (M1-S2)
Protocols, layers, and interfaces

Layer 5 protocol
Layer 4 protocol
Layer 3 protocol
Layer 2 protocol
Layer 1 protocol
Physical medium

Anthropological analogy


Repeated encapsulation

Layer 5 protocol
Layer 4 protocol
Layer 3 protocol
Layer 2 protocol
Layer 1 protocol
Physical medium
TCP/IP reference model (1974)

<table>
<thead>
<tr>
<th>OSI</th>
<th>TCP/IP</th>
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<tr>
<td>7</td>
<td>Application</td>
</tr>
<tr>
<td>6</td>
<td>Presentation</td>
</tr>
<tr>
<td>5</td>
<td>Session</td>
</tr>
<tr>
<td>4</td>
<td>Transport</td>
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<td>3</td>
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TCP/IP: comparison

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<tr>
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TCP/IP example

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**TCP/IP: concept**

- **Host A**
  - Application X
  - Application Y
  - TCP
  - IP
  - Physical
  - Network Access Protocol #1
  - Logical connection (e.g., virtual circuit)
  - Subnetwork attachment point address

- **Host B**
  - Application X
  - Application Y
  - TCP
  - IP
  - Physical
  - Network Access Protocol #2
  - Logical connection (TCP connection)
  - Port or service access point (SAP)

- **Router J**
  - IP
  - NAP 1
  - NAP 2

- **Network 1**
  - Logical connection
  - Network Access Protocol #1

- **Network 2**
  - Logical connection
  - Network Access Protocol #2

**TCP/IP: sender actions**

- **Data**
  - Physical
  - LLC
  - MAC
  - Data
  - TCP
  - IP
  - Application

**TCP/IP: router actions**

- **Data**
  - Physical
  - LLC
  - MAC
  - Data
  - TCP
  - IP
  - NAP 1
  - NAP 2

**TCP/IP: receiver actions**

- **Data**
  - Physical
  - LLC
  - MAC
  - Data
  - TCP
  - IP
  - Application