UCL Université catholique de Louvain

Computer Networks : Protocols and Practice

Part 1 : Introduction

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Module 1 : Basics

- Contents
- Introduction
  - Services in computer networks
    - Connectionless service
    - Connection oriented service
  - Layered reference models

A network ...

- A network is ...
  - a set of hardware and software that allows to transmit information from one sender to one or more receivers
- Current networks
  - Plain Old Telephone System (POTS)
  - Mobile Telephone
  - Broadcast networks
    - television, radio
  - Computer networks
    - Internet
    - Proprietary networks

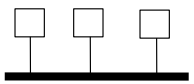
Network classification

- Based on their geographical coverage
  - 0.1-1 m : Internal bus/network
  - 10 m - 1 km : Local Area Network (LAN)
  - 1 km - 100 km : Metropolitan Area Network(MAN)
  - 100 km ->... : Wide Area Network (WAN)
  - and more ... : Satellite networks

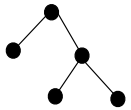
    Interplanetary network

Network classification (2)

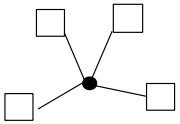
- Based on their topologies



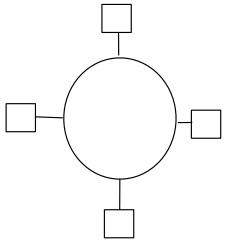
Bus



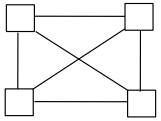
Tree



Star

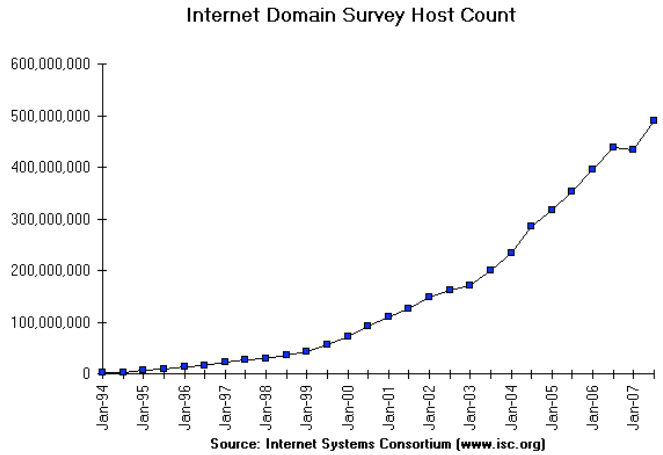


Ring

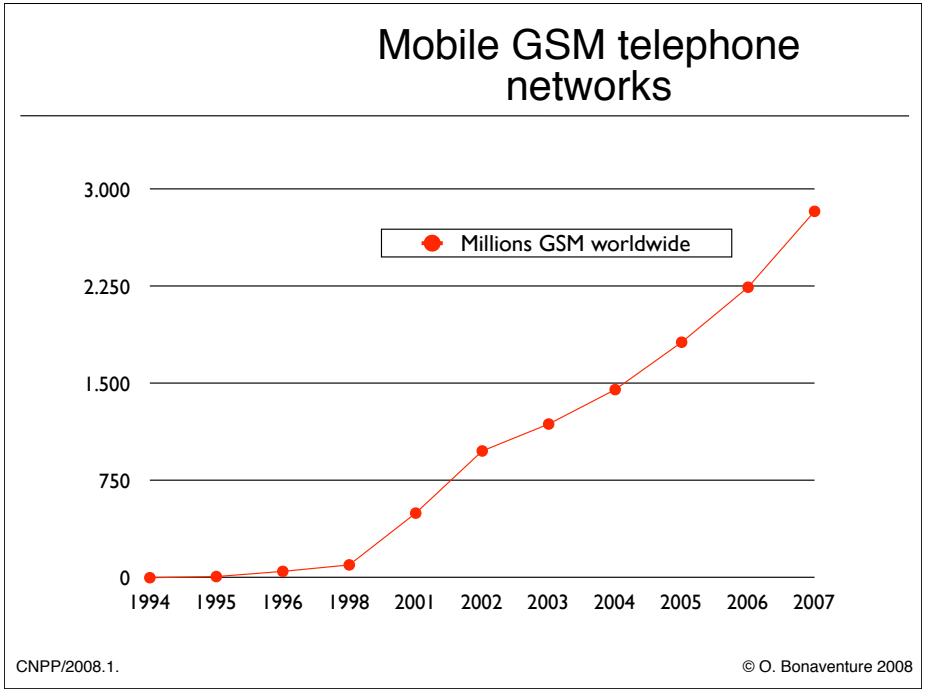


Full-mesh

Internet growth



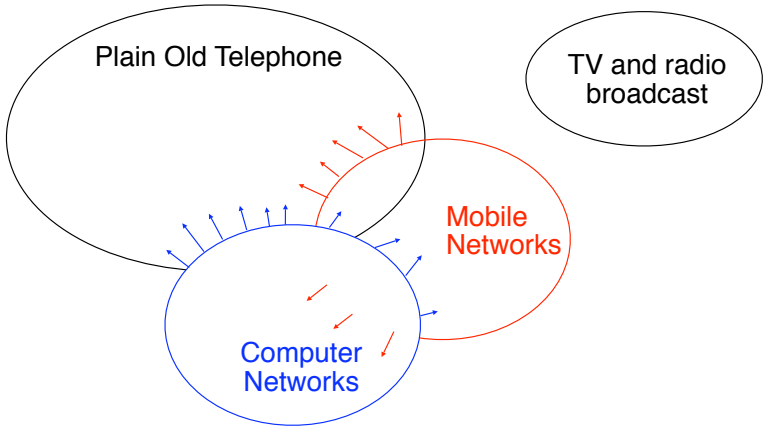
Source : http://www.isc.org
See also http://hdr.undp.org/ for information about how Internet is spread across countries



Source : http://www.gsmworld.com/news/statistics/index.shtml and http://www.gsmworld.com/about/history.shtml

The number of fixed telephone lines reached 1 billion worldwide in 2000 and the growth of fixed lines has been rather slow since then to reach 1.2 billions in 2005. See http://www.itu.int/ITU-D/ict/mdg/storyline/index.html

Evolution of networks

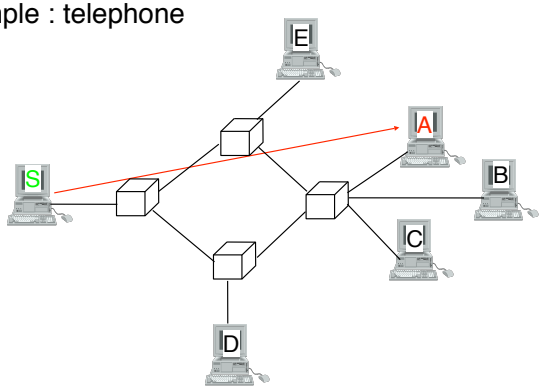


The future

- Most specialists expect
  - A strong convergence between all technologies
    - Triple play
    - Quadruple play
- New services will probably be deployed first (and perhaps exclusively) on data networks
  - Television service provided by telecom operators
  - Mobile data services
  - Mobile television services
  - Voice or video over IP
  - New services

Transmission modes
Unicast

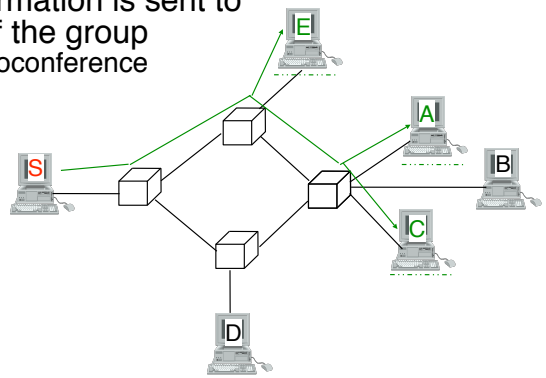
- Unicast or point-to-point
  - one sender
  - one receiver
    - example : telephone



The unicast mode is the most widely used transmission mode. We will study it in details.

Transmission modes
Multicast

- Multicast or point-to-multipoints
  - one sender
  - a group of receivers
  - The same information is sent to all members of the group
    - example : videoconference

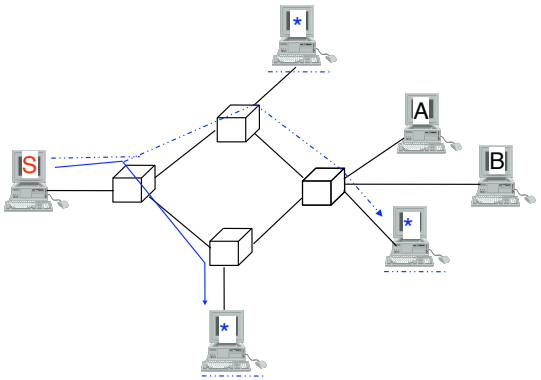


  - Broadcast
  - The same information is sent to everyone

The multicast transmission mode is described later.

Anycast

- Anycast
  - Information is sent from one sender to one receiver among a group of possible receivers
    - Example :find server hosting popular content

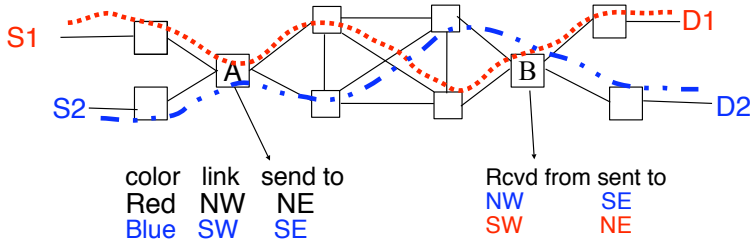


The anycast transmission mode was proposed in

C. Partridge, T. Mendez, W. Milliken, Host Anycasting Service, RFC 1546, 1993

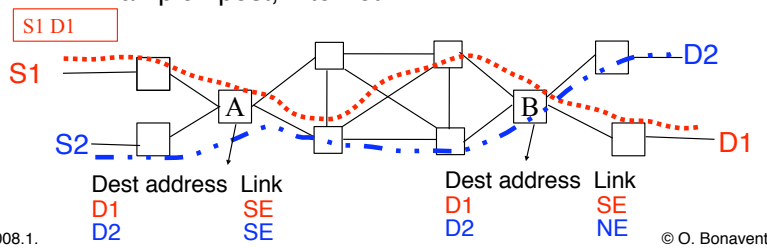
How to carry data through a network ?

- Circuit switching
  - Principle
    - before transmitting data, a circuit is established from the source to the destination hosts
    - each intermediate host knows how to forward information received on a circuit that crosses itself
  - Example : POTS

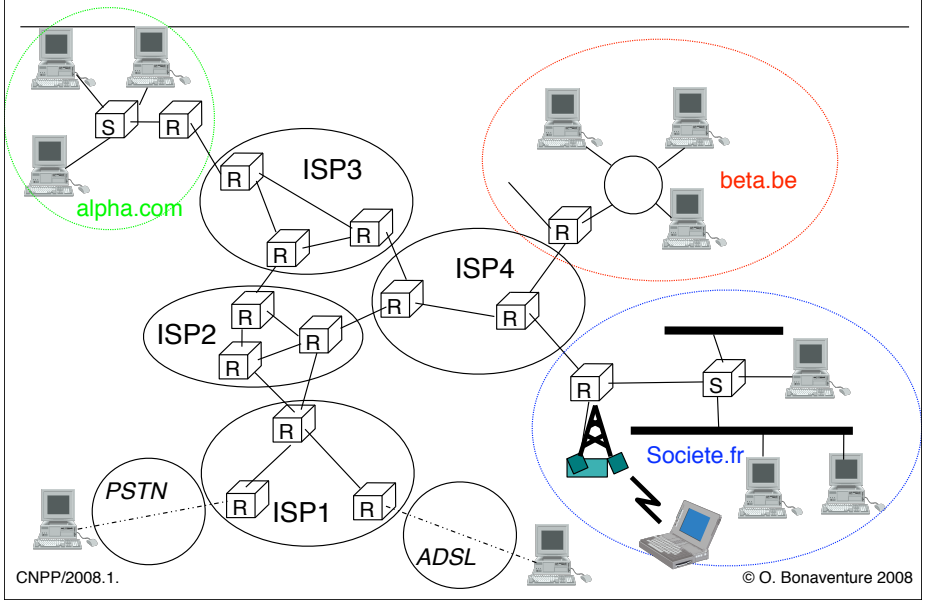


How to carry data through a network ? (2)

- Packet switching
  - Principles
    - An address is associated to each host
    - data is divided in small packets
      - each packet contains
        - the data to be exchange
        - the address of the source host
        - the address of the destination host
    - Each intermediate host knows how to reach each destination
    - Example : post, Internet



A small Internet



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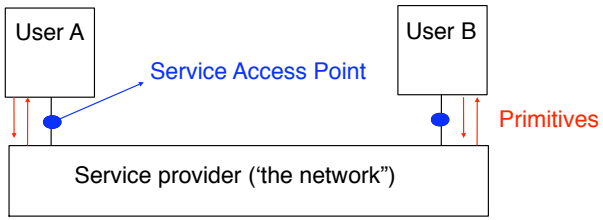
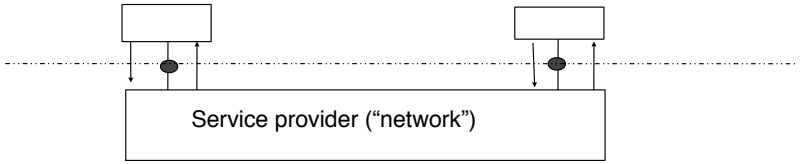
Basic concepts

- Abstract model of the network behaviour
  - Network is considered as a black box
  - Users interact with the network by using primitives that are exchanged through a service access point (SAP)

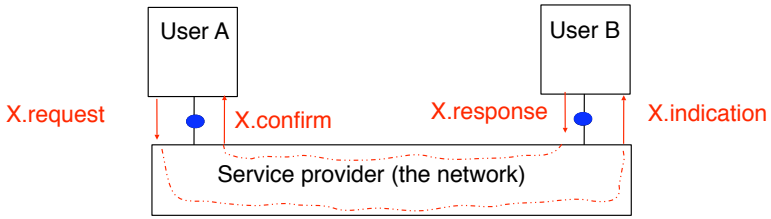


Types of primitives



- Primitive
  - Abstract representation of the interaction between one user and its network provider
  - Can contain parameters such as :
    - source
    - destination
    - message (SDU or Service Data Unit)

Types of primitives (2)



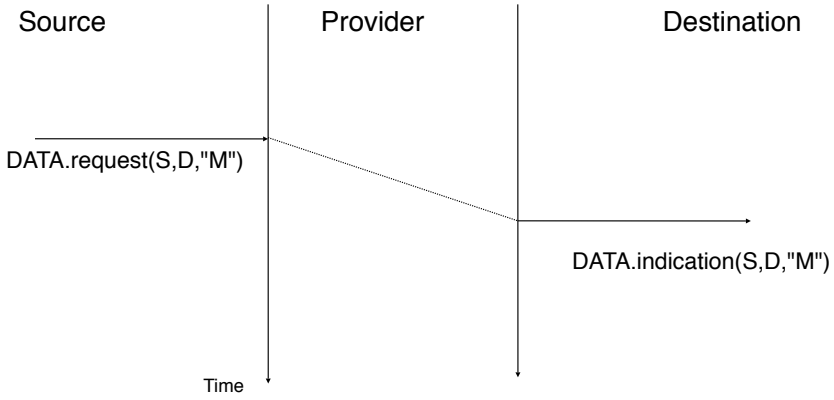
- X.request
  - request from a user to a service provider
- X.indication
  - primitive generated by the network provider to a user (often related to an earlier and remote X.request primitive)
- X.response
  - primitive used to answer to an earlier X.indication primitive
- X.confirm
  - primitive generated by the network provider to a user (related to a remote X.response primitive)

The connectionless service

- Goal
  - Allow a sender to quickly send a message to one receiver
- Principle
  - The sender places the message to be transmitted in a DATA.req primitive and gives it to the network provider
  - The network provider carries the message and delivers it to the receiver by using a DATA.ind primitive
- Utilisation
  - useful to send short-length messages
  - example : post office

Connectionless service

- Primitives
  - DATA.request(source, destination, SDU)
  - DATA.indication(source, destination, SDU)

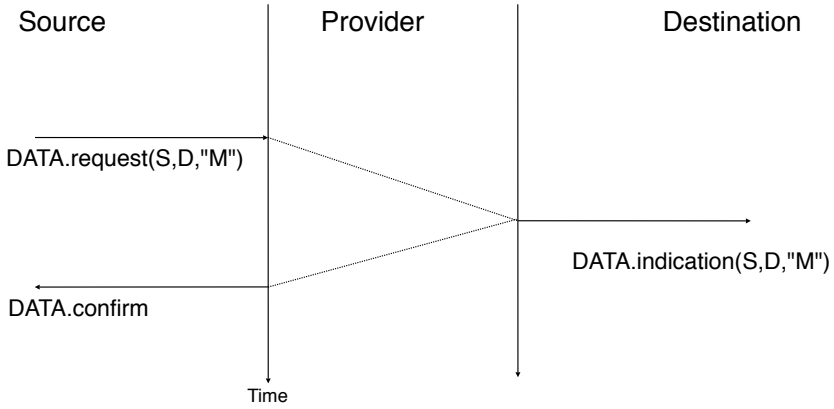


Connectionless service (2)

- Variants of connectionless service
  - confirmation
    - primitive DATA.confirm delivered by provider to sender to confirm that some message has been delivered to destination
  - reliability
    - reliable connectionless service (no errors)
    - unreliable connectionless service (errors are possible)
  - protection against transmission errors
    - service may or may not detect/correct errors
  - protection against losses
    - the service may or cannot lose messages
  - in sequence delivery
    - not guaranteed
    - in-sequence delivery for all messages sent by one source

Connectionless service (3)

- Example of acknowledged service

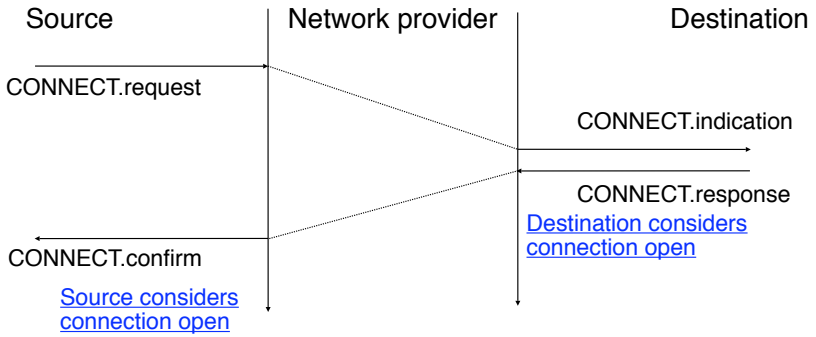


Connection-oriented service

- Goal
  - Create a logical binding (connection) between two users to allow them to efficiently exchange messages
- Main phases of service
  - Connection establishment
  - Data transfer
    - both users can send and receive messages over connection
  - Connection release
- Utilisation
  - useful when the two users either
    - must exchange a large number of messages
    - need a structured exchange
    - example : telephone

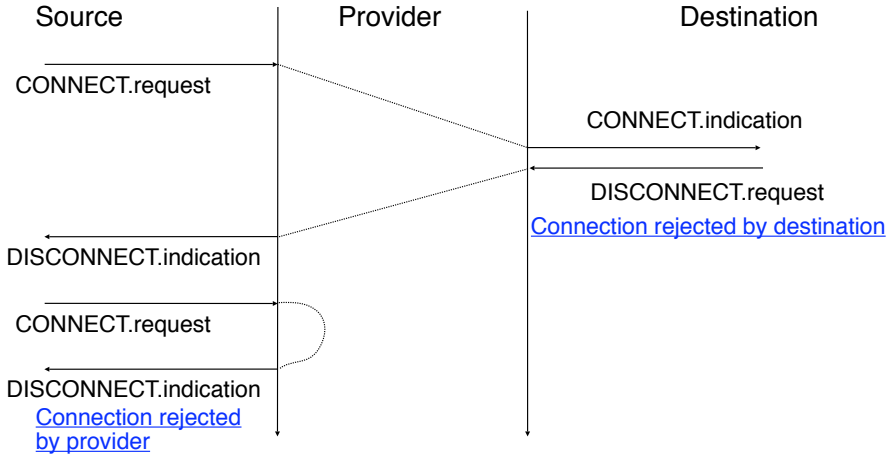
Connection oriented service

- Connection establishment
  - Primitives
    - CONNECT.request
    - CONNECT.indication
    - CONNECT.response
    - CONNECT.confirm

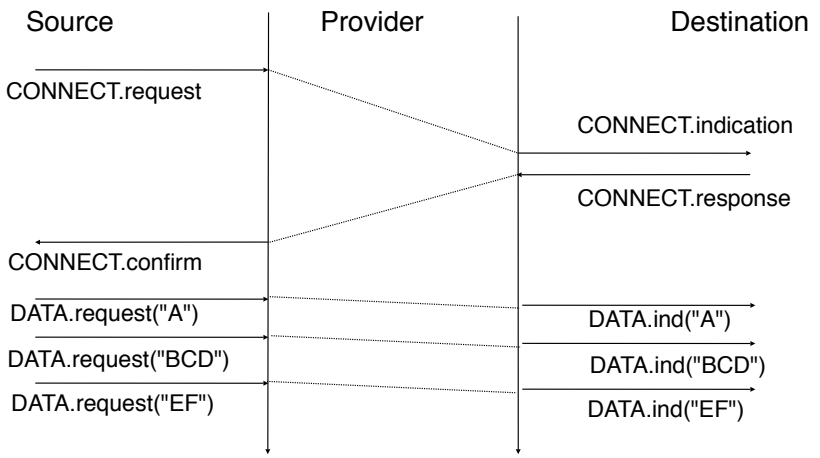


Connection oriented service (2)

- Connection can be rejected



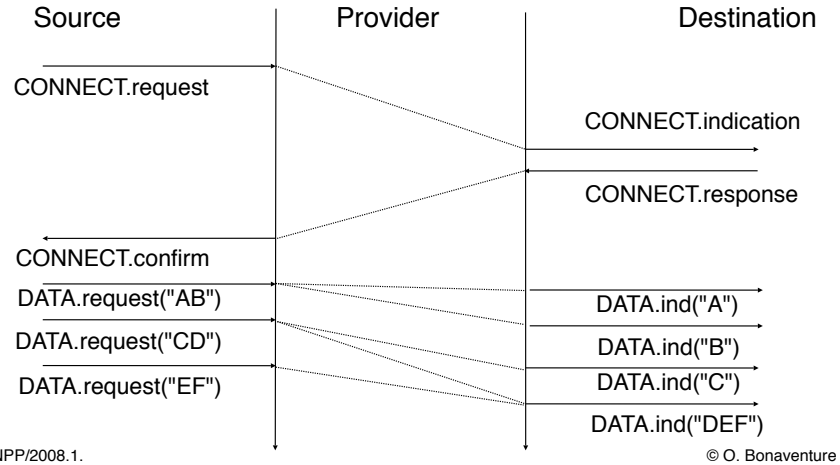
Data transfer : message mode



- Provider delivers one Data.ind for each Data.req

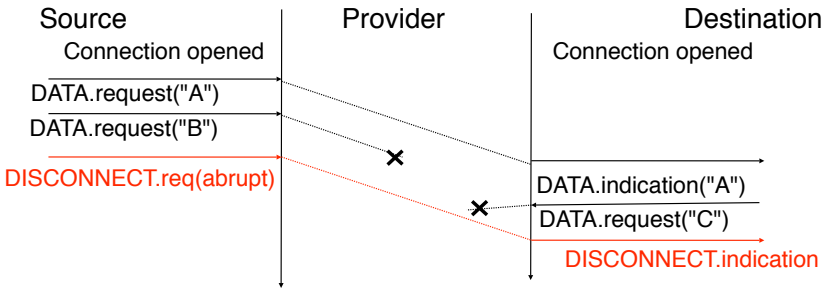
Data transfer : stream mode

- The providers delivers a stream of characters from source to destination



Connection release

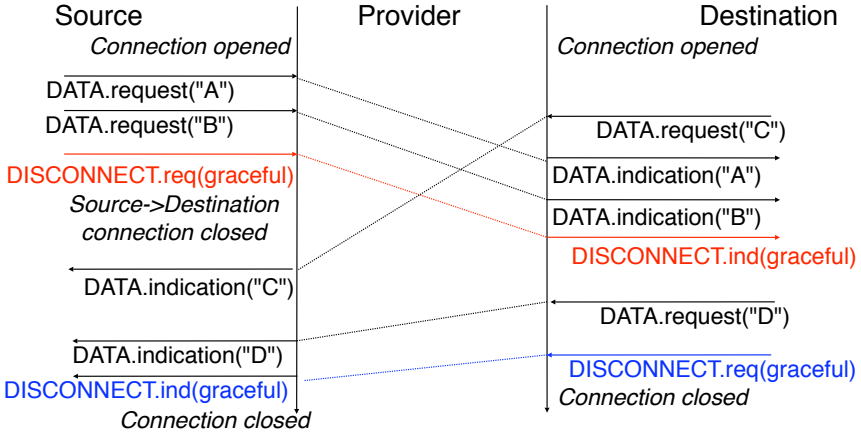
- Abrupt release
  - SDUs can be lost during connection release



  - Such an abrupt connection release can be caused by the network provider or by the users

Connection release (2)

- Ordered/graceful connection release
  - A single direction is closed at a time
  - no SDUs can be lost



Characteristics of the connection-oriented service

- Possible characteristics
  - bidirectional transmission
    - both users can send and received SDUs
  - reliable delivery
    - All SDUs are delivered in sequence
    - No SDU can be lost
    - No SDU can be corrupted
  - message mode or stream mode
  - Connection release
    - Usually abrupt when the provider is forced to release a connection
    - Abrupt or graceful when the users request the end of a connection

Module 1 : Basics

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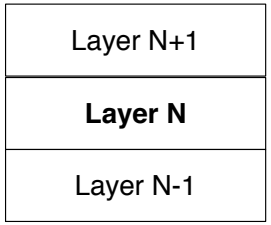
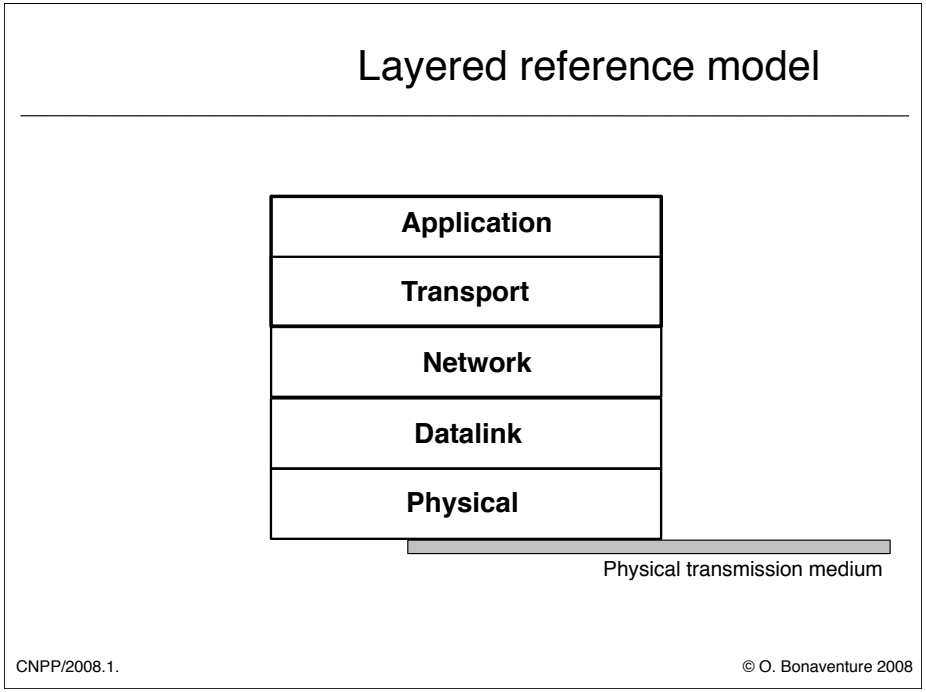
Layered reference models

- Problem
  - How is it possible to reason about complex systems such as computer networks or the Internet ?
- Solution
  - Divide the network in layers
  - Layer N provides a well defined service to layer N+1 by using the service provided by layer N-1





For more information about the design philosophy of the Internet Protocols, see:

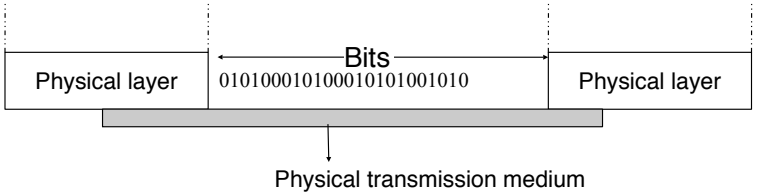
D. Clark, The Design Philosophy of the DARPA Internet Protocols, Proceedings of ACM SIGCOMM 1988, August 1998, http://www.acm.org/sigcomm/ccr/archive/995/jan95/ccr-9501-clark.html

A widely known reference model is the OSI reference model :

H. Zimmerman. Osi reference model - the iso model of architecture for open systems interconnection. IEEE Transactions on Communications, 28(4):425--432, April 1980.

In this reference model, the upper layer is divided in three layers
- application layer
- session layer
- présentation layer

The physical layer



- Goal
  - Transmit bits between two physically connected devices
- Service provided by physical layer
  - bit transmission and reception
  - unreliable service
    - The receiver may decode a 1 while the sender sent 0
    - Some transmitted bits may be lost
    - The receiver may decode more bits than the bits that were sent by the sender

Physical layer : an example

- A very simple physical layer operating at one megabit per second
  - One bit is transmitted by sender every microsecond
  - One bit is receiver by receiver every microsecond
  - Sender operation
    - To transmit bit=1, set V=5 Volts during one microsecond
    - To transmit bit=0, set V=-5 Volts during one microsecond
  - Receiver operation
    - During each microsecond, measure V
      - If V=5 Volts, a 1 has been decoded
      - If V=-5 Volts, a 0 has been decode
  - Possible problems
    - electromagnetic perturbations
    - clock drift (sender faster than receiver or opposite)

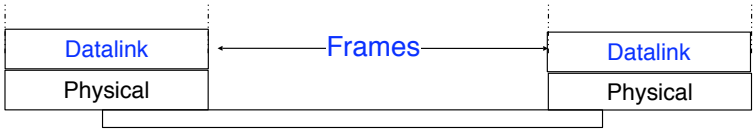
Transmission mediums

- Tapes, CDROMs and DVD
- Twisted pair
  - Telephone networks, ADSL, VDSL, ...
    - bandwidth : from a few megabits to a few 10 Mbps depending on the distance between endpoints
  - Enterprise networks
    - UTP (category 3, category 5)
    - STP (rarely used today)
    - bandwidth :up to 1 Gigabit today
      - new types of cables are being developed to reach 10 Gbps
- Wireless
  - radio
  - optical

Transmission mediums (2)

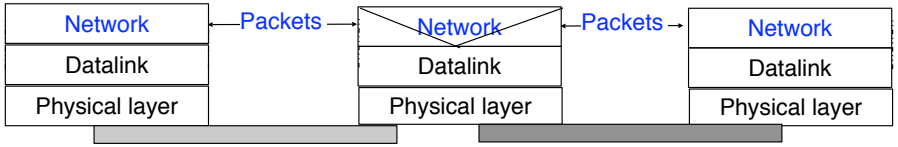
- Coaxial cable
  - Cable TV networks (CATV)
    - about 1Ghz frequency range
    - available bandwidth : depends on the split among tv distribution and data transmission
  - Computer networks
    - Used a few years ago, but not anymore today
- Optical fiber
  - monomode (laser, long distance)
  - multimode (LED, short distance)
    - frequency range : up to 100.000 Ghz
    - available bandwidth
      - 10 Gbps per wavelength and more
      - hundreds of wavelength per fiber

The datalink layer



- Goals
  - Provide a service that allows the exchange of frames
    - Frame : structured group of bits
  - Support local area networks
- Services
  - Reliable connection-oriented service
  - Unreliable connectionless service

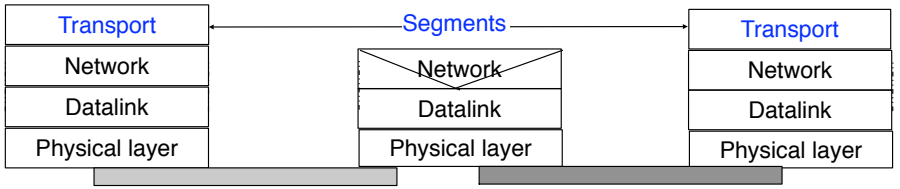
The Network Layer



- Goals
  - Allow information to be exchanged between hosts that are not attached to the same physical medium by using relays
  - The unit of information in the network layer is called a packet

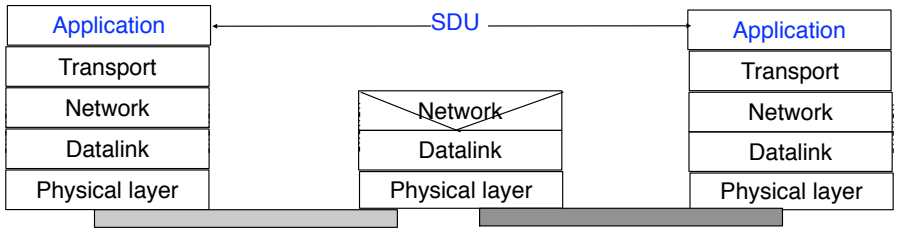
  - Services
    - unreliable connectionless (Internet)
    - reliable connection-oriented

The Transport Layer



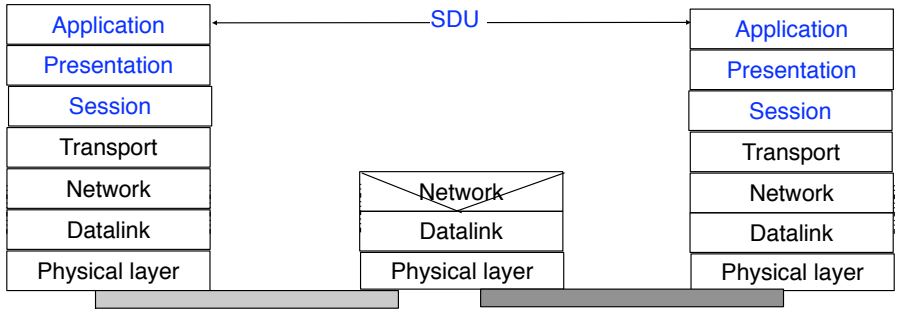
- Goals
  - Ensure a reliable exchange of data between endsystems even if the network layer does not provide a reliable service
- Services
  - Unreliable connectionless service
  - Reliable connection-oriented service

The application layer



- Goals
  - Exchange useful information between applications by relying on the transport layer that hides the complexity of the network
  - Unit of information
    - Service Data Unit, SDU

The OSI reference model



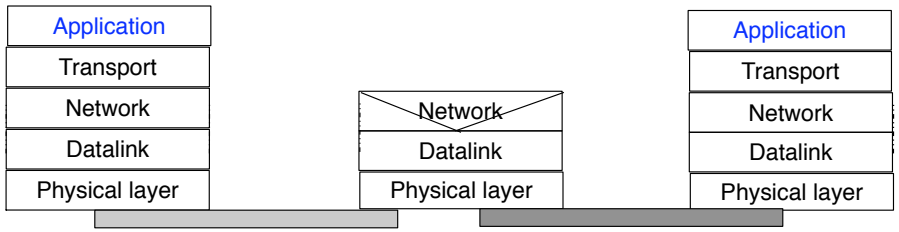
- Higher layers
  - Application
  - Presentation
    - Provides services to hide application from complexities of data/ image/audio/video encoding
  - Session
    - Organise the exchange of information between applications
    - Recover from failures of transport layer

A detailed description of the OSI reference model may be found in :

D. Piscitello, L. Chapin, Open Systems Networking : TCP/IP and OSI, Addison Wesley,1993

Course schedule

- First week : application layer
- Weeks 2-3 : transport layer (key mechanisms)
- Weeks 4-5 : transport layer in Internet (TCP,UDP)
- Weeks 6,7,8 : network layer (IP, RIP, OSPF)
- Weeks 9,10 : interdomain routing (BGP)
- Weeks 11,12 : Datalink layer (Ethernet, 802.11)



Exams and grading

- Oral exam
  - Several questions about theory and exercises
  - 60% of final grade
- Quizzes
  - Short quizzes will be organised randomly during the exercises or the theoretical lessons
  - 5% of final grade for all quizzes
- Project
  - Projects are carried *individually*
  - 35% of final grade for project
  - Project can only be done once

Projects

- Each student can choose one project
  - Transport protocol
    - The objective is to implement in Java by using the sockets API a transport protocol that provides a reliable delivery over an unreliable network
  - Routing protocol
    - The objective is to implement in Java by using the sockets API a link state routing protocol that allows routers to efficiently route packets
  - Research project
    - The objective is to perform a detailed analysis of an Internet packet trace to predict the performance of new router mechanisms