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Computer Networks
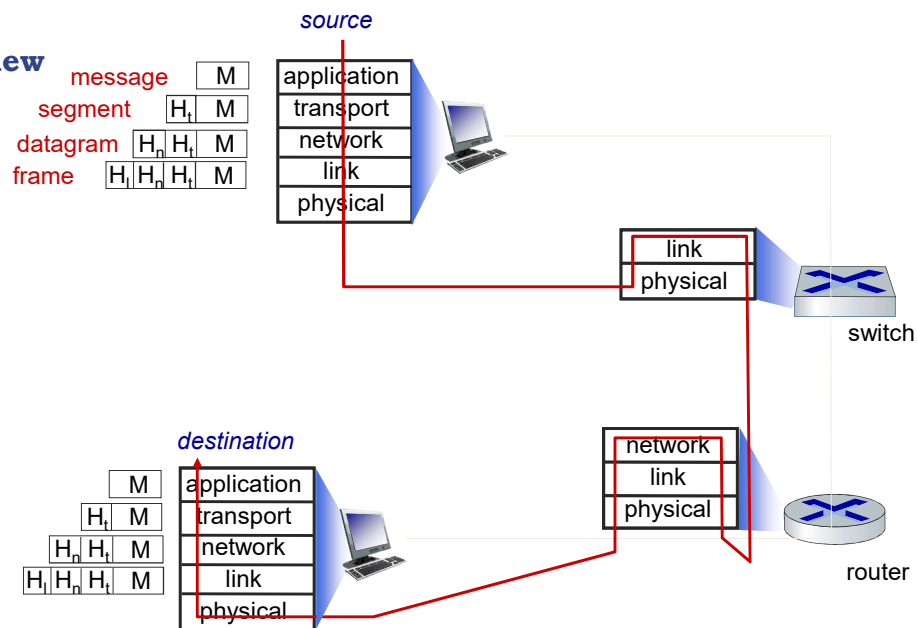https://guilhermeir.github.io/L3Networks.html

Prof. Guilherme Iecker Ricardo
guilherme.iecker-ricardo@dauphine.psl.eu

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Class 1 Review

source

message — M
segment — H_t M
datagram — H_n H_t M
frame — H_l H_n H_t M

application
transport
network
link
physical

link
physical

switch

destination

M
H_t M
H_n H_t M
H_l H_n H_t M

application
transport
network
link
physical

network
link
physical

router

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Computer Networks
Class 2: Physical Layer

Physical Layer

Class goals:

- Introduce physical transmissions and their underlying theoretical foundation.
- Discuss examples of networks that implement the presented concepts

Overview/roadmap:

- **Preliminaries**
- Guided Transmission
- Wireless Transmission
- Using the Spectrum for Transmission
- Fundamentals of Digital Communication

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Introduction EQUIS ACCREDITED

Physical Layer

Preliminaries: Binary Representation

- Communication presumes shared **symbols**
  - Examples: Latin alphabet (a, b, c, …), Arabic numbers (0, 1, 2, …), etc.

- Computer operation is based on **<u>binary digits</u>** or **bits**, e.g., 0's or 1's
  - For N bits, we have 2^N combinations of symbols.
    - How many bits do we need to represent all 26 letters in the standard English alphabet?
  - Why?

- Any piece of information can be discretized and represented by a sequence of bits!
  - Number, text, image, audio, etc.

- Computer communication = **Digital** communication

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Physical Layer

Preliminaries: Binary Conversion and Arithmetic

Decimal <-> Binary

Logic Operators

Unary Operation (Single Operand)	
A	**<u>not</u>** A
0	0
1	1

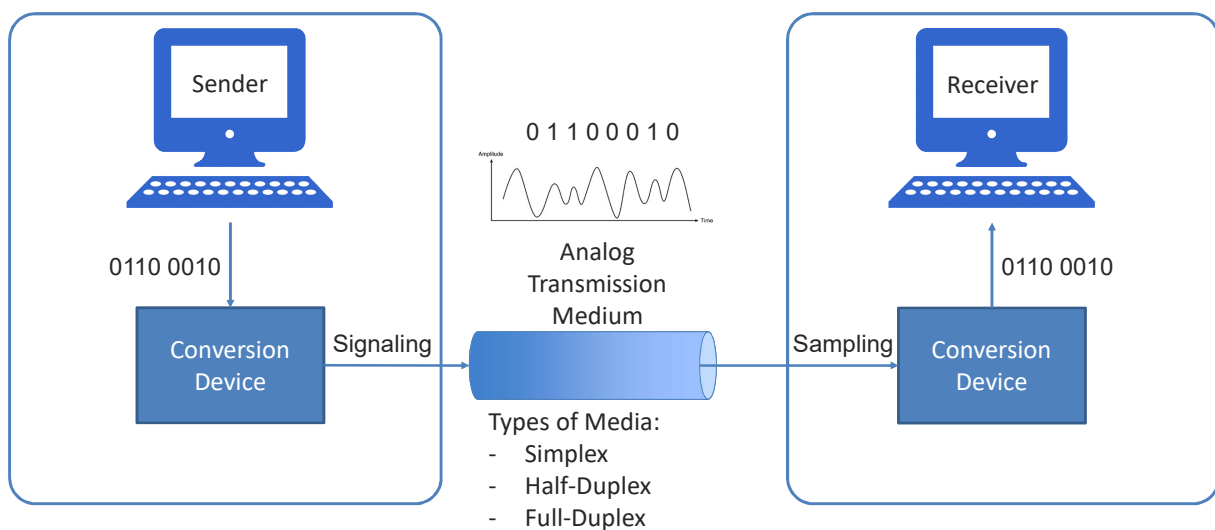| N-ary Operation (N operands) – Ex.: N=2				
A	B	A **<u>and</u>** B	A **<u>or</u>** B	A **<u>xor</u>** B
0	0	0	0	0
0	1	0	1	1
1	0	0	1	1
1	1	1	1	0

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Physical Layer

Preliminaries: Binary Coding

- Real number representation
  - Scientific applications
  - Increase precision
- More operations
  - Numerical approximation of sophisticated functions
- Architectural limitations (Overflow)
- Massive applications in networks!
  - Gray Coding

Decimal	Binary No Coding	Binary Gray
0	0000	0000
1	0001	0001
2	0010	0011
3	0011	0010
4	0100	0110
5	0101	0111
6	0110	0101
7	0111	0100
8	1000	1100
9	1001	1101
10	1010	1111
11	1011	1110
12	1100	1010
13	1101	1011
14	1110	1001
15	1111	1000

(Gray Code)

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Physical Layer

Preliminaries: Digital Communication

Sender

0110 0010

Conversion Device → Signaling →

0 1 1 0 0 0 1 0

Analog Transmission Medium

Types of Media:
- Simplex
- Half-Duplex
- Full-Duplex

→ Sampling → Conversion Device

0110 0010

Receiver

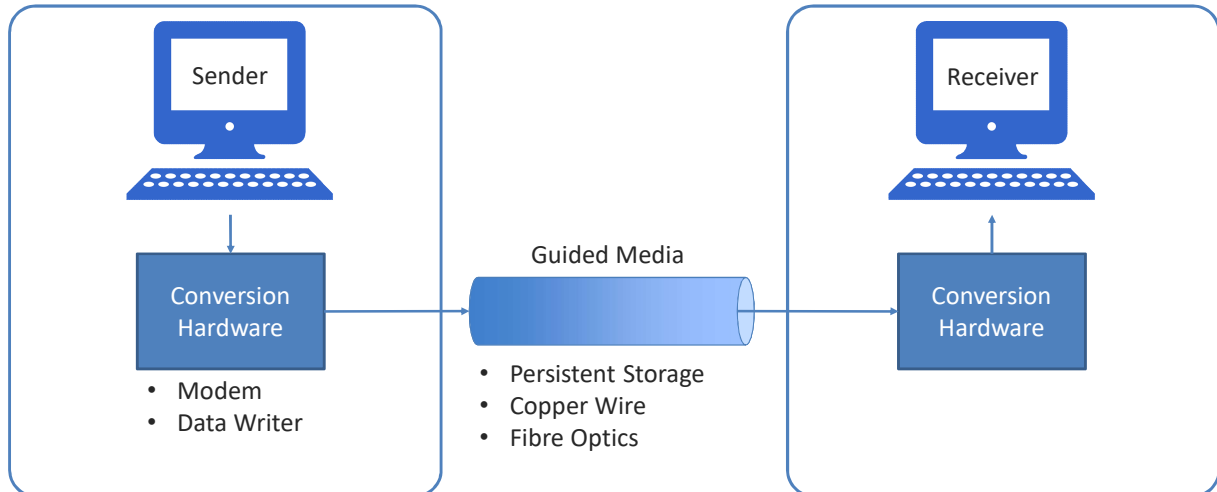**Dauphine** | PSL

Physical Layer

Preliminaries: Waves

Physical Layer

Overview/roadmap:

- Preliminaries
- **Guided Transmission**
- Wireless Transmission
- Using the Spectrum for Transmission
- Fundamentals of Digital Communication
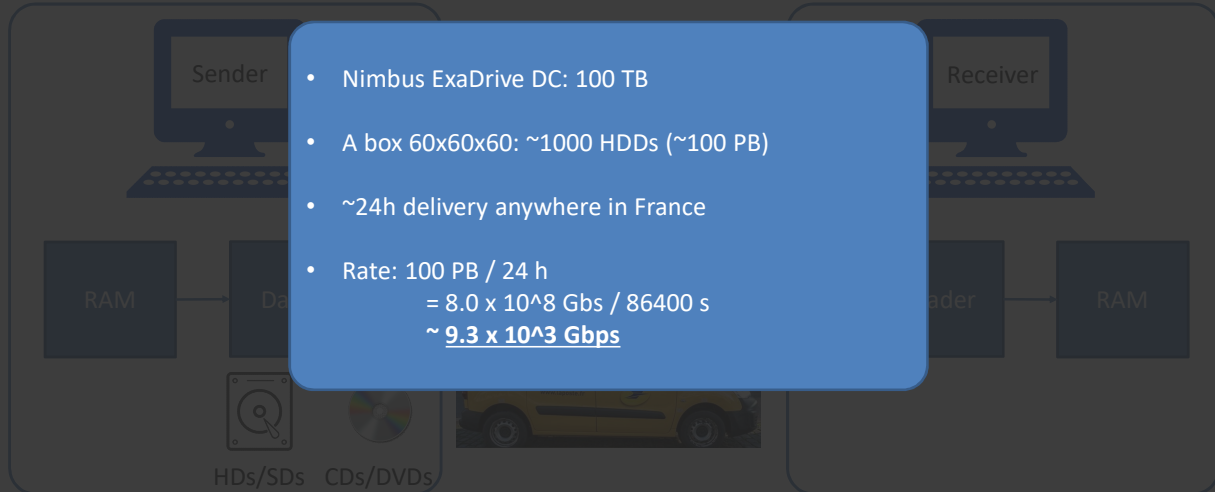
Physical Layer

Guided Transmission Media

Physical Layer

Guided Transmission Media: Persistent Storage

Physical Layer

Guided Transmission Media: Persistent Storage

- Nimbus ExaDrive DC: 100 TB

- A box 60x60x60: ~1000 HDDs (~100 PB)

- ~24h delivery anywhere in France

- Rate: 100 PB / 24 h
  $= 8.0 \times 10^8$ Gbs / 86400 s
  ~ 9.3×10^3 Gbps

Sender   Receiver

RAM   HDs/SDs   CDs/DVDs   RAM

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Physical Layer

Guided Transmission Media: Persistent Storage - Examples

Amazon "Snowmobile"

- Hundreds of HDDs (~100 PB)
- High-speed internal network
- Optic fibre upload/download
- Connectivity for remote access

Opportunistic Transmission

- Electric car charging station nets.
- ~8 hours to fully charge a car
- Wireless upload/download
- Non-reliable transmission

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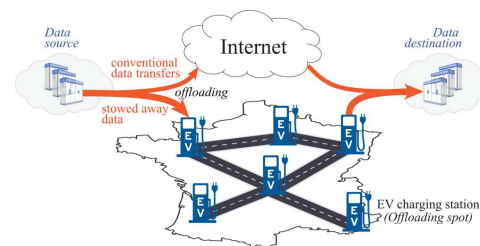
Physical Layer

Guided Transmission Media: Copper Wires – Twisted Pairs

Characteristics

- 1mm copper wire
- Difference of voltage transmission
- Pairs in helical form
- Application: Telephone, xDSL, etc.
- Analog and digital info
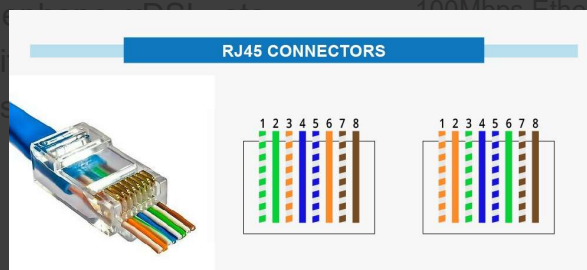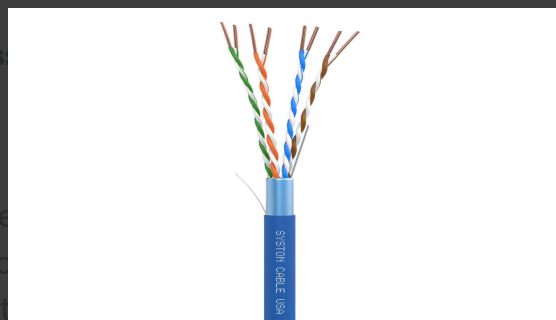- Rate: Thickness and distance

Category "Cat" 5e

- 4 twisted pairs
- Full-Duplex
- Standards:
  - 100Mbps Ethernet LAN
  2 pairs for each direction
  - 1Gbps Ethernet LAN
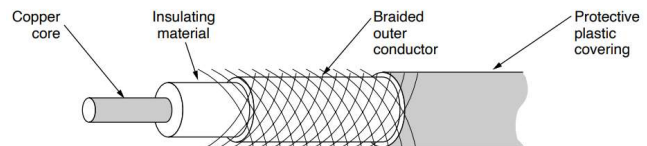 Each pair in both directions

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Physical Layer

## Guided Transmission Media: Copper Wire – Coaxial Cables

Characteristics

- Better shielding ("isolation")
  - higher distances and better rates
- Types:
  - 50-ohm: digital transmission
  - 75-ohm: analog transmission
- Bandwidth of up to 6GHz
- Full-duplex
- Usage: TV, Cable internet

Copper core — Insulating material — Braided outer conductor — Protective plastic covering

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Physical Layer

Guided Transmission Media: Electrical Power Lines

Characteristics

- Application: Home LAN
  - Electrical signals: 50Hz-60Hz
- Embedded information signal
  - Data signals: Order of MHz – GHz
- Bad news:
  - electric wire has natural attenuation
  - power network change wires properties
- Similar idea: landline telephony

Electric cable — Data signal — Power signal

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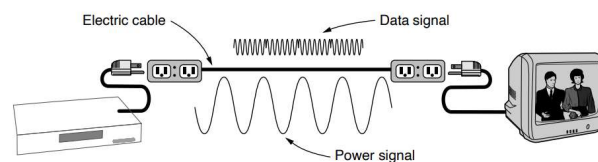
Physical Layer

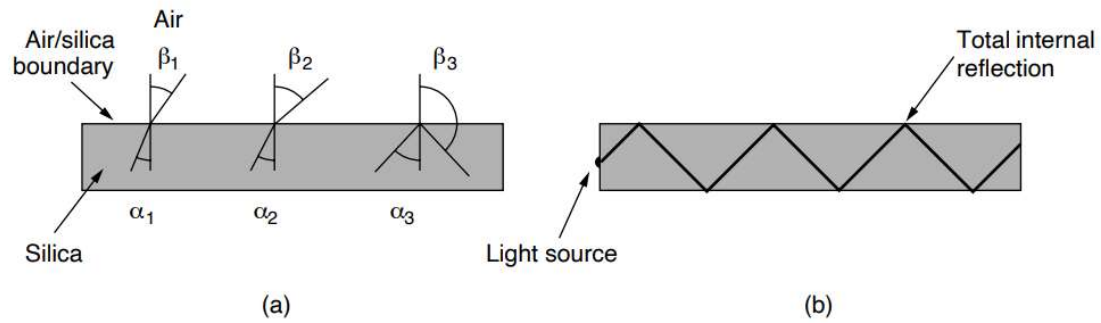## Guided Transmission Media: Fiber Optics - Motivation

- Technological evolution
  - Computers: 1981 PCs @ 4.77 MHz – 2021 PCs @ 3GHz – Factor: ~2500
  - Networks: 1981 Telephone lines @ 45Mbps – 2021 MANs @ 100Gbps – Factor: ~2000
- Physical limits
  - Computers: Achieved – performance increase is only in the number of CPU cores
  - Networks: 50Tbps (fiber optics) – still a lot of room for improvement
- Bottlenecks
  - conversion between electric and optical signals is still slow
  - implementation and communication costs
- Usage
  - Networks' (and Internet's) backbone
  - High-speed LAN
  - Fiber-to-the-Home

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Physical Layer

Guided Transmission Media: Fiber Optics – Big Picture

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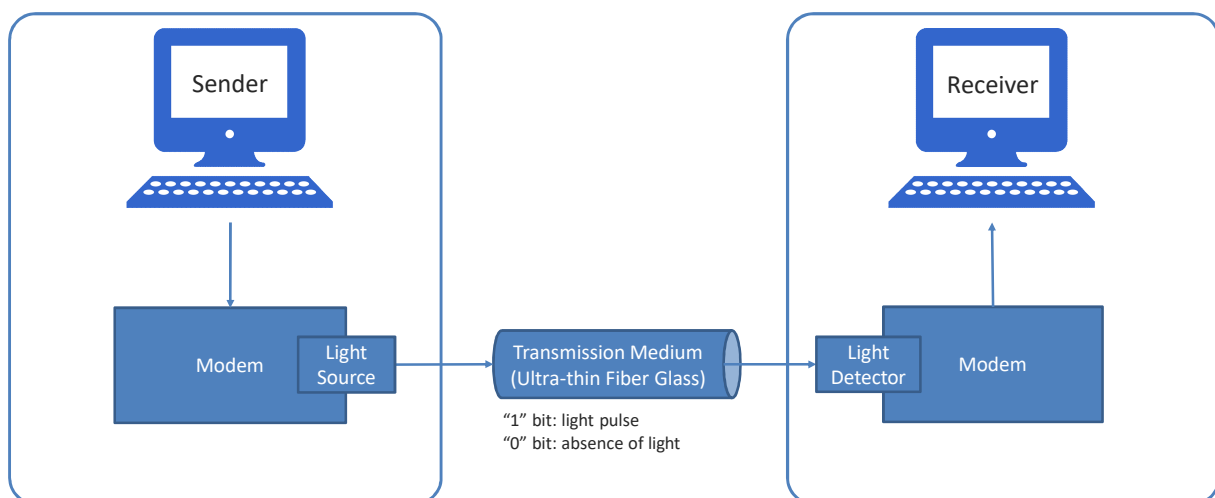
Guided Transmission Media: Fiber Optics - Refraction

Property	Diameter	Trajectory	Reach	Cost
Multimode	50µm	"bouncing"	100km	$
Single-mode	10µm	straight line	15km	$$$

Physical Layer

Guided Transmission Media: Fiber Optics – Light Transmission
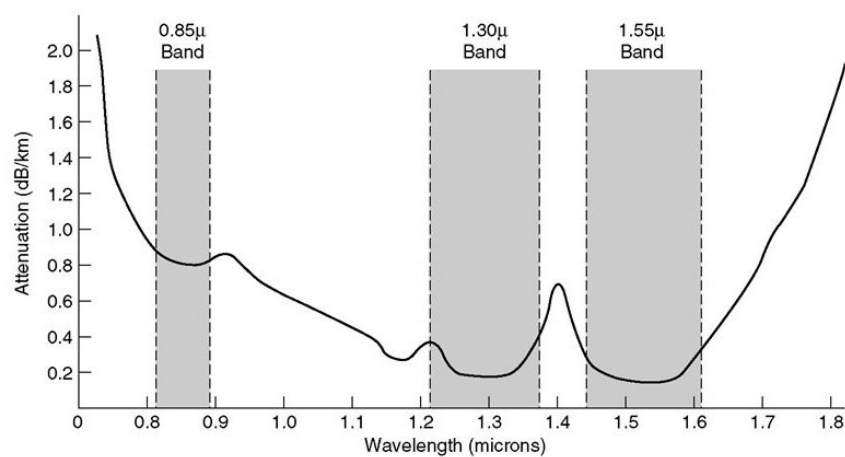
Questions?

guilherme.iecker-ricardo@dauphine.psl.eu

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UNIVERSITÉ PARIS DAUPHINE - PSL
Place du Maréchal de Lattre de Tassigny – 75775 Paris cedex 16