École Pour l'Informatique et les Techniques Avancées – EPITA

BSc L1 – 27 April 2024

Course: Introduction to Computer Networks

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Introduction to Computer Networks

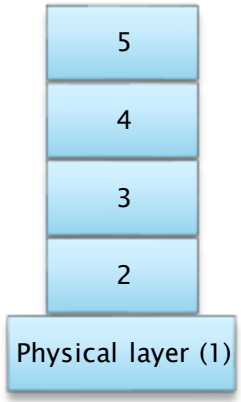
Course schedule (tentative)

Date & Time	No.	Topics	Duration (hours)
Fri 19/04/24 – 10:00–13:00	1	Primer, Network protocols, types, topology, architecture	3
Fri 26/04/24 – 10:00–13:00	2	Network models, TCP/IP model, Packet switching	3
Sat 27/04/24 – 10:00–13:00	**3**	**Physical Layer (Function, Signals, Modulation, Multiplexing, Transmission media & Hardware, Optical networks)**	**3**
Sat 27/04/24 – 14:00–17:00	4	Data Link Layer (Function, Framing, Protocols, Flow control, Access control, Error correction, Hardware)	3
Fri 03/05/24 – 14:30–17:30	5	Network Layer (Function, IP addressing and subnets)	3
Sat 04/05/24 – 10:00–13:00	6	Network Layer (Routing algorithms and protocols), Internet Control Message Protocol	3
Fri 17/05/24 – 14:00–17:00	7	Network Layer (IGP & EGP), Autonomous System, Border Gateway Protocol	3
Fri 18/05/24 – 14:00–17:00	8	Transport Layer (Function, Flow and congestion controls, Protocols)	3
Fri 24/05/24 – 10:00–13:00	9	Application Layer (Function, Protocols)	3

Lecture 3 Outline

- **Physical Layer (TCP/IP)**
  - **Functions**
  - **Signals & their types**
  - **Modulation & demodulation**
  - **Baseband & broadband**
  - **Class exercise 4**
- Physical Layer (TCP/IP)
  - Topologies
  - Transmission hardware
  - Optical Network
  - Noise (and interference)
  - Class exercise 5

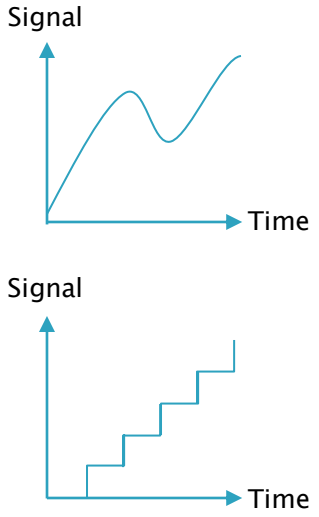
Physical Layer (Function)



- The lowest layer (Layer-1) of TCP/IP model -> also known as hardware layer
- Primary function is to transmit bits:
  - by encoding them into **signal** (decoded on the recipient side)
  - over a physical medium/link (cables or free space)
  - using transmission/reception hardware providing bit synchronization (using clock) and rate control (number of bits to transmit each second)
- Responsible for establishment and maintenance of a physical link between devices
  - Based on network topology (ref. lecture 2 slide no. 7) and transmission mode (ref. lecture 2 slide no. 12)

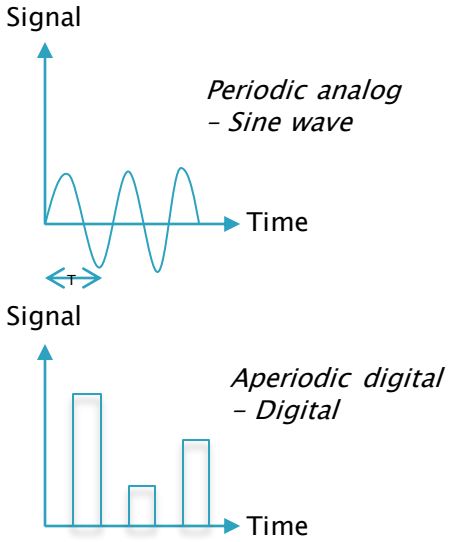
Signals

- Electrical or electromagnetic current that is used for carrying data from one device or network to another:
  - Electromagnetic waves are commonly used because they travel around the speed of light in a vacuum
- Types:
  - Analog Signals: Continuous, varying signals that can take any value within a range of values (e.g., voice, music)
  - Digital Signals: Discrete, non-varying signals that can only take specific values (e.g., binary code)



Signals <-> Modulation & Demodulation

- Signal types (or sub-types):
  - Periodic Signals: Repetitive patterns that occur at regular intervals (e.g., sine wave)
  - Aperiodic Signals: Non-repetitive patterns that occur irregularly (e.g., human speech)



- Modulation: Digital bits are encoded into a format (signal) suitable for transmission over the physical medium (using amplitude or frequency or phase modulation)
  - Digital-to-analog (or vice versa) or digital-to-digital (using Manchester or Differential Manchester or Non-Return-to-Zero) encoding depending on the type of modulation
- Demodulation: Decoding signals into digital bits, using coherent (requires synchronization) or incoherent (no synchronization requirement) techniques

Which hardware performs modulation/demodulation?

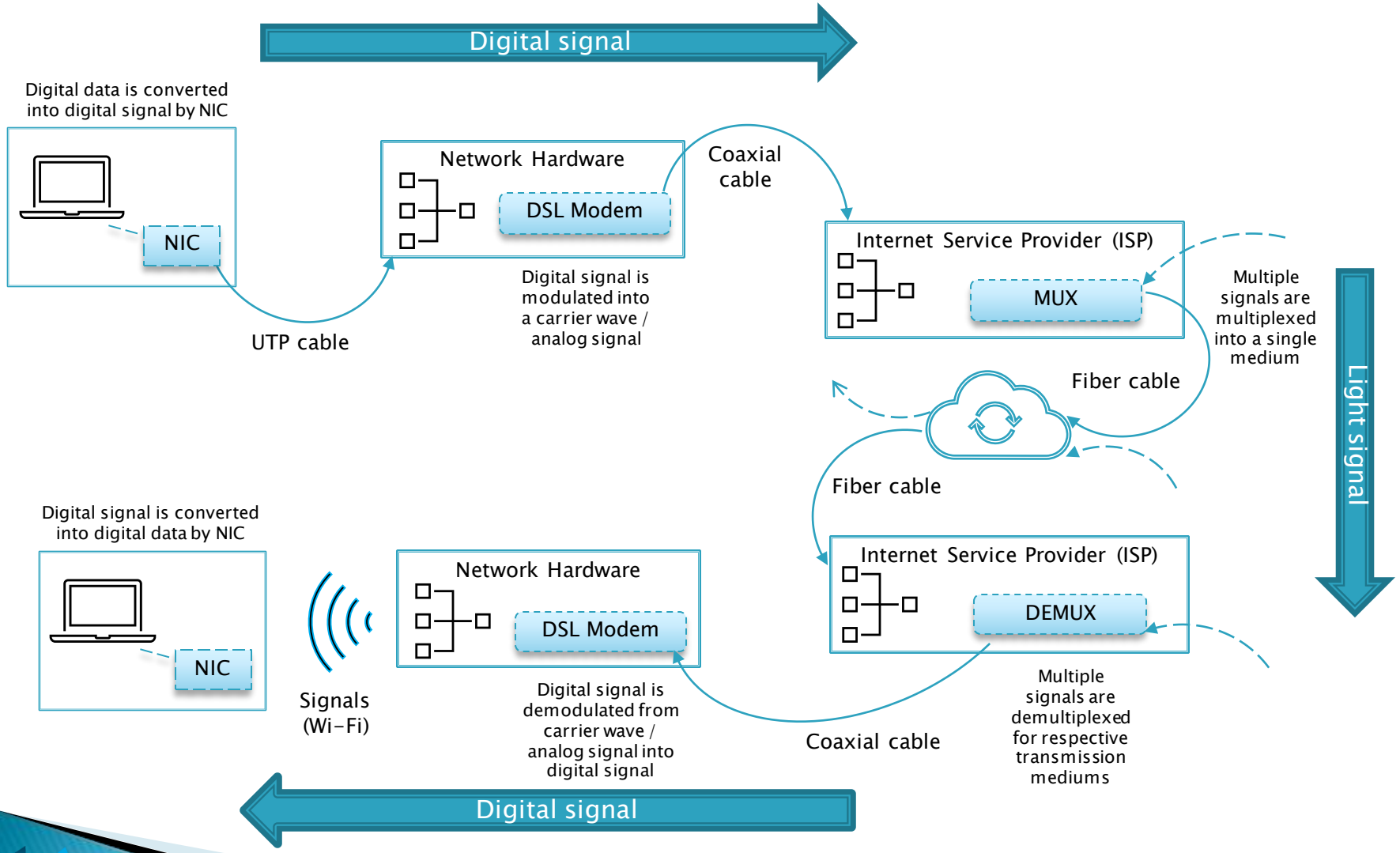
Signals <-> Baseband and broadband

- When a (digital) signal is transmitted, over a transmission medium, without any modulation (or encoding), using a single frequency range, the transmission system is known as **baseband**
  - In other words, a baseband signal is transmitted as-is. This is useful (cost-effective) in short-distance networks (e.g., LAN, WAN)
- To achieve high-speed and reliable long-distance networks, **broadband** systems utilize the simultaneous transmission of multiple signals over multiple frequency ranges
  - **Modem** modulates (encode) digital data onto multiple frequency ranges
  - **Multiplexer** transmitts multiple signals using a single medium (by dividing the available frequency range into multiple sub-bands using Frequency Division method OR by dividing the Time Domain into multiple time slots)

Baseband

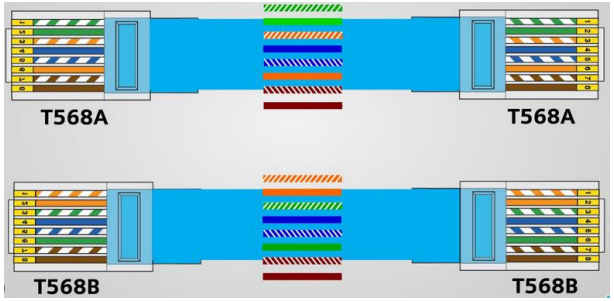
Broadband

Data transmission visualization (example)



Exercise 4: Connector analysis

- Using the pre-crimped twisted pair (copper) cables with RJ45 connectors:
  1. Describe the color coding of the wires and discuss the reasons behind the color-coded scheme (T568A and T568B wiring standards).
  2. Map each wire to its corresponding pin and discuss the purpose of each pin in the connector.



  3. Note the effects of crosstalk and electromagnetic interference (EMI) on signal quality and how the twisted pair design helps mitigate these issues.

Lecture 3 Outline

- Physical Layer (TCP/IP)
  - Functions
  - Signals & their types
  - Modulation & demodulation
  - Baseband & broadband
  - Class exercise 4

- **Physical Layer (TCP/IP)**
  - **Topologies**
  - **Transmission hardware**
  - **Optical Network**
  - **Noise (and interference)**
  - **Class exercise 5**

Topologies specifications

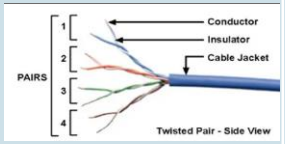
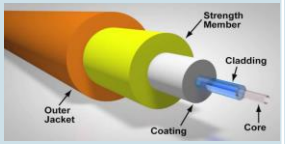
- Lecture 2 slide no. 7

Name	Connection	No. of cables for 'n' number of devices	No. of ports for 'n' number of devices	Filtering/Collision domain
Bus	All devices connected to a shared cable (Multi-point)	n (droplines) $+ 1$ (backbone)	n	Entire network is a single collision domain
Ring	Each device is connected to two neighbors (Closed-loop, Multi-point)	n (droplines) $+ 1$ (backbone)	n	Entire network is a single collision domain
Star	All devices are connected to a central hub/switch (Point-to-point)	n	n	Each node has its own collision domain
Mesh	All devices are connected to each other (point-to-point)	$\frac{n*(n-1)}{2}$	$n*(n-1)$	Depends on network devices and topology

Hardware (boxes)

Name	Function	Duplexity	Ports	Collision domain	Network type
Modem 	Modulation/ Demodulation	Simplex, Half-duplex, Full-duplex (Depends on the type/model)	1	NA (depends on communication medium)	LAN, MAN, WAN
Repeater 	Regenerate signal to avoid Attenuation	Single, Half-duplex	2 (input & output)	Single-collision	LAN, MAN, WAN
Hub 	Broadcast only, amplify (active hub) Or regenerate (active or passive hub) signal to avoid Attenuation	Half-duplex	4, 8, 16, 24, or 48 ports	Single-collision	LAN

Hardware (cables and connectors)

Protocol	Signal	Media	Media	Media connector	Maximum Data Rate (and distance)*	Advantages	Disadvantages
Ethernet (802.3)	Electrical	Copper 	Twisted Pair cable (UTP/STP) **	RJ-45	10 Mbps – 10 Gbps (>100m)	Widely used, easy to install, low cost, backward compatibility	Susceptible to interference, limited distance, limited bandwidth
		Copper 	Coaxial cable (Thinnet/ Thicknet)	BNC/TNC	10 Mbps – 100 Mbps (185m – 500m)	Higher bandwidth than twisted pair, longer distance	Difficult to install, inflexible, expensive, bulky
Ethernet (802.3), Fiber SONET/SDH	Light	Optical 	Single-mode/ multi-mode cable	LC/SC/ST/MTP	Up to 400 Gbps (100km – 40km)	High bandwidth, long distance, secure, immune to interference	Expensive, requires special equipment and expertise
Wi-Fi (IEEE 802.11)	Radio	'Free space' (waves of 2.4 GHz and 5 GHz frequencies)	Air or Vacuum	N/A (Antenna)	Up to 10 Gbps (100m – 200m) depending on AP	Wireless, flexible, easy to use, mobile, relatively low cost	Susceptible to interference, limited bandwidth, limited range

* Maximum data rates and distances are approximate and may vary depending on factors such as signal strength / cable quality, interference, and environmental factors

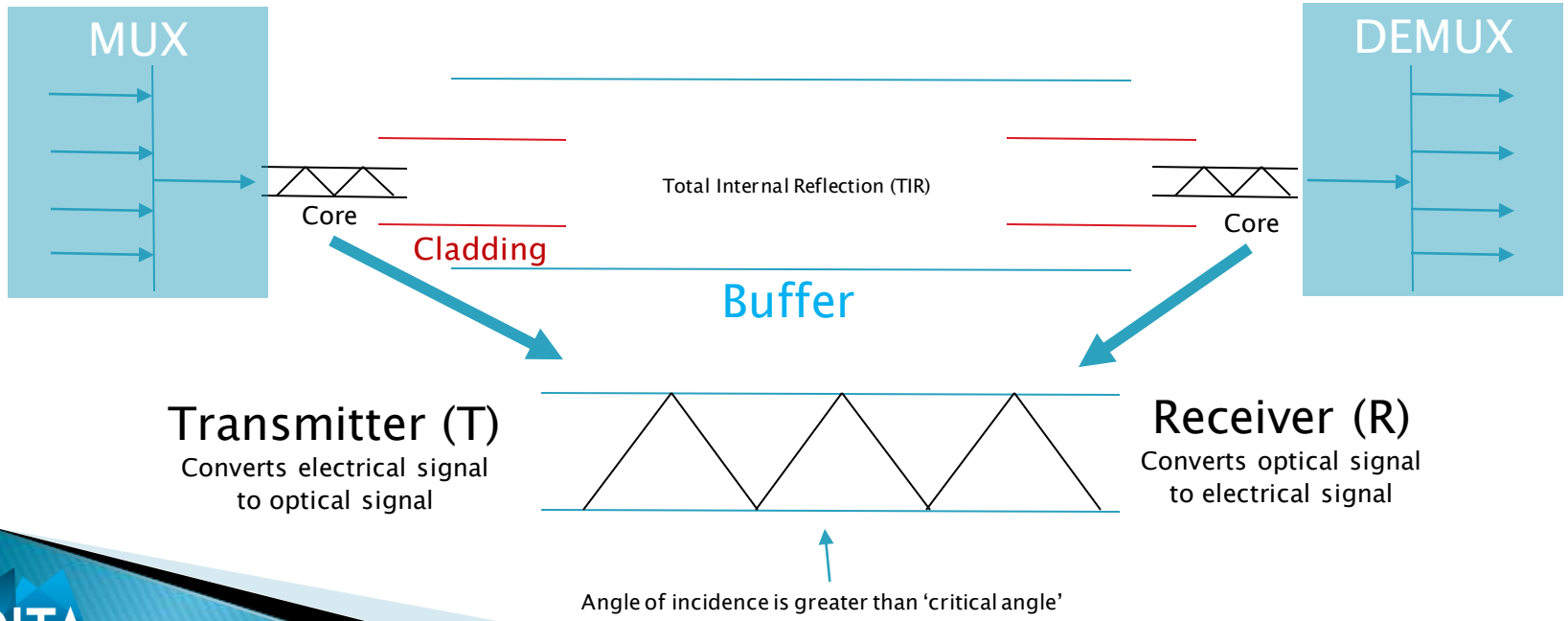
Hardware (more on twisted pair cables)

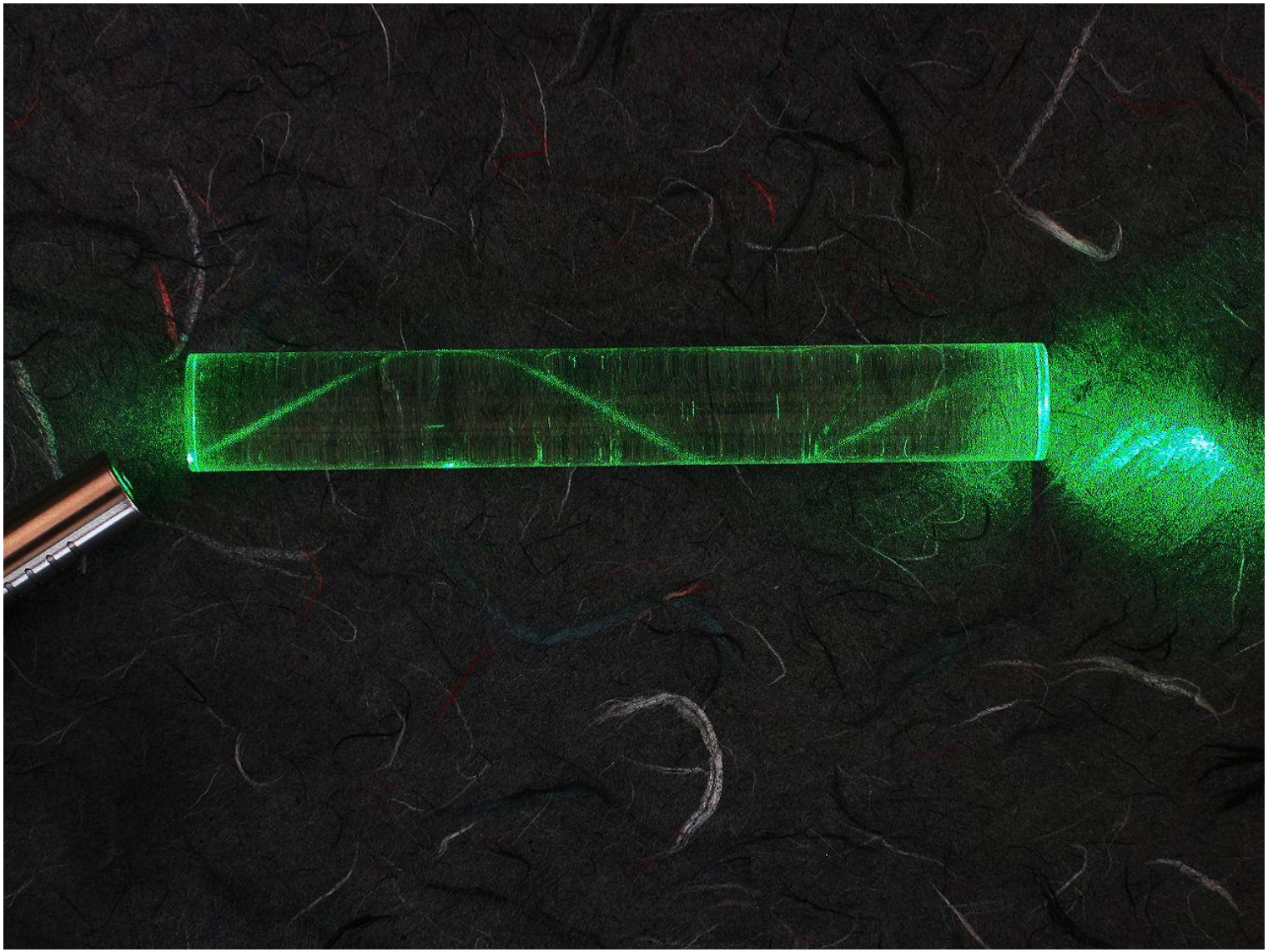
- CAT Classification (categories)

Category	Standard Bandwidth	Max Data Rate	Shielding
CAT1	1 MHz	1 Mbps	Unshielded twisted pair (UTP)
CAT2	4 MHz	4 Mbps	UTP
CAT3	16 MHz	10 Mbps	UTP
CAT4	20 MHz	16 Mbps	UTP, ScTP
CAT5	100 MHz	100 Mbps	UTP, ScTP
CAT5e	100 MHz	1 Gbps	UTP, ScTP, STP
CAT6	250 MHz	10 Gbps	UTP, ScTP, STP
CAT6a	500 MHz	10 Gbps	UTP, ScTP, STP
CAT7	600 MHz	10 Gbps	STP
CAT7a	1000 MHz	10 Gbps	STP
CAT8	2000 MHz	40 Gbps	STP
CAT8.1	2000 MHz	25 Gbps	STP
CAT8.2	2000 MHz	40 Gbps	STP

Optical Network (ON)

- Connects devices using 'optical fiber'
  - Optical fibers are very thin glass cylinders or filaments which carry signals in the form of light
  - Working principal:
    both single-mode (9/125 microns), multi-mode (50/125 microns)

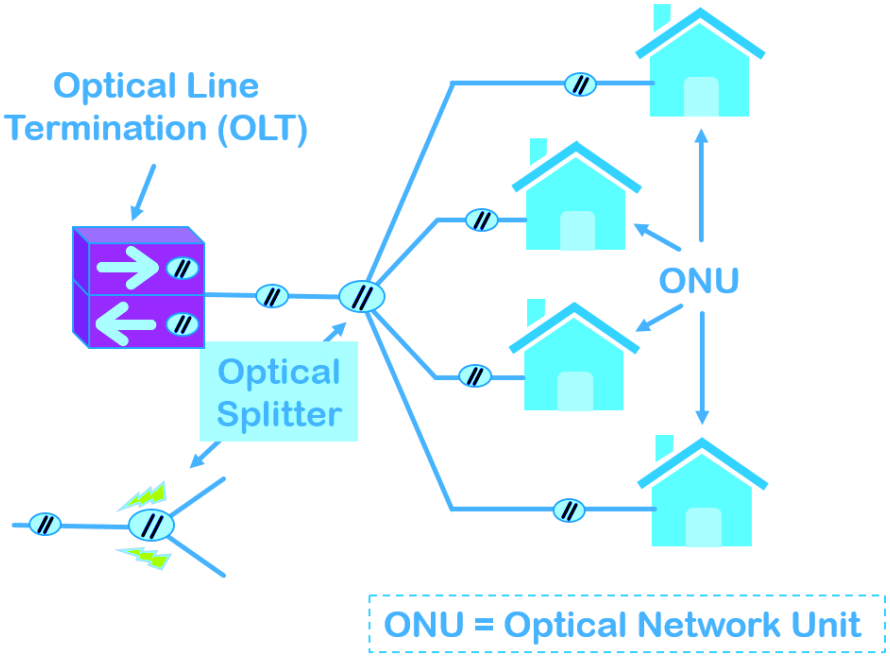




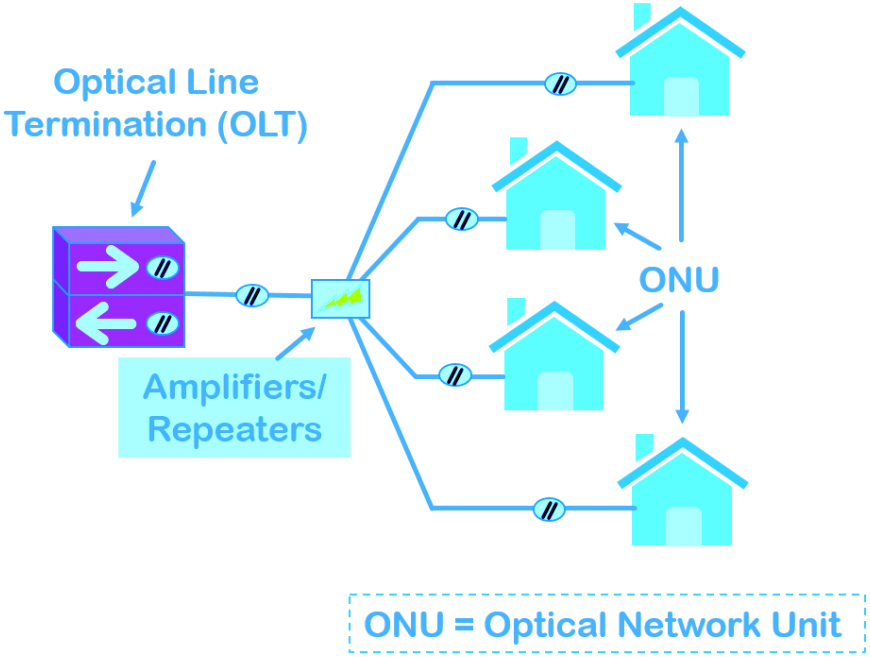
A laser bouncing down an acrylic rod, illustrating the total internal reflection of light in a multi-mode optical fiber
Ref. https://en.wikipedia.org/wiki/Optical_fiber#/media/File:Laser_in_fibre.jpg

Types of ON

Passive Optical Network | PON



Active Optical Network | AON



Source: http://www.hymax.co.za

Point to multipoint: Shared bandwidth
Distance: ~(10-20)km; residential use

Point to point: Dedicated bandwidth
Distance: ~(80-100)km; business use

Why do we need ON?

- Growing online users
- Increasing bandwidth demand
- Why do we use fiber in ON's?
  - Cost effective with small size & weight
  - Carries large amount of information (upto 10 GBPS)
  - Long distance transmission without regeneration (i.e., less no. of wires & repeaters needed)
  - Electric isolation & signal security (CRC errors)
  - Resistance to High temperature

(i.e., silica melting point 1,713 °C – source: https://en.wikipedia.org/wiki/Silicon_dioxide)

Noise / interference

- Noise is any unwanted signal that interferes with the transmission of the desired signal
- Types: thermal noise, intermodulation noise, crosstalk noise, and impulse noise
  - Each type of noise has a different source and affects the signal differently
- There are several ways to reduce noise, including shielding, filtering, and equalization
  - These techniques can help improve the quality of the signal and reduce errors in communication

Can we simulate noise or interference in network topology using Cisco Packet tracer?

Exercise 5: Micro project

- Design network for your business (work in a group of 3 members)
  - Company introduction: A growing startup (Small to Medium Size – SME) providing Language learning platform with an AI-enhanced experience
    - Architecture is based on
      - 3 LANs comprising:
        - 1 Confidential LAN (C) including 3 servers IP assignments)
        - 1 Public LAN (P) including 2 servers IP assignments (for Firewall and Load balancing) and the Confidential LAN
        - 1 LAN (O) for the Office premise
      - 1 MAN connecting the Public LAN (P) to the ISP MAN
      - 1 MAN connecting the Office LAN (O) to the ISP MAN

Lecture 3 ends here

- Course Slides: Go to MS Teams:
  'Introduction to Computer Networks - Spring 2024 | BSc'
  -> Files section

- Send your questions by email:
  mohammad-salman.nadeem@epita.fr
  OR via direct message using MS Teams

- Thank You!