Véronique Vèque
Professeur Université Paris-Sud 11
L2S
Veronique.veque@lss.supelec.fr

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for the slides I adapted from them
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Chapter 1: roadmap

1. What is a Network?

2. Network Technologies
   1. Transmission Media
   2. Access Networks

3. Network core
   1. Circuit switching
   2. Packet switching

4. Architecture, Protocols, layers, service models
Simplified Network Model
**Simplified Network Model**

- Addressing and routing
- Network Management
- Packet Transfer
- Multiplexing

*Source: Stallings*
Definition

- A computer network, often simply referred to as a network, is a group of computers and devices interconnected by communications channels that facilitate communications among users and allows users to share resources.


- Networks may be classified according to a wide variety of characteristics depending on their scale, technology, scope and purpose...
Network classification/ scale

PAN - Personal Area Network
LAN – Local Area Network
MAN – Metropolitan Area Network
WAN – Wide Area Network

Differences:
Clock
Parallel vs Serial
Hierarchical view of a network

Wide Area Network

Metropolitan Area Network

Access Network

Long-Haul Networks (WANs)

Optical WDM cross-connect mesh

Multiple regional and backbone providers

Intra-metro connection

Inter-metro connection

Residential x-DSL or cable modem networks

PSTN/cellular

Regional ISP

Corporate enterprise clients
Networks: access

- **Access Network**
  - Layers 1/2
  - Private
  - Residential access nets
  - Institutional access networks (school, company) or Local Area Network
  - Mobile access networks

- **Metropolitan Network**

- **Long-haul Network**
Networks: metro

- **Access Network**
- **Metropolitan Network**
  - a large computer network that spans a metropolitan area or campus.
  - between a WAN and LAN
  - provide Internet connectivity for LANs in a metropolitan region, and connect them to wider area networks like the Internet
  - Use optical fiber and Giga-Ethernet
- **Long-haul Network**
Networks: long haul

- Access Network
- Metropolitan Network
- Long-haul (backhaul) Network or Wide Area Network
  - Large geographical area (regions, countries, world)
  - To connect the others
  - Crossing public rights of way
  - Alternative technologies to share efficiently the infrastructure
    - Circuit switching
    - Packet/cell switching
    - Optical Technologies

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A closer look at network structure:

- **network edge:**
  - applications and hosts
- **access networks,**
  - physical media: wired, wireless
  - communication links
- **network core:**
  - interconnected routers
  - network of networks
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Types of media

- Copper wire
- Wireless
- Laser
- Optical fiber

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Physical Media

- **Bit**: propagates between transmitter/rcvr pairs
- **physical link**: what lies between transmitter & receiver
- **guided media**:
  - signals propagate in solid media: copper, fiber, coax
- **unguided media**:
  - signals propagate freely, e.g., radio

**Twisted Pair (TP)**
- two insulated copper wires
  - Category 3: traditional phone wires, 10 Mbps Ethernet
  - Category 5: 100Mbps Ethernet
# Twisted Pair categories

https://en.wikipedia.org/wiki/Twisted_pair

<table>
<thead>
<tr>
<th>Category</th>
<th>Bandwidth</th>
<th>Max Data Rate</th>
<th>Intended Use</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>0.4 MHz</td>
<td>1 Mbps</td>
<td>Voice only-Telephone and modem lines</td>
</tr>
<tr>
<td>2</td>
<td>4 MHz</td>
<td>4 Mbps</td>
<td>Older terminal systems, e.g. IBM 3270</td>
</tr>
<tr>
<td>3</td>
<td>16 MHz</td>
<td>16 Mbps</td>
<td>10BaseT Ethernet</td>
</tr>
<tr>
<td>4</td>
<td>20 MHz</td>
<td>20 Mbps</td>
<td>16 Mbps Token Ring</td>
</tr>
<tr>
<td>5</td>
<td>100 MHz</td>
<td>100 Mbps (2 pair)</td>
<td>100BaseTX - 1000BaseT Ethernet</td>
</tr>
<tr>
<td>5e</td>
<td>100 MHz</td>
<td>1000 Mbps (4pair)</td>
<td>100BaseTX - 1000BaseT Ethernet</td>
</tr>
<tr>
<td>6</td>
<td>500 MHz</td>
<td>1000 Mbps (4pair)</td>
<td>10GBaseT - Ethernet</td>
</tr>
<tr>
<td>6a</td>
<td>600 MHz</td>
<td>10 Gbps</td>
<td>10GBaseT - Ethernet</td>
</tr>
<tr>
<td>7</td>
<td>1000 MHz</td>
<td>10 Gbps</td>
<td>Telephone, CCTV, 1000BASE-TX in the same cable. 10GBASE-T Ethernet.</td>
</tr>
<tr>
<td>7a</td>
<td>1600-2000 MHz</td>
<td>1 - 10 Gbps</td>
<td>Telephone, CATV, 1000BASE-TX in the same cable. 10GBASE-T Ethernet.</td>
</tr>
<tr>
<td>8.1</td>
<td>1600-2000 MHz</td>
<td>1- 40 Gbps</td>
<td>Telephone, CATV, 1000BASE-TX in the same cable. 40GBASE-T Ethernet.</td>
</tr>
<tr>
<td>8.2</td>
<td>1600-2000 MHz</td>
<td>1- 40 Gbps</td>
<td>Telephone, CATV, 1000BASE-TX in the same cable. 40GBASE-T Ethernet.</td>
</tr>
</tbody>
</table>
Physical Media: coax, fiber

**Coaxial cable:**
- two concentric copper conductors
- bidirectional
- baseband:
  - single channel on cable
  - legacy Ethernet
- broadband:
  - multiple channels on cable
  - HFC

**Fiber optic cable:**
- glass fiber carrying light pulses, each pulse a bit
- high-speed operation:
  - high-speed point-to-point transmission (e.g., 10’s-100’s Gps)
- low error rate: repeaters spaced far apart; immune to electromagnetic noise
**Structure**

- **Pure Glass Core**: 8.3 micron*
- **Glass Cladding**: Protects “core” Serves as a “Light guide”
- **Inner Polymer Coating**
- **Outer Polymer Coating**: 250 micron

**Lightpack Cable Design**

**Typical Loss**: 0.2 - 0.25 dB/km

*Single Mode Fiber; Multi-Mode Has A 50 Micron Core

*Source: Stallings*
Generations : 1st et 2nd

First generation
- $\lambda=850$ nm (first spectral window)
- Step index multimode
  - Attenuation: 40 MHz/km
- Gradient index multimode
  - Attenuation: 500 MHz/km
- Diameter: 50-125 $\mu$m
- Code 4B/5B LED or lasers multimodes
- $B=45$ Mbit/s
- $L=10$ km

Exemple : Fiber Distributed Data Interface (FDDI)

2° generation
- $\lambda=1300$ nm (second)
- Fiber optic single mode
- Diameter: 2-8 $\mu$m
- Low losses: 100 GHz/km
- Null dispersion
- Lasers multimode
- $B>1$ Gbit/s
- $L>50$ km
Generations: 3th and 4th

- 3rd generation
  - $\lambda=1550$ nm (third)
  - Fiber optic single mode
  - Min Losses (0.2 db/km)
  - Dispersion
  - Lasers monomode
  - $B=10$ Gbit/s
  - $L=60-70$ km

- 4th generation
  - $\lambda=1550$ nm
  - Fibers optic single mode
  - Lasers single mode
  - $B=10-40$ Gbit/s
  - Optical Amplifiers
  - Wavelegth Multiplexing: WDM (~200 GHz spacing), DWDM (~50 GHz spacing)
  - $L=60-80$ km between 2 amplifiers, total length >1000 km
  - Capacity>1 Tbit/s
  - Usage: transcontinental links
Optical Fiber Transmission Modes

(a) Step-index multimode

(b) Graded-index multimode

(c) Single mode
Physical media: radio

- signal carried in electromagnetic spectrum
- no physical “wire”
- bidirectional
- propagation environment effects:
  - reflection
  - obstruction by objects
  - interference

Radio link types:

- terrestrial microwave
  - e.g. up to 45 Mbps channels
- LAN (e.g., Wifi)
  - 11Mbps, 54 Mbps
- wide-area (e.g., cellular)
  - 3G cellular: ~ 1 Mbps
- satellite
  - Kbps to 45Mbps channel (or multiple smaller channels)
  - 270 msec end-end delay
  - geosynchronous versus low altitude
Throughput vs Distance
### Frequencies

- Frequency: $\nu$
- Wavelength: $\lambda$

$$c = \nu \lambda$$
Electromagnetic Spectrum

Source: Data and Computer Communications W. Stallings

Frequency (Hertz)

- ELF = Extremely low frequency
- VF = Voice frequency
- VLF = Very low frequency
- LF = Low frequency
- MF = Medium frequency
- HF = High frequency
- VHF = Very high frequency
- UHF = Ultrahigh frequency
- SHF = Superhigh frequency
- EHF = Extremely high frequency

Wavelength in space (meters)

- ELF
- VF
- VLF
- LF
- MF
- HF
- VHF
- UHF
- SHF
- EHF

Power and telephone
- Rotating generators
- Musical instruments
- Voice microphones

Twisted Pair

Coaxial Cable

AM Radio

FM Radio and TV

Terrestrial and Satellite Transmission

Infrared
- Lasers
- Guided missiles
- Rangefinders

Visible light

Optical Fiber
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Dial-up Modem

- Uses existing telephony infrastructure
  - Home is connected to central office
- up to 56Kbps direct access to router (often less)
- Can’t surf and phone at same time: not “always on”
residential Access: xDSL, ADSL

To increase throughput of twisted pairs more than 33.6 or 56 Kbps

- Physical problems:
  - Energy dissipation
  - Joule effect: white noise (SNR)
  - Ohm Law: attenuation / propagation length, diameter of cable, and signal frequency
  - Diaphony: transfer of energy between neighbour pairs

- Alternatives:
  - Fiber-to-the-home: some deployments, not everywhere
  - TV cable: not everywhere, limited throughput

DSL = Digital Subscriber Line
ADSL: DMT technique

- Type of frequency multiplexing (OFDM)

- DMT (Discrete MultiTone): bandwidth divided into 256 channels 4.3 kHz each separated by 4.3 kHz bands
  - 1: voice
  - 2-6: unused
  - 32 channels: upstream
  - γ signaling channels
  - x channels: downstream
Digital Subscriber Line (DSL)

- Also uses existing telephone infrastructure
- Up to 1 Mbps upstream (today typically < 256 kbps)
- Up to 8 Mbps downstream (today typically < 1 Mbps)
- Dedicated physical line to telephone central office
ADSL: Throughput vs distance

Débits en fonction de la distance

ADSL1 : 1,1 MHz
ADSL2 : modul QAM
ADSL2+: 2,2 MHz
Residential access: cable modems

- Does not use telephone infrastructure
  - Instead uses cable TV or fiber optics infrastructure

- First generation
  - HFC: hybrid fiber coax
  - asymmetric: up to 30Mbps downstream, 2 Mbps upstream
  - network of cable (before) and fiber attaches homes to ISP router
  - homes share access to router
  - unlike DSL, which has dedicated access
Cable Network Architecture: Overview

Typically 500 to 5,000 homes
Next generation: Fiber to the Home

- Optical links from central office to the home
- Two competing optical technologies:
  - Passive Optical network (PON)
  - Active Optical Network (PAN)
- Much higher Internet rates; fiber also carries television and phone services
Institutional network

to external network

router

mail server

web server

IP subnet

5: DataLink Layer
Internet access: Ethernet

- Typically used in companies, universities, etc
- (10 Mbps) 100Mbps, 1Gbps, 10Gbps Ethernet
- Today, end systems typically connect into Ethernet switch
MAC Addresses and ARP

- **32-bit IP address:**
  - network-layer address
  - used to get datagram to destination IP subnet

- **MAC (or LAN or physical or Ethernet) address:**
  - function: get frame from one interface to another physically-connected interface (same network)
  - 48 bit MAC address (for most LANs)
    - burned in NIC ROM, also sometimes software settable

- **Address Resolution Protocol (ARP)**
  - Request broadcasted by a source: “who has the Ethernet addr corresponding of @IP=X.Y.Z.W?”
  - Response by the host @IP=X.Y.Z.W: “my Ethernet addr is FF:FE:12:34:A6:E8”
LAN Addresses and ARP

Each adapter on LAN has unique LAN address

Broadcast address = FF-FF-FF-FF-FF-FF

= adapter

1A-2F-BB-76-09-AD

71-65-F7-2B-08-53

58-23-D7-FA-20-B0

0C-C4-11-6F-E3-98

LAN (wired or wireless)

5: DataLink Layer
Where is the link layer implemented?

- in each and every host
- link layer implemented in “adaptor” (aka network interface card NIC)
  - Ethernet card, PCMCI card, 802.11 card
  - implements link, physical layer
- attaches into host’s system buses
- combination of hardware, software, firmware
Wireless access networks

- **shared wireless access** network connects end system to router
  - via base station aka “access point”

- **wireless LANs:**
  - 802.11b/g (WiFi): 11 or 54 Mbps

- **wider-area wireless access**
  - provided by telco operator
  - ~1Mbps over cellular system (EVDO, HSDPA)
  - next up (?) : WiMAX (10’s Mbps) over wide area
**Home networks (1)**

Typical home network components: first generation

- DSL or cable modem
- router/firewall/NAT
- Ethernet
- wireless access point

![Diagram of home network components](image)
Home networks (2)

Typical home network components: Now

- DSL or cable modem
- router/firewall/NAT
- Ethernet
- wireless access point

- television to/from cable headend

"box" Ethernet wireless laptops
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The Network Core

- mesh of interconnected routers
- the fundamental question: how is data transferred through net?
  - circuit switching: dedicated circuit per call: telephone net
  - packet-switching: data sent thru net in discrete “chunks”
Network Sharing = Multiplexing

- FDM: Frequency Division Mux
- TDM: Time Division Mux
  - Synchronous: STDM  Circuit-switching
  - Asynchronous: ATDM  Packet-switching
Circuit Switching: FDM and TDM

Example:
4 users

FDM

TDM

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Synchronous Time Division Multiplexing

- Data rate of medium exceeds data rate of digital signal to be transmitted
- Multiple digital signals interleaved in time
- May be at bit level of blocks
- Time slots preassigned to sources and fixed
- Time slots allocated even if no data
- Time slots do not have to be evenly distributed amongst sources
Synchronous TDM

- Synchronous mode
  - The frame (multiplex) is synchronized with the input link rate
  - The output rate is a multiple of the input rate
  - Demux = N * d_i

- Static allocation of bandwidth
  - circuit

- Adaptable to periodic traffic
- No waiting in nodes
- Inefficient bandwidth allocation

Examples of frames:
- T1 (G.733): 24 bytes (+ 1 bit synchro) every 125 μs (1.544 Mbit/s)
- E1 (G.732): 32 bytes every 125 μs (2.048 Mbit/s)
**Network Core: Circuit Switching**

End-to-end resources reserved for “call”

- link bandwidth, switch capacity, translation table
- dedicated resources: no sharing
- circuit-like (guaranteed) performance
- The switching node switches the time slots on the next multiplex
- synchronous: no buffering
- call setup required
  1. Connection Set Up
  2. Data Transfer
  3. End of connection
Digital Carrier Systems

- Hierarchy of TDM
- USA/Canada/Japan use one system
- ITU-T uses a similar (but different) system
- US system based on DS-1 format
- Multiplexes 24 channels
- Each frame has 8 bits per channel plus one framing bit
- 193 bits per frame
G 733

Réseau partie 1 / 78
V. Vèque - U. Psud
Numerical example

- How long does it take to send a file of 6,000,000 bits from host A to host B over a circuit-switched network?
  - G732 standard
  - (All links are 2,048 Mbit/s)
  - Each link uses TDM with 30 slots/sec to send data
  - 500 msec to establish end-to-end circuit

Let’s work it out!
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Network Core: Packet Switching

each end-end data stream divided into packets

- user A, B packets share network resources
- each packet uses full link bandwidth
- resources used as needed

Bandwidth division into "pieces"
- Dedicated allocation
- Resource reservation

resource contention:
- aggregate resource demand can exceed amount available
- congestion: packets queue, wait for link use
- store and forward: packets move one hop at a time
  - Node receives complete packet before forwarding
Message Switching vs Packet Switching

Message are divided into small packets

Pipeline!
**Packet Switching: Statistical Multiplexing**

Sequence of A & B packets does not have fixed pattern, bandwidth shared on demand → **statistical multiplexing**.

TDM: each host gets same slot in revolving TDM frame.
Packet-switching: store-and-forward

- Takes \( \frac{L}{R} \) seconds to transmit (push out) packet of \( L \) bits on to link at \( R \) bps
- **Store and forward**: entire packet must arrive at router before it can be transmitted on next link
- Delay = \( 3L/R \) (assuming zero propagation delay and zero processing delay)

**Example:**
- \( L = 7.5 \) Mbits
- \( R = 1.5 \) Mbps
- Transmission delay = 15 sec

More on delay shortly...
Packet switching versus circuit switching

Packet switching allows more users to use network!

- 1 Mb/s link
- each user:
  - 100 kb/s when “active”
  - active 10% of time
- circuit-switching:
  - 10 users
- packet switching:
  - with 35 users, probability > 10 active at same time is less than 0.0004

Q: how did we get value 0.0004?
Packet switching versus circuit switching

Is packet switching a “slam dunk winner?”

- great for bursty data
  - resource sharing
  - simpler, no call setup
- excessive congestion: packet delay and loss
  - protocols needed for reliable data transfer, congestion control
- Q: How to provide circuit-like behavior?
  - bandwidth guarantees needed for audio/video apps
  - still an unsolved problem (QoS Chapter)

Q: human analogies of reserved resources (circuit switching) versus on-demand allocation (packet-switching)?
Packet-switched networks: forwarding

- **Goal**: move packets through routers from source to destination
  - we'll study several path selection (i.e. routing) algorithms (Lec.xx)

- **Datagram network**:
  - *destination address* in packet determines next hop
  - routes may change during session
  - analogy: driving, asking directions

- **Virtual circuit network**:
  - each packet carries tag (virtual circuit ID), tag determines next hop
  - fixed path determined at *call setup time*, remains fixed thru call
  - *routers maintain per-call state*
Virtual Circuit principles

As for circuit switching, 3 steps
1. Connection Set Up: consist to register connection Id in tables
2. Data Transfer (using cx Id)
3. End of connection (remove table entry)
Network Taxonomy

Telecommunication networks

Circuit-switched networks
- FDM
- STDM

Packet-switched networks
- Networks with VCs
- Datagram Networks

Physical Level

Another classification!

Network/Link Level
Network Taxonomy

Telecommunication networks

Circuit-switched networks
- FDM
  - Wireless Networks / frequency planning
- STDM
  - Digital Services integrated Network (fixed telephony & GSM) Satellite

Packet-switched* Networks (ATDM)
- Networks with VCs
  - (X25) Frame Relay, ATM, MPLS
- Datagram Networks
  - IP

*now packet switching becomes frame switching
Switching Techniques Revisited

(a) Circuit switching
- Call request signal
- Propagation delay
- Processing delay
- Call accept signal
- User data
- Acknowledge-ment signal

(b) Virtual circuit packet switching
- Call request packet
- Packet packets
- Acknowledge-ment packet

(c) Datagram packet switching
- Call accept packet
- Packet packets
**Exercise**

N = number of hops  
L = message length (bits)  
R = data rate (bps)  
P = packet size (bits)  
H = packet overhead (not included in packet size)  
S = setup time (sec)  
D = propagation delay per hop (sec)

Compute end-to-end delay for
1. circuit switching,
2. datagram
3. virtual circuit packet switching,

For N=4, L=3200, R=9600, P=1024, H=16, S=0.2, D=0.001
Exercice (Kurose, Ross)

- Consider an application which transmits data at a steady rate (e.g., the sender generates a N bit unit of data every k time units, where k is small and fixed). Also, when such an application starts, it will stay on for relatively long period of time. Answer the following questions, briefly justifying your answer:

- Would a packet-switched network or a circuit-switched network be more appropriate for this application? Why?

- Suppose that a packet-switching network is used and the only traffic in this network comes from such applications as described above. Furthermore, assume that the sum of the application data rates is less that the capacities of each and every link. Is some form of congestion control needed? Why?
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What’s a protocol?

human protocols:
- “what’s the time?”
- “I have a question”
- “excuse-me, could you…”
- introductions

... specific msgs sent
... specific actions taken when msgs received, or other events

network protocols:
- machines rather than humans
- all communication activity in Internet governed by protocols

protocols define format, order of msgs sent and received among network entities, and actions taken on msg transmission, receipt
What’s a protocol?

a human protocol and a computer network protocol:

Q: Other human protocols?
Protocol “Layers”

Networks are complex!
- many “pieces”:
  - hosts
  - routers
  - links of various media
  - applications
  - protocols
  - hardware, software

Question:
Is there any hope of organizing structure of network?
Or at least our discussion of networks?
What is Layering?

- A technique to organize a network system into a succession of logically distinct entities, such that the service provided by one entity is solely based on the service provided by the previous (lower level) entity.

- Advantages
  - Modularity - protocols easier to manage and maintain
  - Abstract functionality - lower layer can be changed without affecting the upper layer
  - Reuse - upper layer can reuse the functionality provided by lower layer

- Disadvantages
  - Information hiding - inefficient implementations
**Organization of air travel**

- ticket (purchase)
- baggage (check)
- gates (load)
- runway takeoff
- airplane routing

- ticket (complain)
- baggage (claim)
- gates (unload)
- runway landing
- airplane routing

- a series of steps
Layering of airline functionality

Layers: each layer implements a service
- via its own internal-layer actions
- relying on services provided by layer below
Why layering?

Dealing with complex systems:
- explicit structure allows identification, relationship of complex system’s pieces
  - layered reference model for discussion
- modularization eases maintenance, updating of system
  - change of implementation of layer’s service transparent to rest of system
  - e.g., change in gate procedure doesn’t affect rest of system
- layering considered harmful?
Internet protocol stack

- **application**: supporting network applications
  - FTP, SMTP, HTTP
- **transport**: process-process data transfer
  - TCP, UDP
- **network**: routing of datagrams from source to destination
  - IP, routing protocols
- **link**: data transfer between neighboring network elements
  - PPP, Ethernet
- **physical**: bits “on the wire”, signal transmission
ISO OSI Reference Model

- **ISO** – International Standard Organization
- **OSI** – Open System Interconnection
- Started to 1978; first standard 1979
  - ARPANET started in 1969; TCP/IP protocols ready by 1974
- **Goal**: a general open standard
  - Allow vendors to enter the market by using their own implementation and protocols
ISO OSI Reference Model

- Seven layers
  - Lower three layers are peer-to-peer
  - Next four layers are end-to-end
Data Transmission

- A layer can use only the service provided by the layer immediate below it.
- Each layer may change and add a header to data packet.

![Diagram of data transmission](image-url)
**OSI Model Concepts**

- **Service** - says *what* a layer does
- **Interface** - says *how to access* the service
- **Protocol** - says *how* is the service implemented
  - A set of rules and formats that govern the communication between two peers
**Physical Layer (1)**

- **Service:** move the information between two systems connected by a physical link
- **Interface:** specifies how to send a bit
- **Protocol:** coding scheme used to represent a bit, voltage levels, duration of a bit

- **Examples:** coaxial cable, optical fiber links; transmitters, receivers
Datalink Layer (2)

- **Service:**
  - Framing, i.e., attach frames separator
  - Send data frames between peers attached to the same physical media
  - Others (optional):
    - Arbitrate the access to common physical media
    - Ensure reliable transmission
    - Provide flow control

- **Interface:** send a data unit (packet) to a machine connected to the same physical media

- **Protocol:** layer addresses, implement Medium Access Control (MAC) (e.g., CSMA/CD)...
Network Layer (3)

- **Service:**
  - Deliver a packet to specified destination
  - Perform segmentation/reassemble (fragmentation/defragmentation)
  - **Others:**
    - Packet scheduling
    - Buffer management

- **Interface:** send a packet to a specified destination

- **Protocol:** define global unique addresses; construct routing tables
Data and Control Planes

- Data plane: concerned with
  - Packet forwarding
  - Buffer management
  - Packet scheduling

- Control Plane: concerned with installing and maintaining state for data plane
Example: Routing

- Data plane: use Forwarding Table to forward packets
- Control plane: construct and maintain Forwarding Tables (e.g., Distance Vector, Link State protocols)
**Transport Layer (4)**

- **Service:**
  - Provide an *error-free* and *flow-controlled* end-to-end connection
  - Multiplex multiple transport connections to one network connection
  - Split one transport connection in multiple network connections

- **Interface:** send a packet to specify destination

- **Protocol:** implement reliability and flow control

- **Examples:** TCP and UDP
Session Layer (5)

- **Service:**
  - Full-duplex
  - Access management, e.g., token control
  - Synchronization, e.g., provide check points for long transfers

- **Interface:** depends on service

- **Protocols:** token management; insert checkpoints, implement roll-back functions
Presentation Layer (6)

- **Service**: convert data between various representations
- **Interface**: depends on service
- **Protocol**: define data formats, and rules to convert from one format to another
Application Layer (7)

- **Service**: any service provided to the end user
- **Interface**: depends on the application
- **Protocol**: depends on the application
- **Examples**: FTP, Telnet, WWW browser
**OSI vs. TCP/IP**

- **OSI**: conceptually define: service, interface, protocol
- **Internet**: provide a successful implementation

<table>
<thead>
<tr>
<th>OSILayers</th>
<th>TCP/IPLayers</th>
</tr>
</thead>
<tbody>
<tr>
<td>Application</td>
<td>Application</td>
</tr>
<tr>
<td>Presentation</td>
<td>Telnet</td>
</tr>
<tr>
<td>Session</td>
<td>FTP</td>
</tr>
<tr>
<td>Transport</td>
<td>DNS</td>
</tr>
<tr>
<td>Network</td>
<td>TCP</td>
</tr>
<tr>
<td>Datalink</td>
<td>UDP</td>
</tr>
<tr>
<td>Physical</td>
<td>IP</td>
</tr>
<tr>
<td><strong>Host-to-network</strong></td>
<td>LAN</td>
</tr>
<tr>
<td><strong>Internet</strong></td>
<td>Packet radio</td>
</tr>
</tbody>
</table>
Encapsulation

message \( M \)
segment \( H_t \)
datagram \( H_n \)
frame \( H_l \)

source

application
transport
network
link
physical

destination

application
transport
network
link
physical

link
physical

switch

router

Introduction 1-127
Summary ...

- architecture = set of layers and protocols
- decomposition into layers
  - A layer offers and realizes some homogeneous functions to solve a part of the communication
- To distinguish
  - protocols vs interfaces
  - Virtual communications and true communications
- advantages
  - More easy to understand and to implement
  - To avoid some interactions
  - To change a protocol at one layer without modifying all the architecture ex: network card
Homework (1)

<table>
<thead>
<tr>
<th>Question</th>
<th>Answer</th>
</tr>
</thead>
<tbody>
<tr>
<td>What is the difference between ADSL1, ADSL2, ADSL2+?</td>
<td></td>
</tr>
<tr>
<td>What are the transmission rate of Ethernet LANs? For a given transmission rate, can each user on the LAN continuously transmit at that rate?</td>
<td></td>
</tr>
<tr>
<td>Dail-up modems, ISDN, HFC and ADSL are all used for residential access. For each of these access technologies, provide a range of transmission rates and comment on whether the bandwidth is shared or dedicated.</td>
<td></td>
</tr>
<tr>
<td>What advantage does a circuit-switched network have over a packet-switched network?</td>
<td></td>
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</tbody>
</table>
## Homework (2)

<table>
<thead>
<tr>
<th>Question</th>
<th>Answer</th>
</tr>
</thead>
<tbody>
<tr>
<td>Why communications are layered?</td>
<td></td>
</tr>
<tr>
<td>What is the difference between a layer and a protocol?</td>
<td></td>
</tr>
<tr>
<td>What is meant by connection state information in a virtual-circuit network?</td>
<td></td>
</tr>
<tr>
<td>What are some of the networking technologies that use virtual circuits? Find good URLs that discuss and explain these technologies.</td>
<td></td>
</tr>
<tr>
<td>Find the equivalent Moore’s law for communication networks</td>
<td></td>
</tr>
</tbody>
</table>