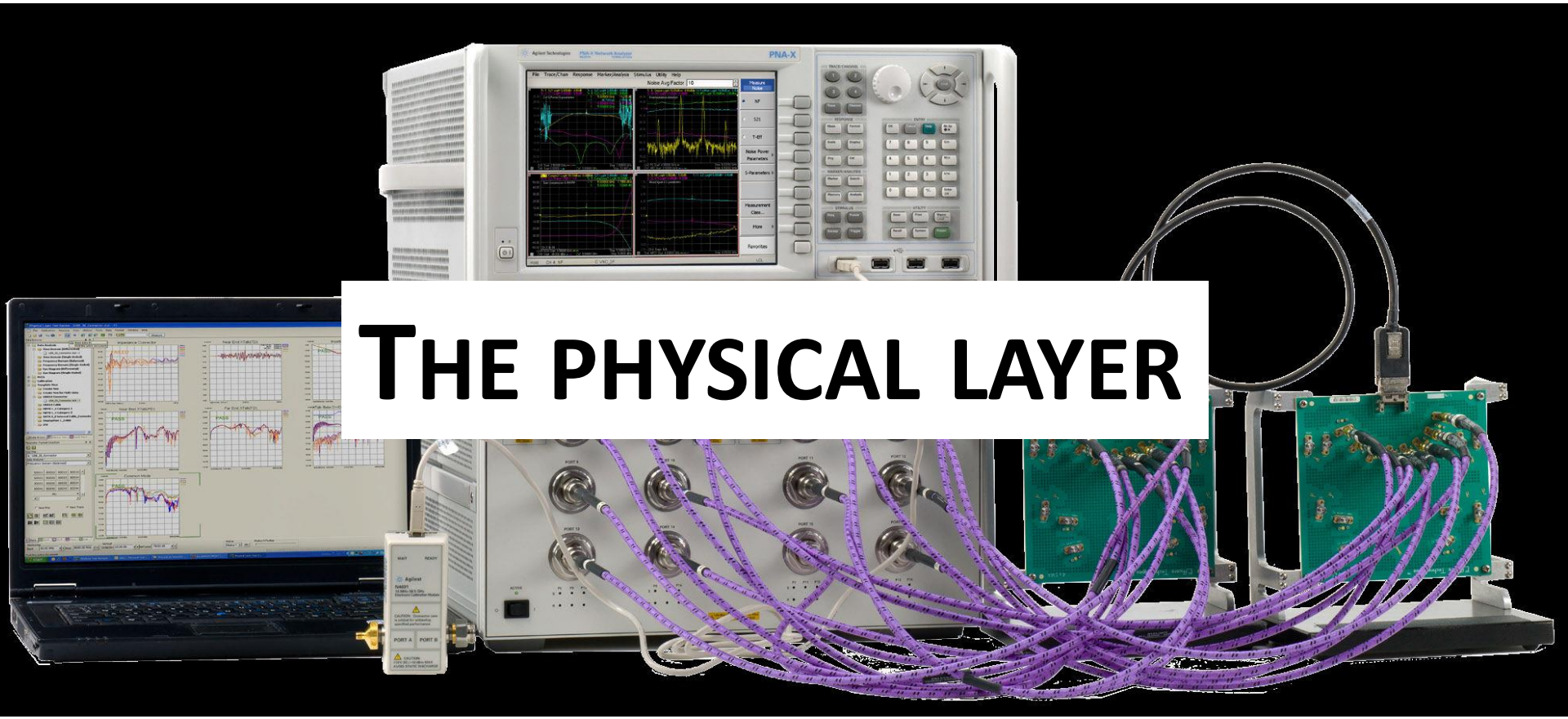
M2101 : Réseaux locaux et équipements actifs

Technologies « Ethernet » et « Wifi » :

- La couche physique
- La sous-couche MAC



THE PHYSICAL LAYER

UNIVERSITÉ DE LORRAINE

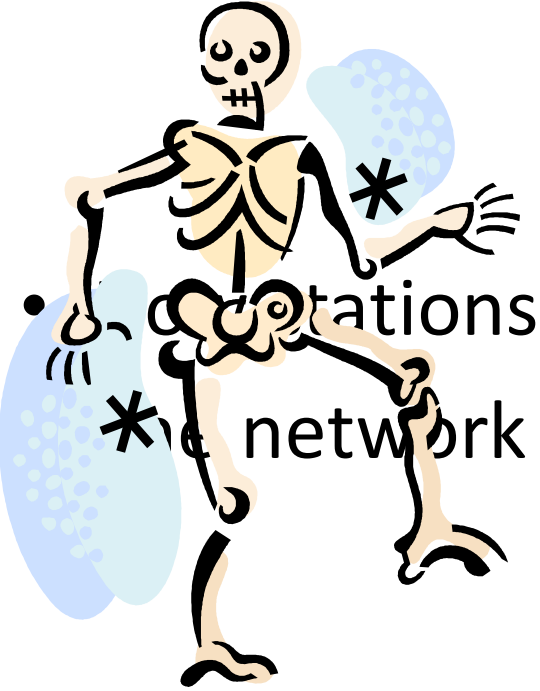
Prof Thierry DIVOUX

Outline

- Topologies
- Transmission mediums
- Transmission channel
- Baseband encoding
- Modulation
- Bit rate / Symbol rate

Voir D. Brie

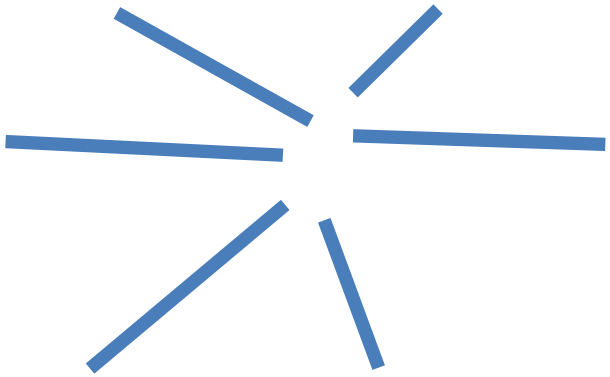
Topologies



- Computations are interconnected
- The network skeleton

Topologies

- How stations are interconnected
- The network skeleton
  - Star topology
    - A central station
      - Only point to point links
      - Central station = bottleneck

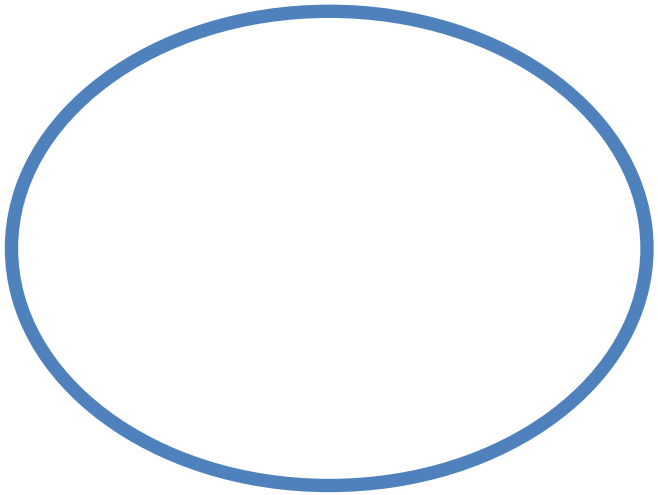


Topologies

- How stations are interconnected
- The network skeleton
  - Star topology
  - Line topology
    - Only point to point links 
    - Every node is critical 

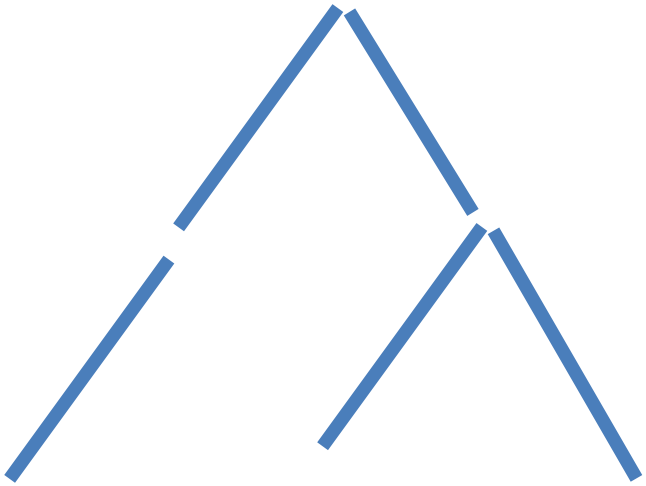
Topologies

- How stations are interconnected
- The network skeleton
  - Star topology
  - Line topology
  - Ring topology
    - Only point to point links 🙂
    - Every node is critical 🙁
      - Excepted if reverse rotation



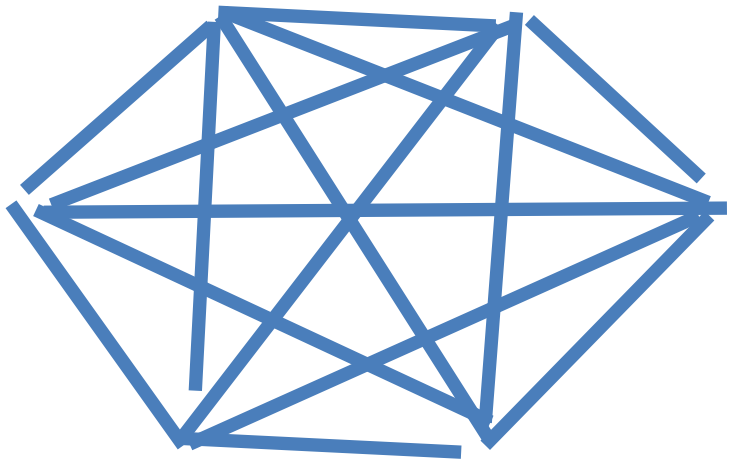
Topologies

- How stations are interconnected
- The network skeleton
  - Star topology
  - Line topology
  - Ring topology
  - Tree topology
    - Only point to point links
    - Some nodes are critical
    - Loops danger



Topologies

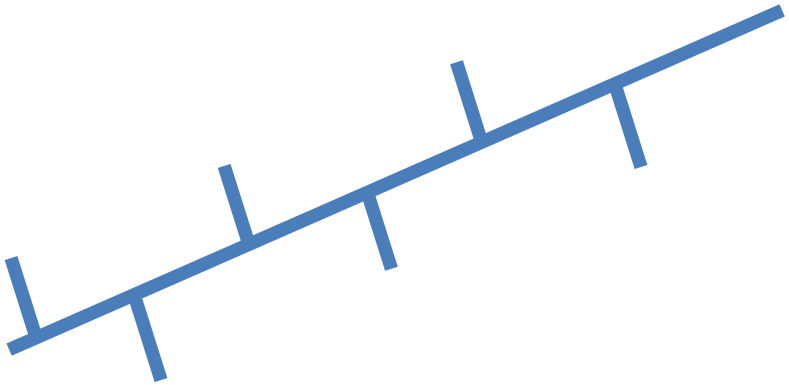
- How stations are interconnected
- The network skeleton
  - Star topology
  - Line topology
  - Ring topology
  - Tree topology
  - Mesh topology
    - Only point to point links
    - Links redundancy
      - Reliability
      - Expensive !
      - Routing



Fully connected mesh topology

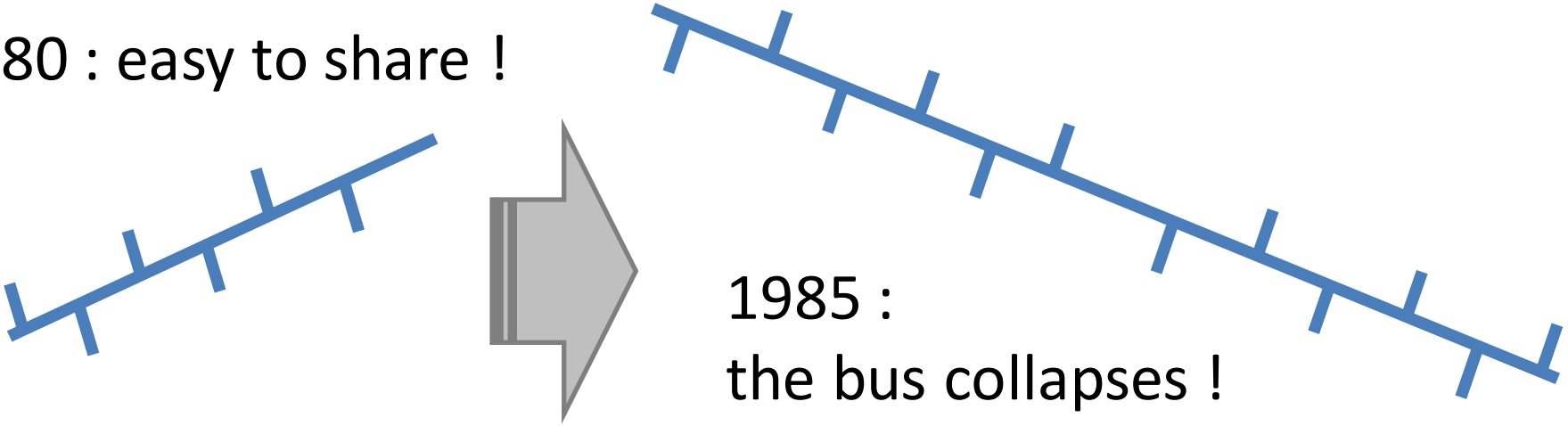
Topologies

- How stations are interconnected
- The network skeleton
  - Star topology
  - Line topology
  - Ring topology
  - Tree topology
  - Mesh topology
  - Bus topology
    - Cheap ! 
    - Medium Access Control 

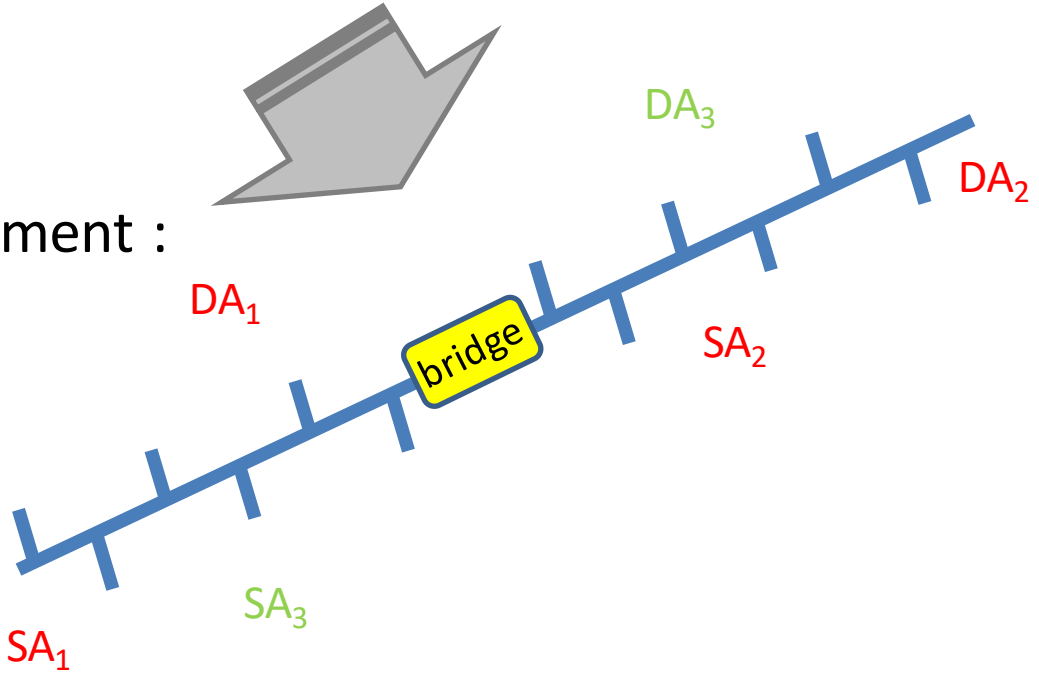


Bus evolution

1980 : easy to share !



1985 :
the bus collapses !



if SA and DA are on the same segment :

the bridge stops the frame

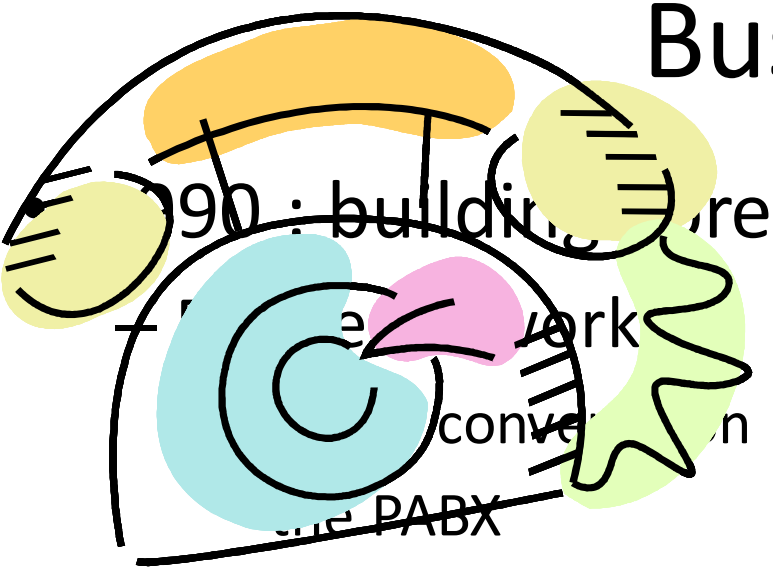
(possibly 2 simultaneous transmissions)

else :

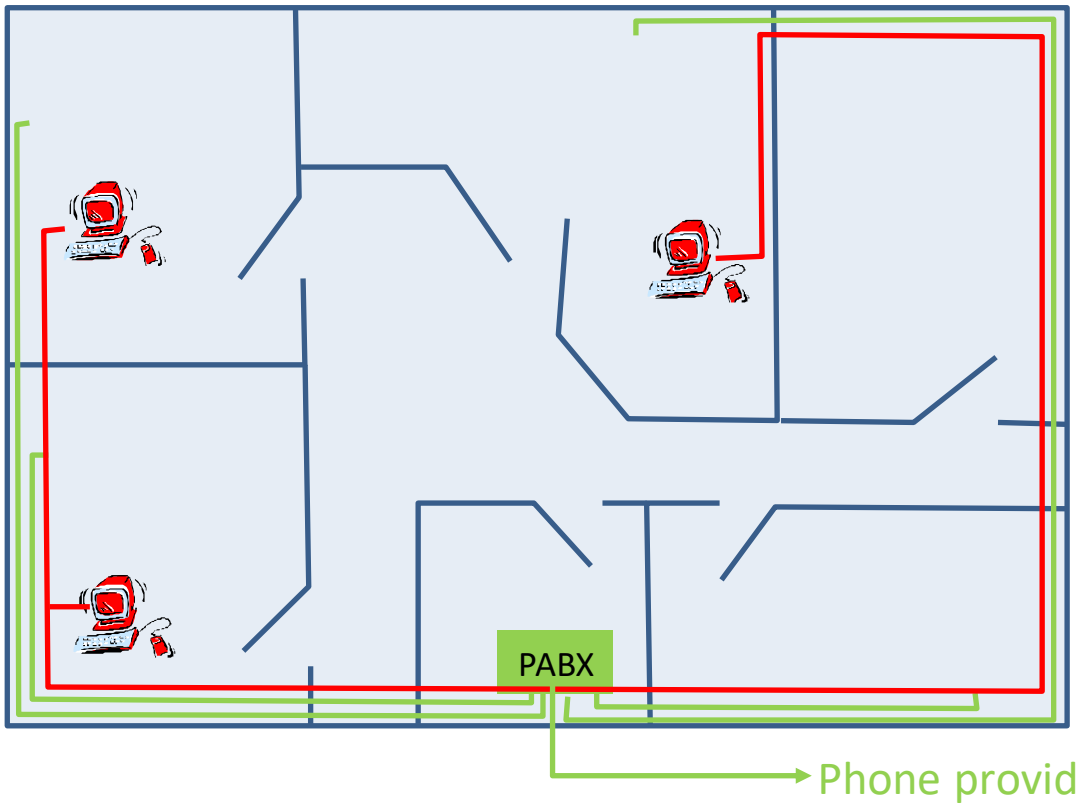
it does nothing

endif

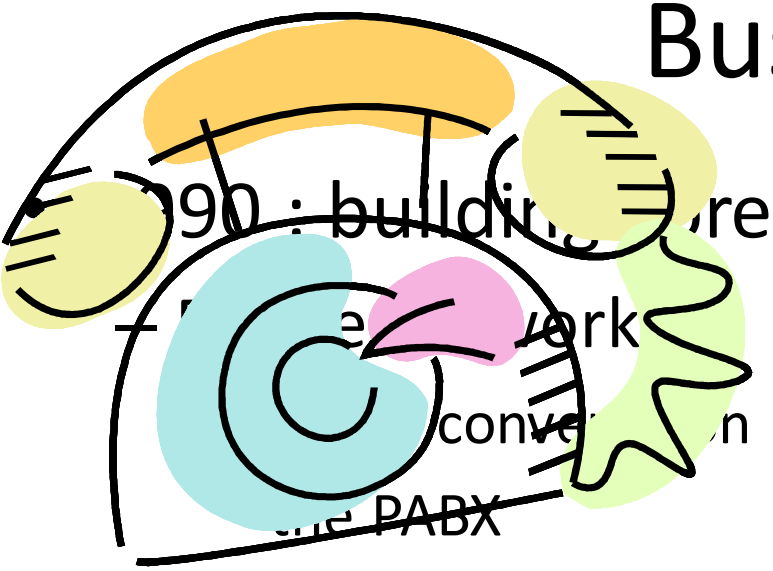
Bus evolution



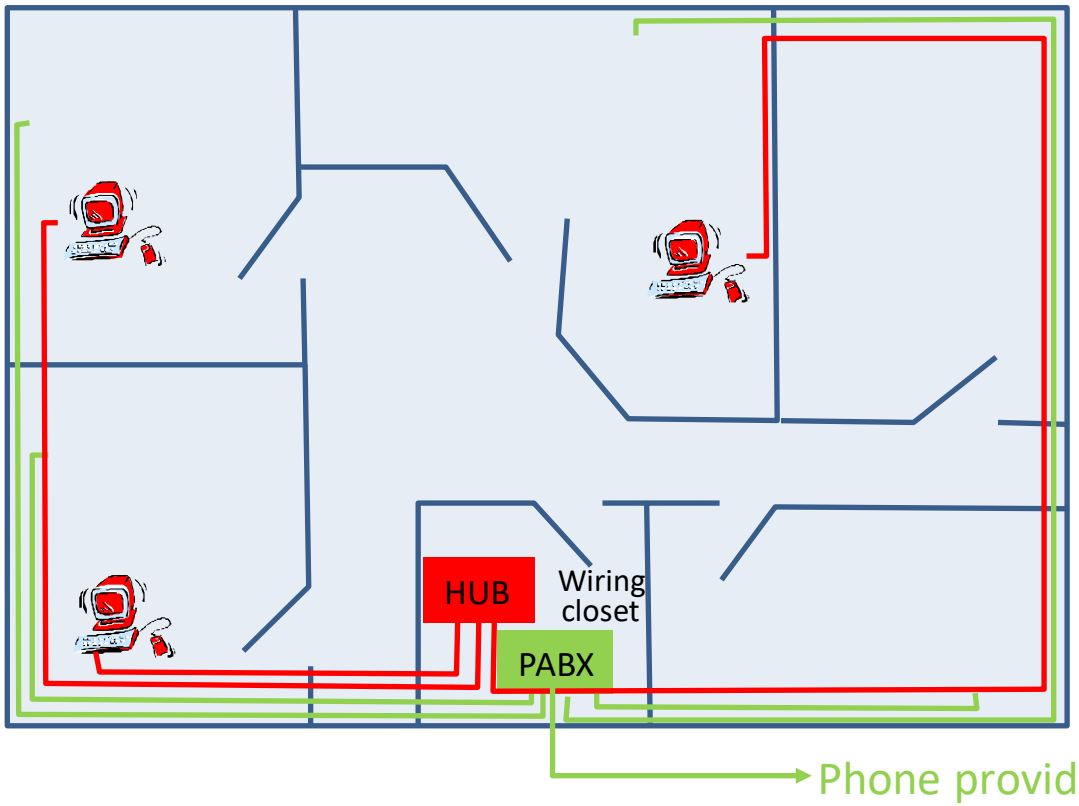
- 1990 : building re-wiring
  - Phone network
    - conversation
    - the PABX
  - Computer network
    - the bus

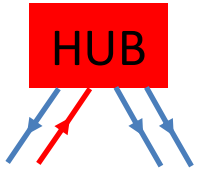


Bus evolution



- 1990 : building pre-wiring
  - Phone network
    - cables converge on the PABX
  - Computer network
    - cables converge on the hub (bus)
- How to make plugs evolutionary ?
  - Star topology
    - « Wiring closet »

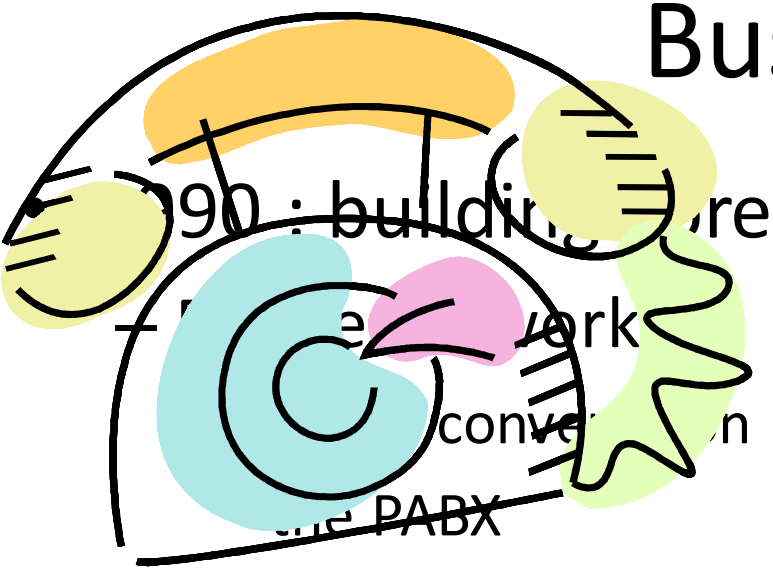




The hub emulates the bus

The maximum bandwith through the hub is the network bit rate

Bus evolution



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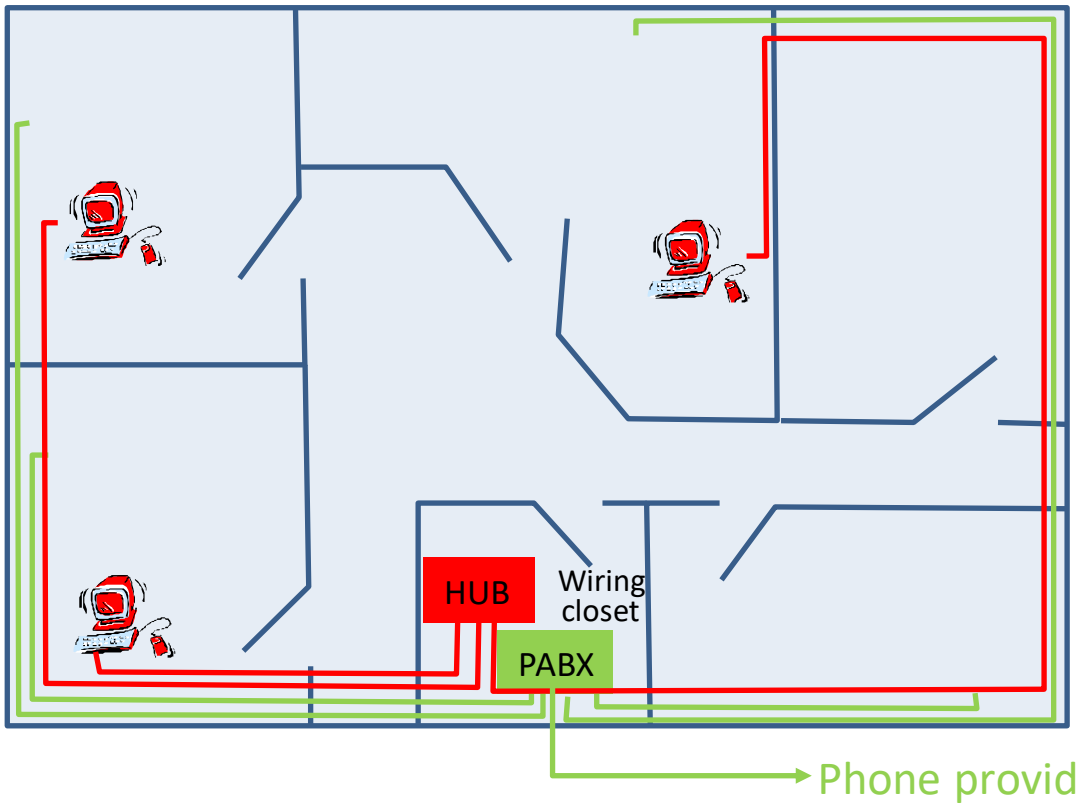
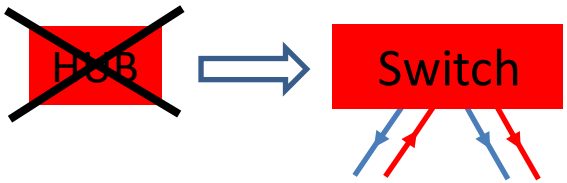




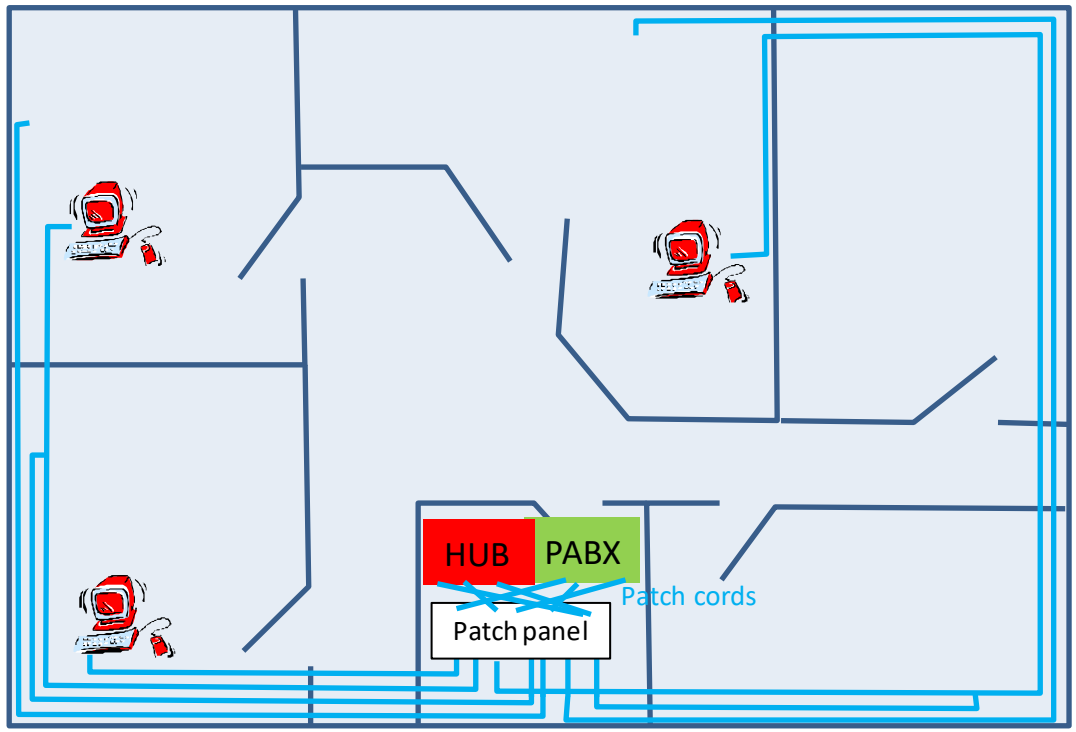
Switch = hub + bridge

The maximum bandwith through the switch is N/2.(network bit rate)

with N = the number of ports

Bus evolution

- 1990 : buildi[illegible]e-wiring
  - Pl[illegible] network
  - [illegible]converge
  - [illegible]BX
  - [illegible]puter network
    - cables converge on the hub (bus)



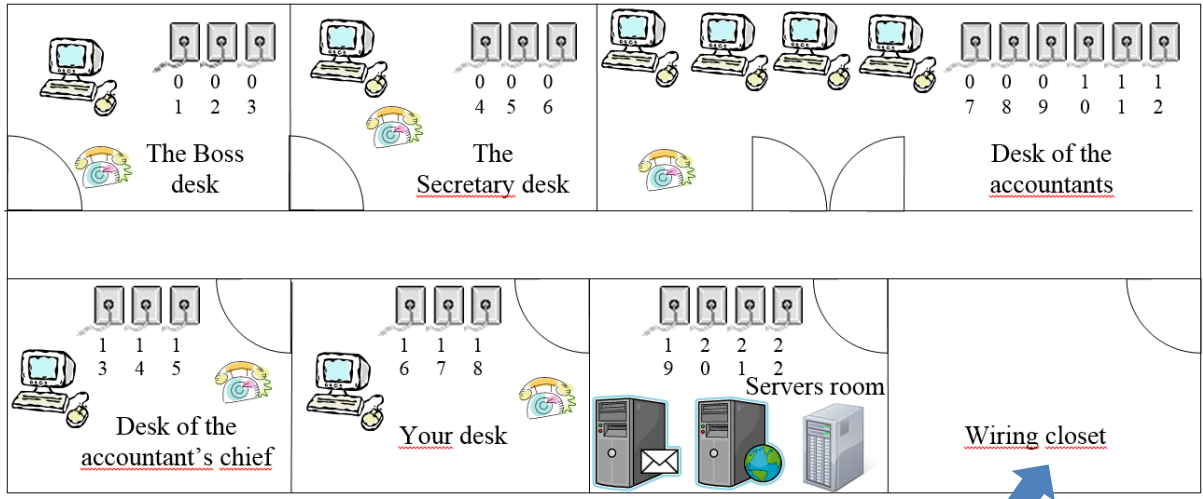
- How to make plugs evolutionary ?
  - Star topology
    - « Wiring closet »
  - Cables trivialization
    - The same kind of cables for both the networks
    - Patch panel, patch cords

A patch panel

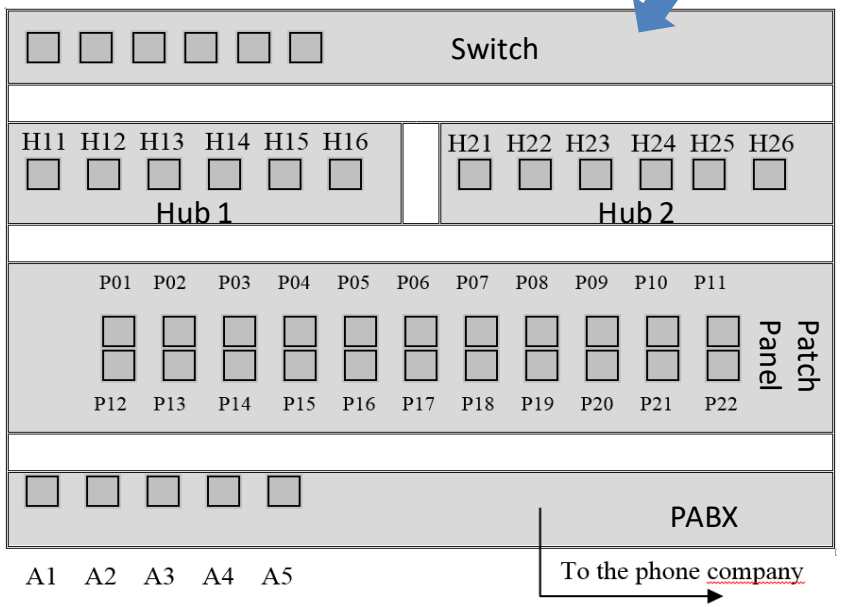
Exercise

You have just been hired as an IT manager in a small service company that handles the financial management of its corporate clients. The company starts with a team of 8 people (boss, secretary, 4 accountants and their chief, and finally you). It rents premises which plans are the following :

Each room is equipped with wall RJ45 sockets numbered 1 to 22. The phones are simple analog phones. In the wiring closet, a PABX, a 6 ports-switch, two 6 ports-hubs and a patch panel are available. Devices to connect are : 8 PC (1 per person), 1 mail server, 1 web server, 1 data server and 5 telephones. Distribute the devices in the rooms and assign sockets to each one :



01:	02:	03:	04:	05:	06:
07:	08:	09:	10:	11:	12:
13:	14:	15:	16:	17:	18:
19:	20:	21:	22:		



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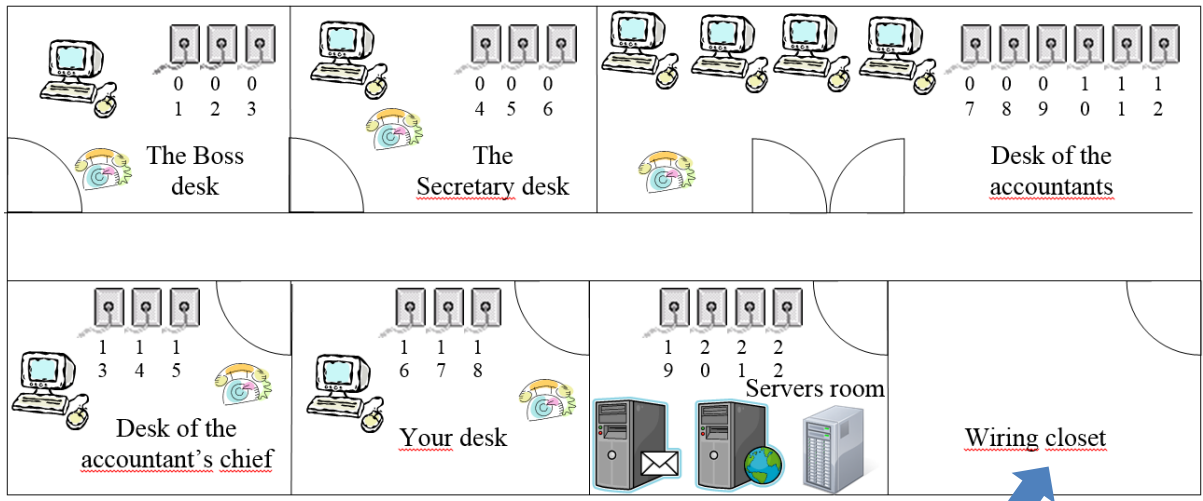
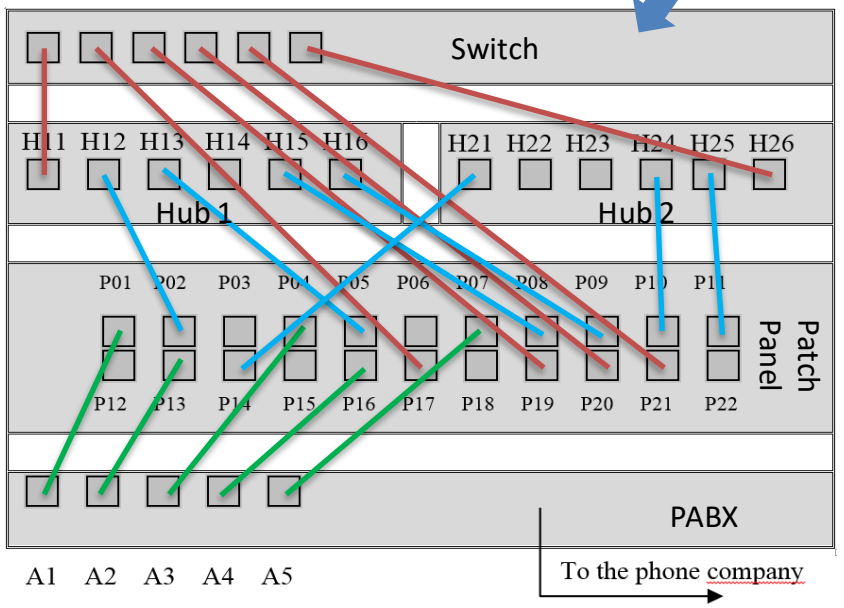
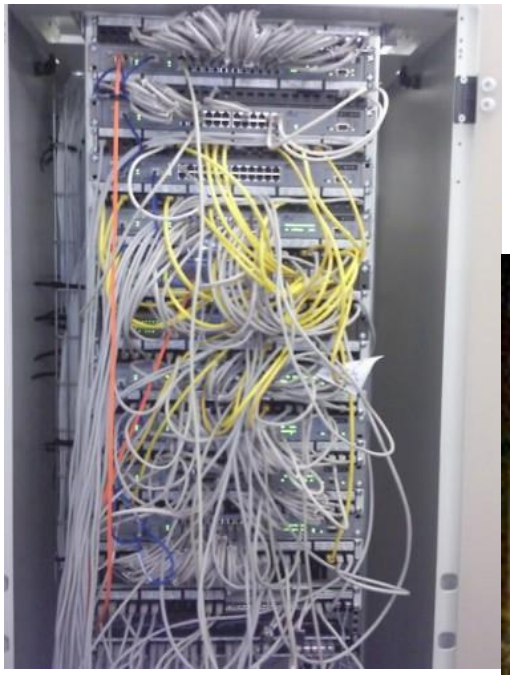


01: Boss phone	02: Boss PC	03:	04: Secretary phone	05: Secretary PC	06:
07: Accountants phone	08: Accountant 1 PC	09: Accountant 2 PC	10: Accountant 3 PC	11: Accountant 4 PC	12:
13: Accountant's chief phone	14: Accountant's chief PC	15:	16: Your phone	17: Your PC	18:
19: Mail server	20: Web server	21: Data server	22:		





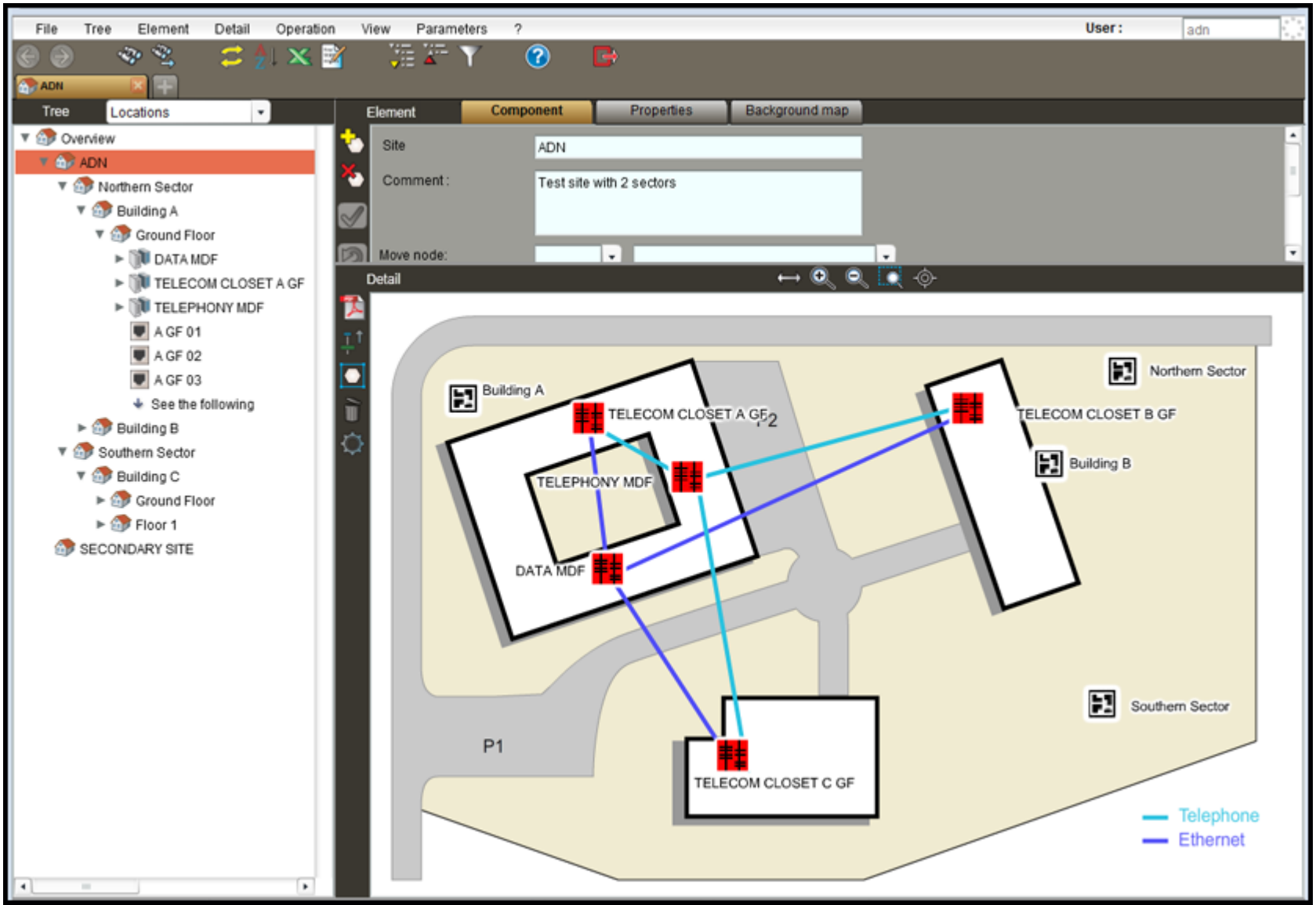
The real life …

Scalability !

dedicated softwares

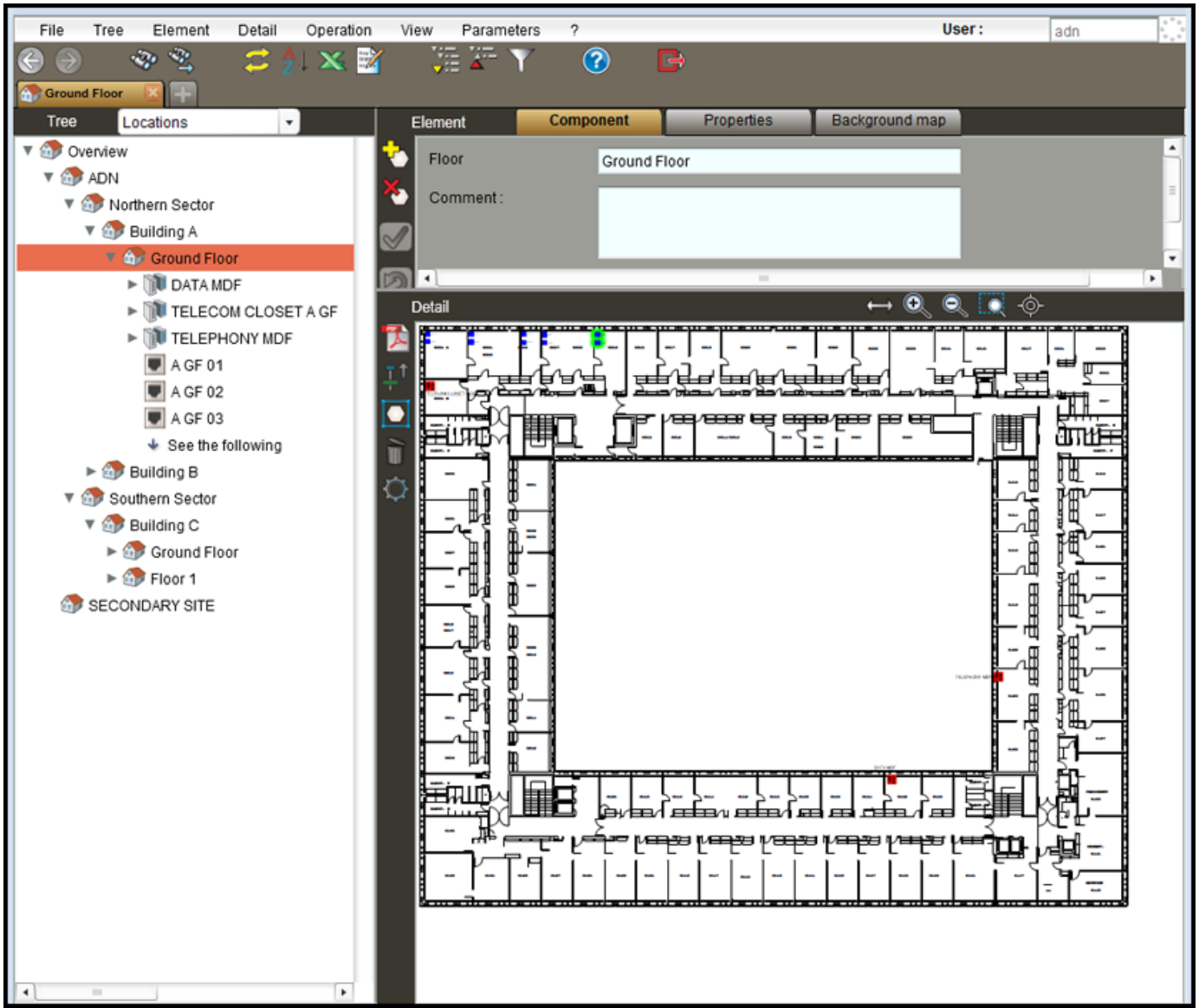
A cabling system manager

- http://adnfrance.com



A cabling system manager

- http://adnfrance.com



A cabling system manager

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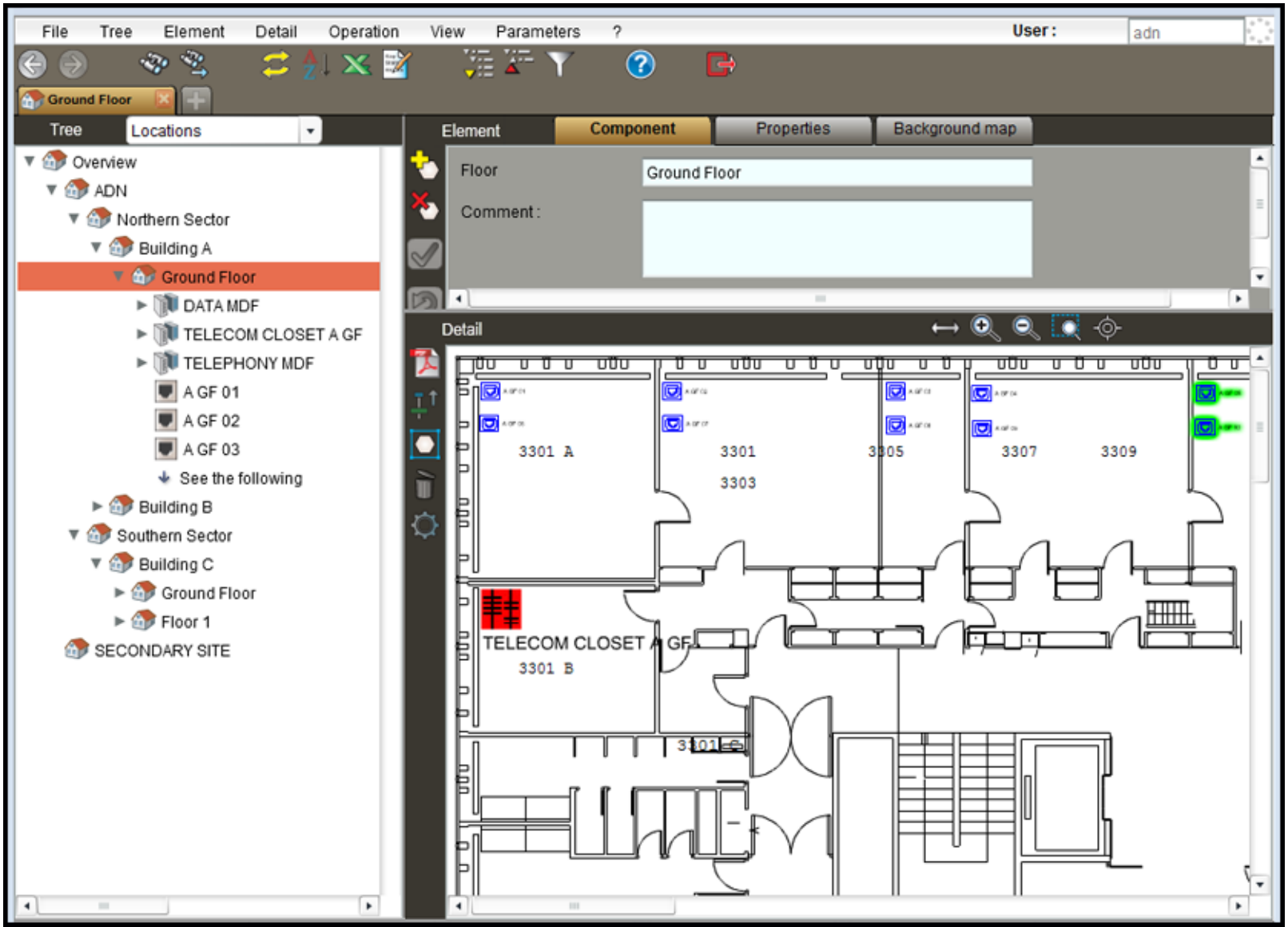

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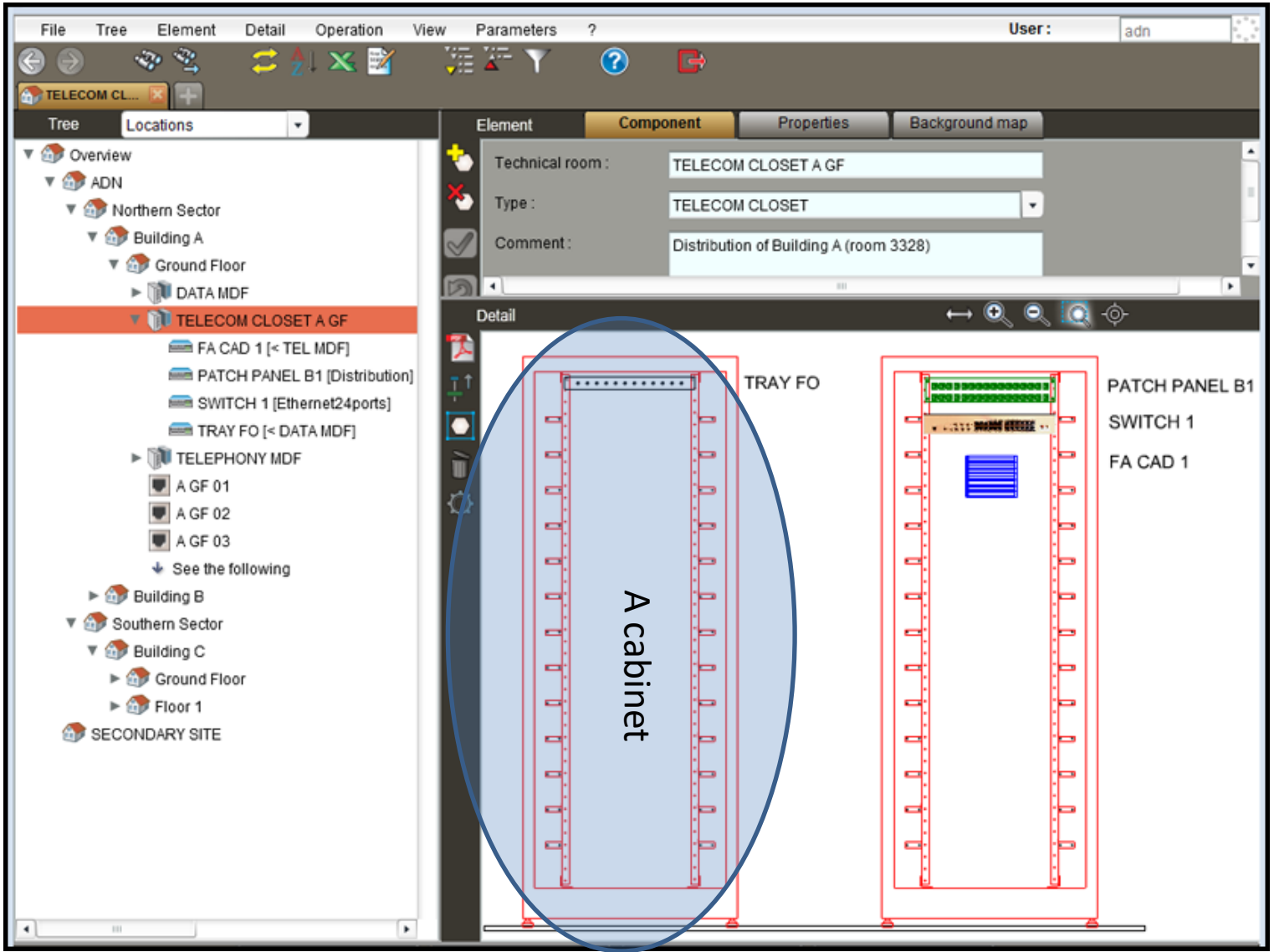

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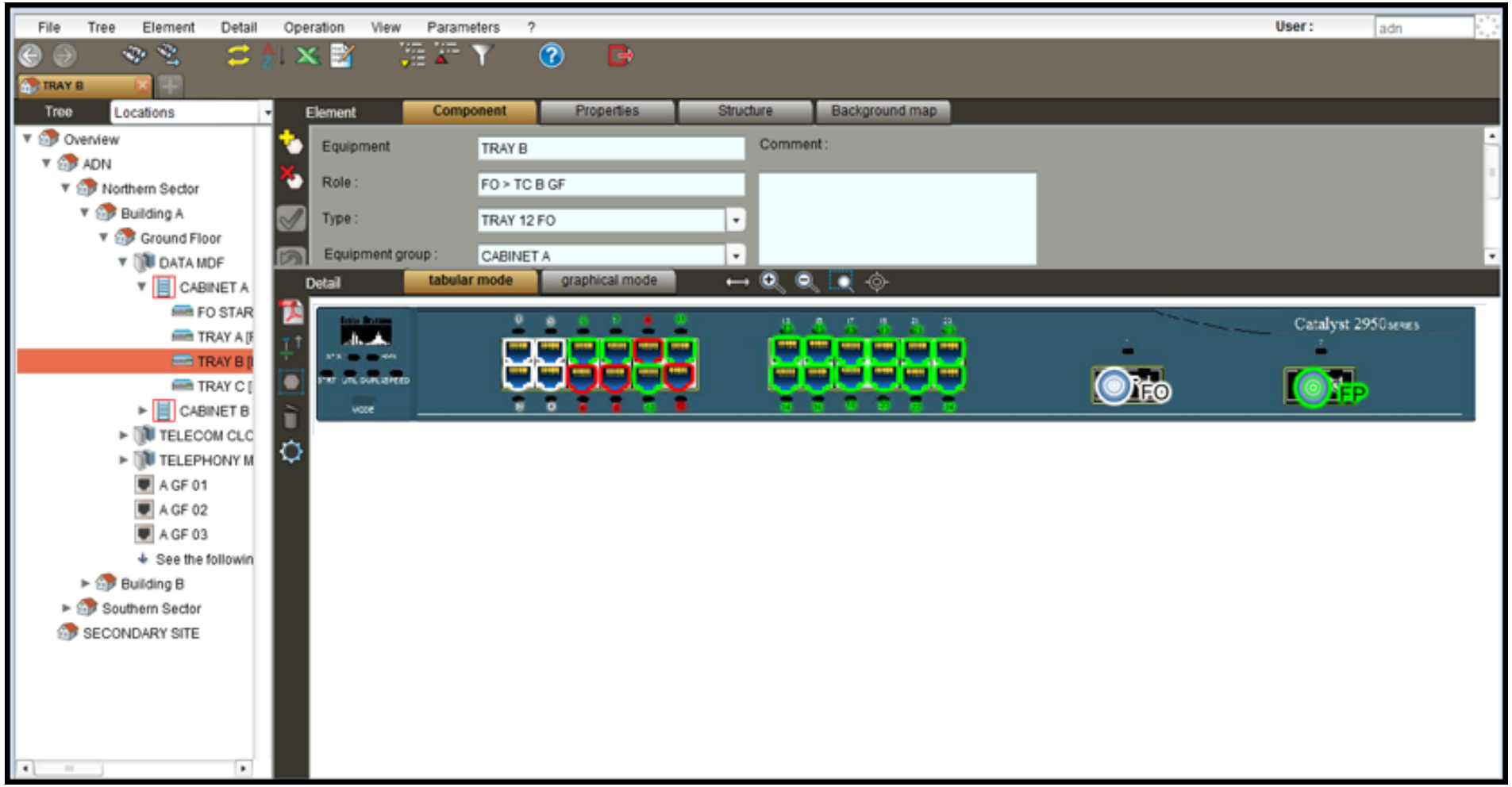
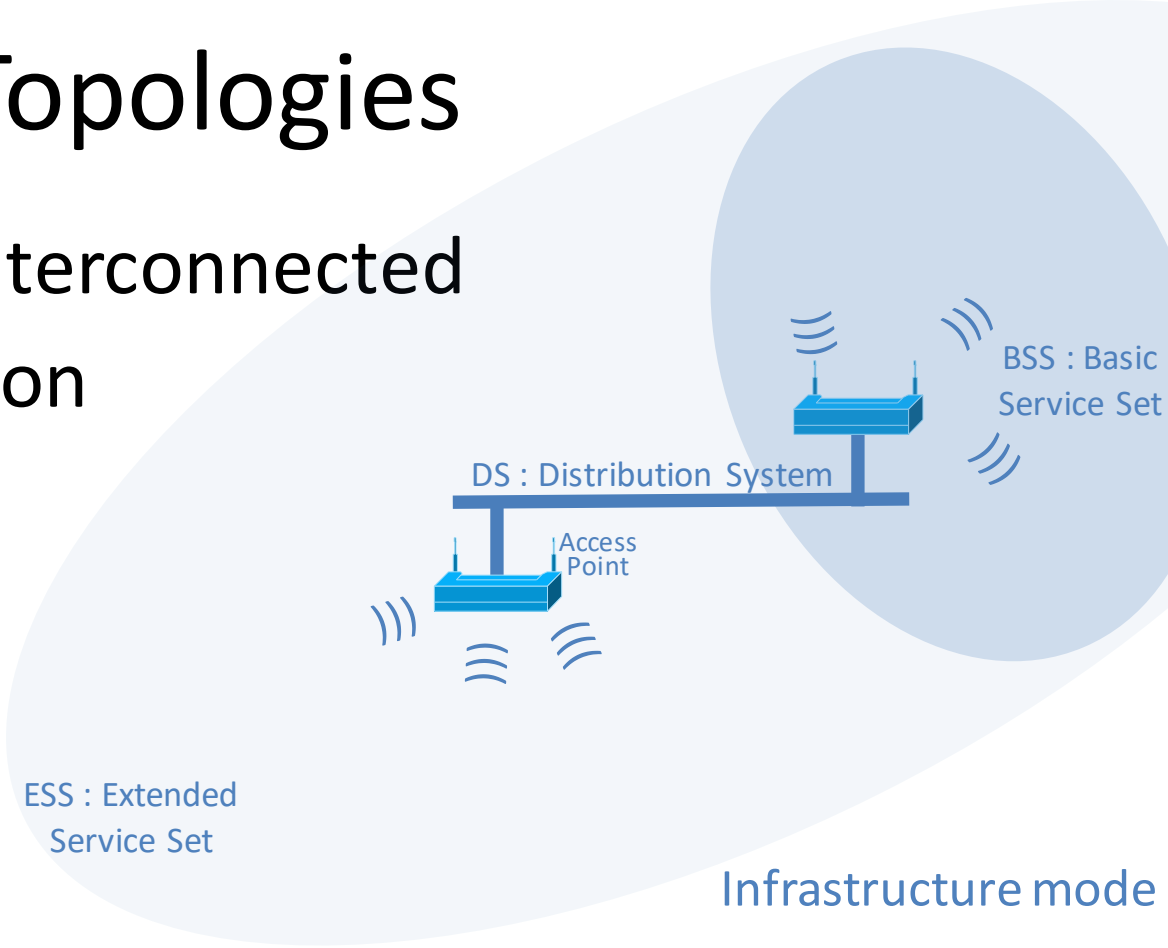


Topologies

- How stations are interconnected
- The network skeleton
  - Star topology
  - Line topology
  - Ring topology
  - Tree topology
  - Mesh topology
  - Bus topology
  - Wireless topology
    - Cheap ! 
    - Medium Acces Control 
    - High bit error rate 

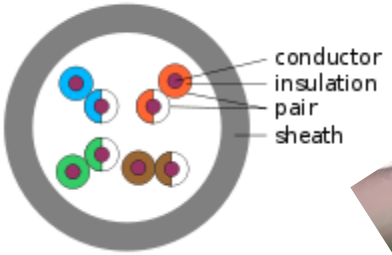


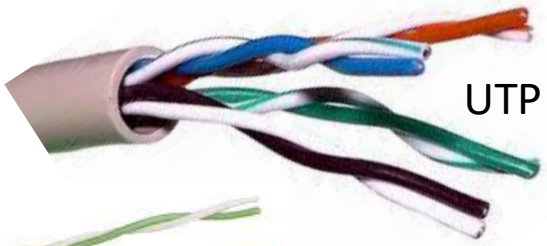
Transmission mediums

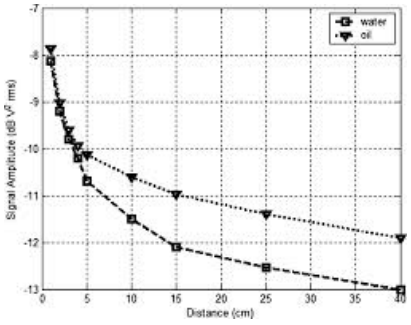
- The transmission may be :
  - Guided :
    - Copper wires
    - Coaxial cables
    - Optical fibers
    - …
  - Unguided :
    - Radio
    - Ultrasound
    - Laser
    - …

Transmission mediums

- Copper wires :
  - UTP Unshielded Twisted Pair
  - STP Shielded Twisted Pair
  - FTP Foiled Twisted Pair
- Advantages :
  - Cheap !
- Disadvantages :
  - Noise sensitive
  - Important attenuation
- Performances :
  - 100 Mb/s over 100 m max



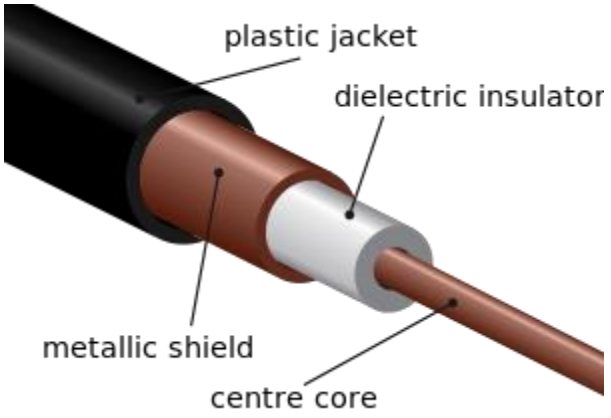




- Plugs : RJ45

Transmission mediums

- Coaxial cables:
  - 2 standardized cables :
    - Characteristic impedance = 50 Ω
      - The first ethernet cable
        - Thick ethernet, yellow cable, 10BAS5
        - Thin ethernet 10BAS2
    - Characteristic impedance = 75 Ω
      - CATV : Community Antenna TeleVision
- Advantages :
  - Limited attenuation
- Disadvantages :
  - expensive
- Performances :
  - 3-400 Mb/s over 500 m max

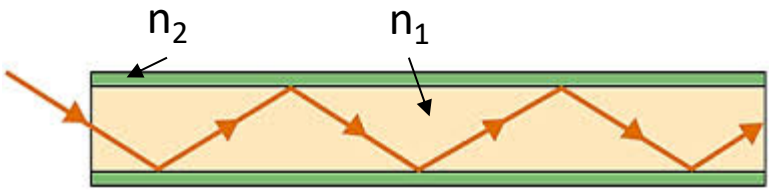


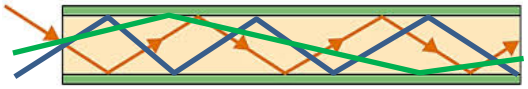
the « yellow » cable

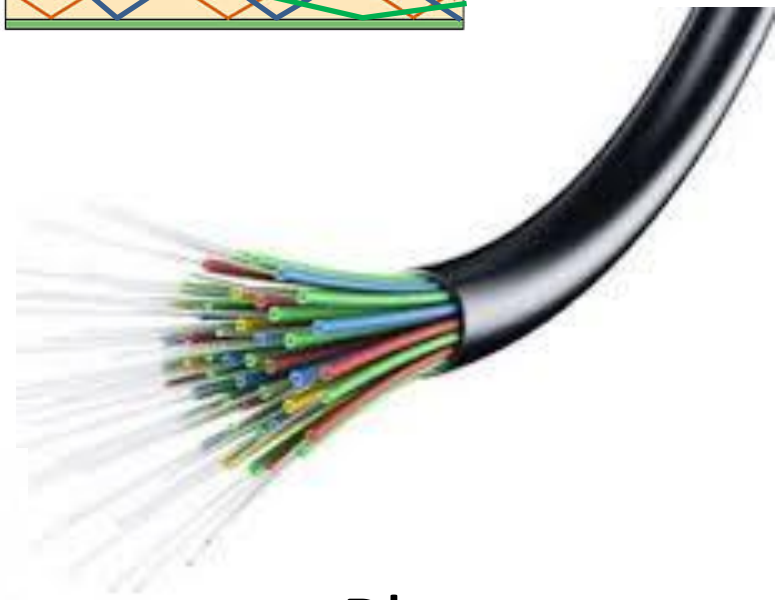
- Plugs : BNC

Transmission mediums

- Optical fibers :
  - Refraction index $n_1 > n_2$
  - Multi-mode
    - Core diameter 50 or 62,5 µm
    - Several « colours » simultaneously
    - « low » bit rates
  - Single-mode
    - Core diameter 9 µm
    - Only one colour in the fiber axis
    - « high » bit rates
- Advantages :
  - Low attenuation
- Disadvantages :
  - Very expensive
- Performances :
  - Up to 50 Mb/s over 100 km !







- Plugs :

THE MEDIUM ACCESS CONTROL

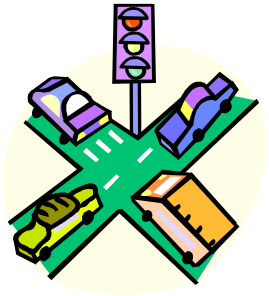
UNIVERSITÉ DE LORRAINE

Prof Thierry DIVOUX

Sept 2013

Outline

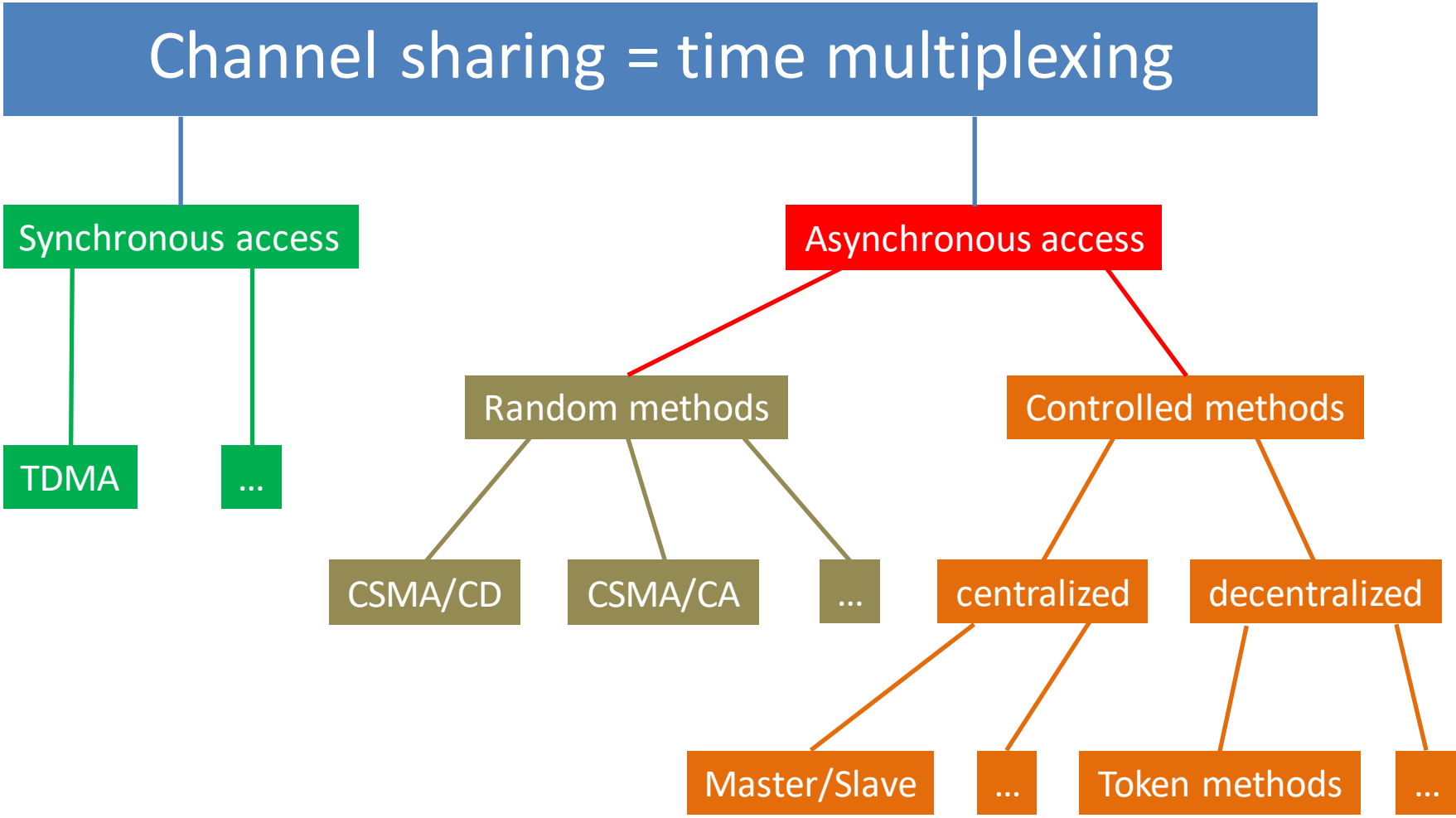
- Medium Access Control classification
- TDMA
- CSMA/CD (Ethernet)
  - History
  - Evolutions
    - Modelling of a switch
    - VLANs
    - Spanning Tree Protocol
    - Green considerations
- CSMA/CA (Wifi)
- Master / Slaves methods
- Token methods



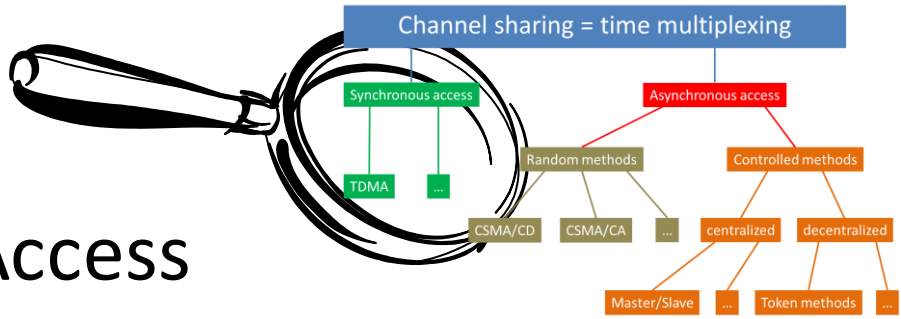
Medium Access Control

- Numerous and various solutions
- Depend on the topology
  - Crossing :
    - Rigth priority
    - Stop
    - redligth
  - Roundabout
    - Left priority
- Several methods are standardized
  - CSMA-CD (Ethernet)
  - CSMA-CA (Wifi)
  - …

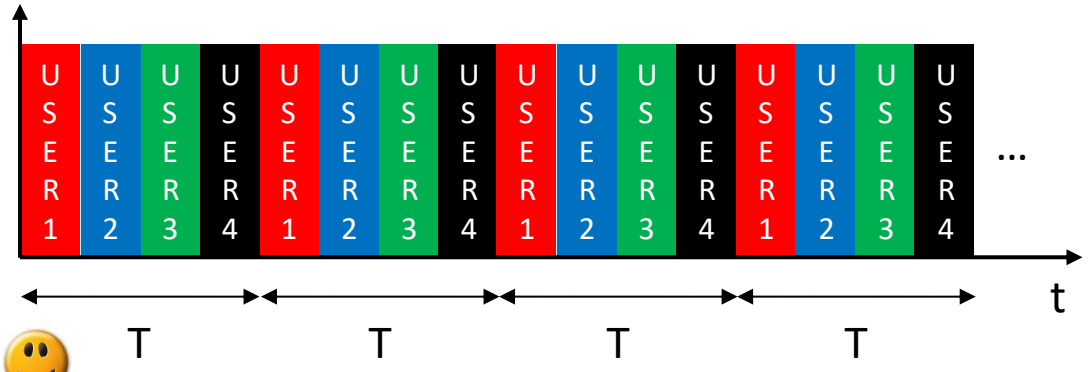
Classification



TDMA

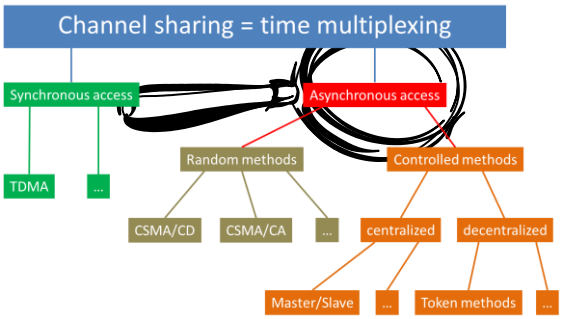


- Time Division Multiple Access
  - Let be T the time reference, N the number of users
  - Each user gets sequentially T/N for transmission



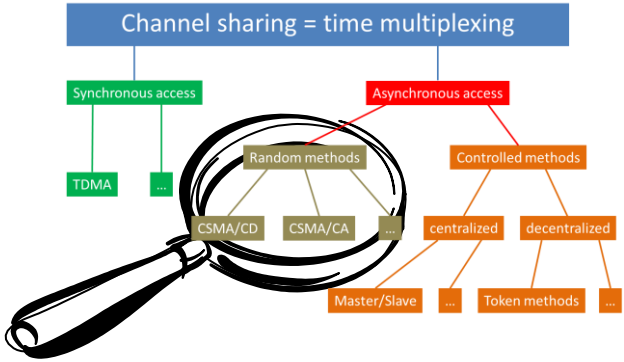
  - Easy 🙂
  - Implicit adressing 🙂
    - If transmission during [(2k/4).T, (3k/4).T] : USER3
  - Medium allocation to a user even if it has nothing to send 🙁
  - Use : PABX, GSM, … (no use for LANs)

Asynchronous access



- Objective :
  - Allocate the network service regarding users transmission needs
    - Large bandwith for those which have a lot to transmit
    - Less for those which have few to send
  - Problem : how long to wait for the network service ?
    - Undefined : random methods
    - Guarantee of a maximum waiting time : controlled methods

Random methods



- Non deterministic methods
  - Impossible to guarantee a maximum delay for transmission
- The Cambridge Ring (1989)
  - Not standardized
- CSMA/CD (Ethernet)
- CSMA/CA (Wi-Fi)

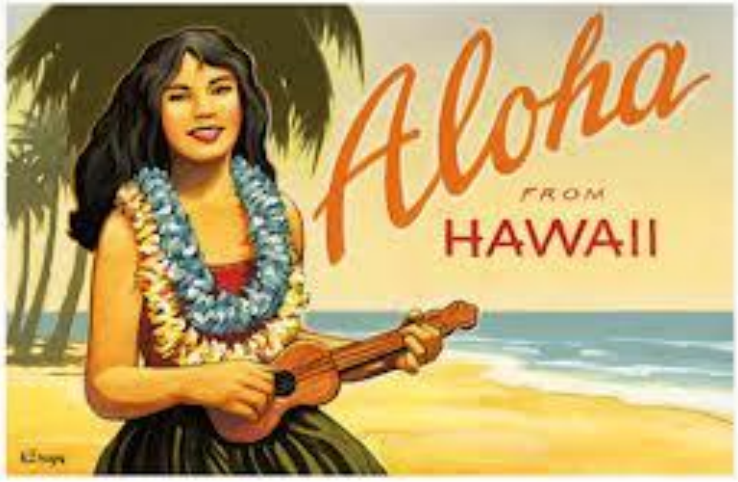
Ethernet :

the most famous wired LAN protocol

3 billions interfaces installed worldwide !

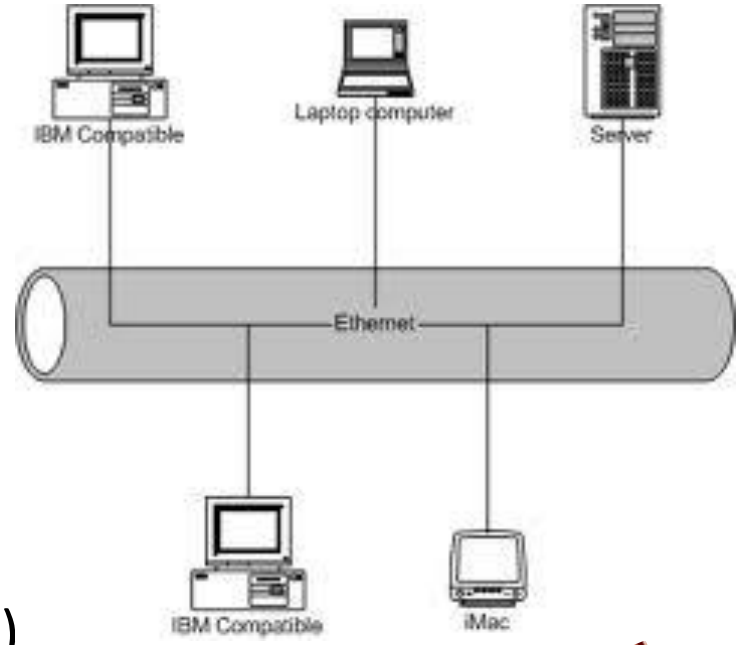
From islands…

- Prof Norman Abrahamson
  - University of Stanford
  - Avid surfer
  - Holidays in Hawaï (1969)…
  - Decides to stay

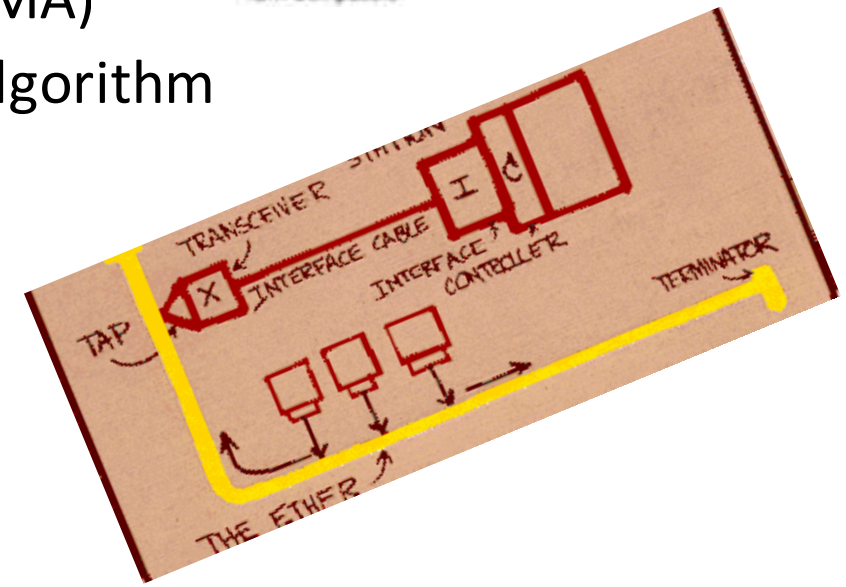


- funds his research with contracts :
  - Designs a distributed system for hotels booking
  - « ALOHA » protocol
    - Something to send ? Try to send !
    - If problem, try again !

… to office …

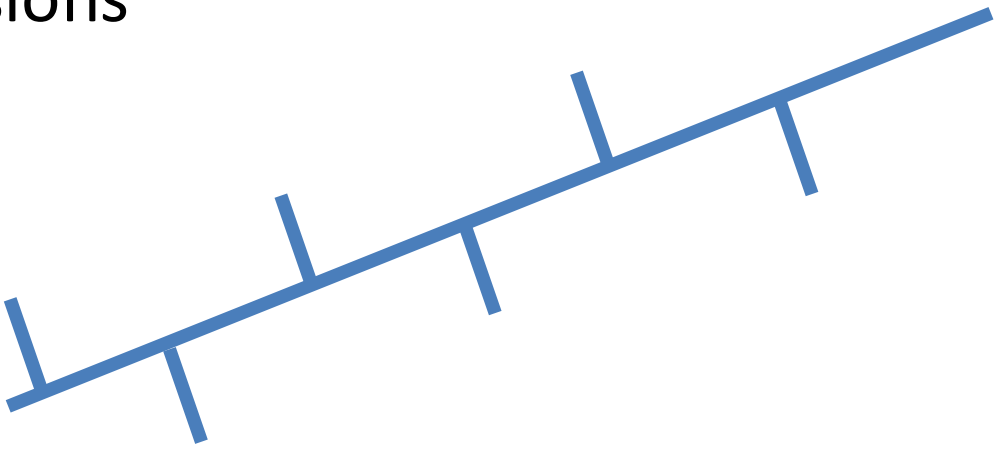


- Bob Metcalfe
  - Xerox engineer
  - In charge of interconnection
  - Ehances ALOHA
    - Listening before sending (CSMA)
    - Binary Exponential Backoff algorithm
  - 1973 : « Ethernet »
  - 1980 : DIX consortium
    - DEC, Intel, Xerox
  - 1983
    - IEEE 802.3 standardization



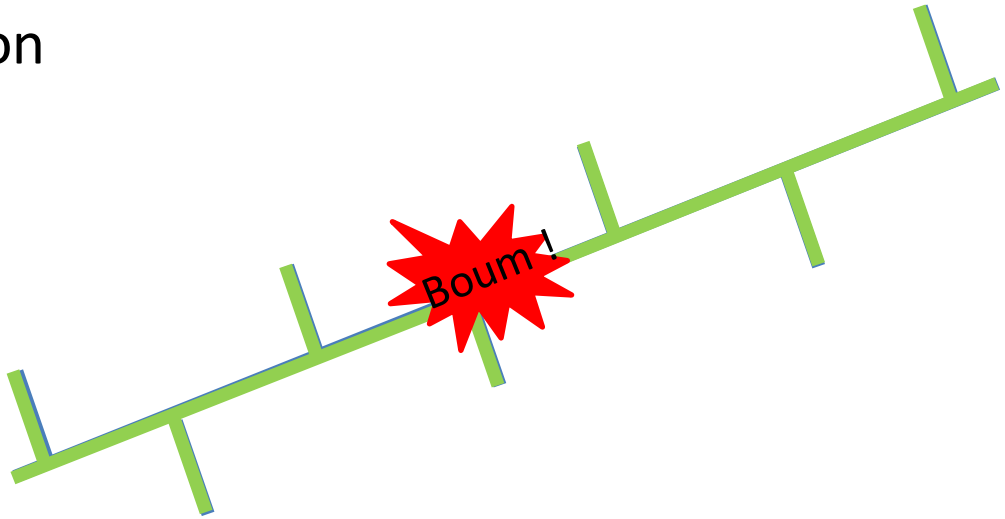
The most famous method : CSMA-CD

- Carrier Sense Multiple Access – Collision Detection
- IEEE 802.3, then IS 8802.3
- Only on a « bus » topology
  - Pb : transmission channel sharing
  - How to solve collisions

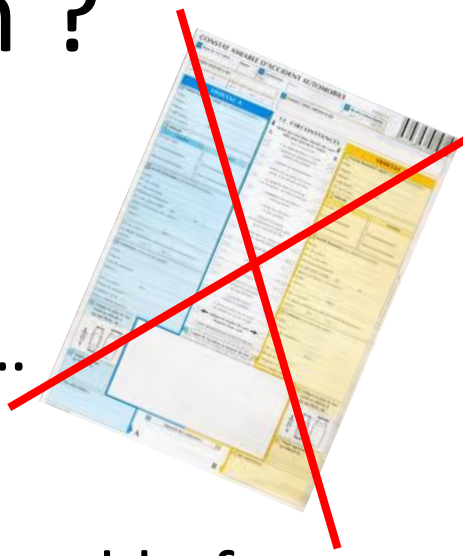


Collision

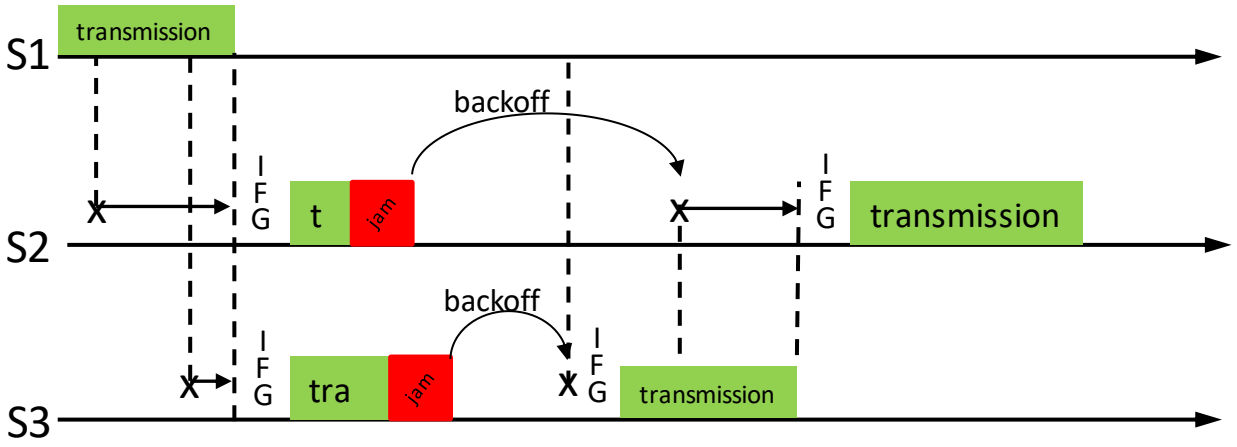
- multaneous transmission :
  - Free channel ?
    - Waiting the Inter Frame Gap (IFG)
    - Transmission
    - Collision



How to solve a collision ?

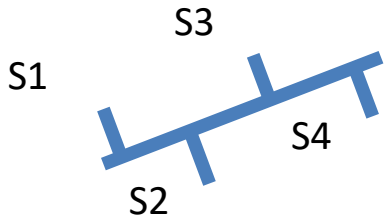


- Accident report is unsuitable !
  - Because communication is impossible …
- We'll leave it to chance …
  - a random waiting time (backoff) is selected before retrying transmission



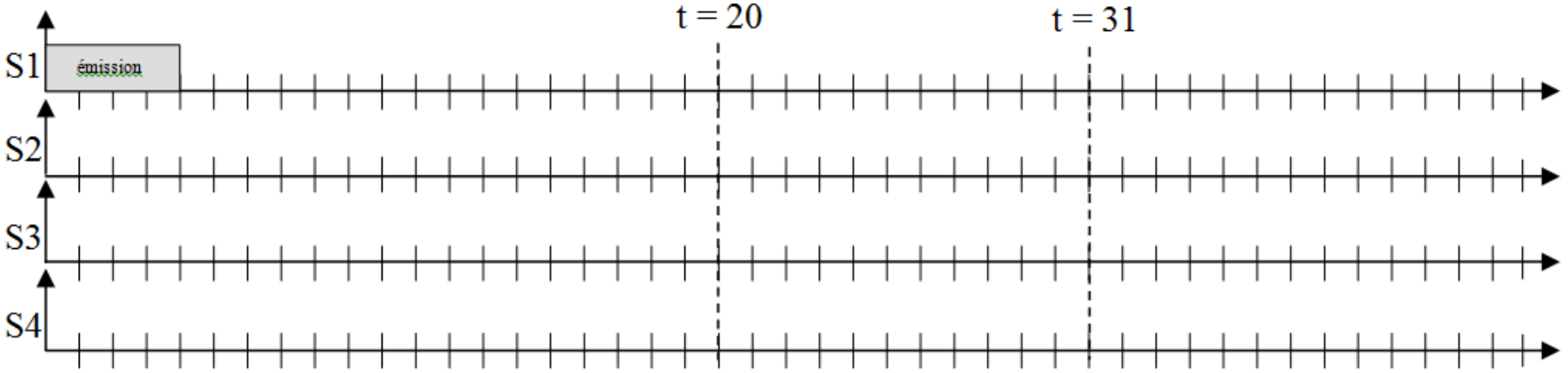
Exercise !

Study of a CSMA/CD communication scenario



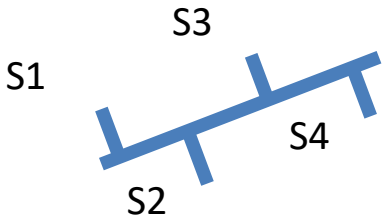
-propagation times are neglegted
-the Inter Frame Gap equals 1 time unit
-collisions are detected after 1 time unit
-the jam sequence is 1 time unit long
-S1 transmits from t = 0 up to t = 4
-firstly, S2, S3 and S4 each have a frame to be transmitted, of respective length 2, 4, and 3 time units, at respectivelly t = 1, t = 2, and t = 3.
- at t= 20, S1 has a new frame to transmit (length = 2)
- at t= 31, S4 has a new frame to transmit (length = 2)
-successive backoffs are for S1 (1-2-3-4), for S2 (2-4-3-4), for S3 (4-3-1-1), and for S4 (3-2-1-2)

Complete the following chronogram



Solution !

Study of a CSMA/CD communication scenario



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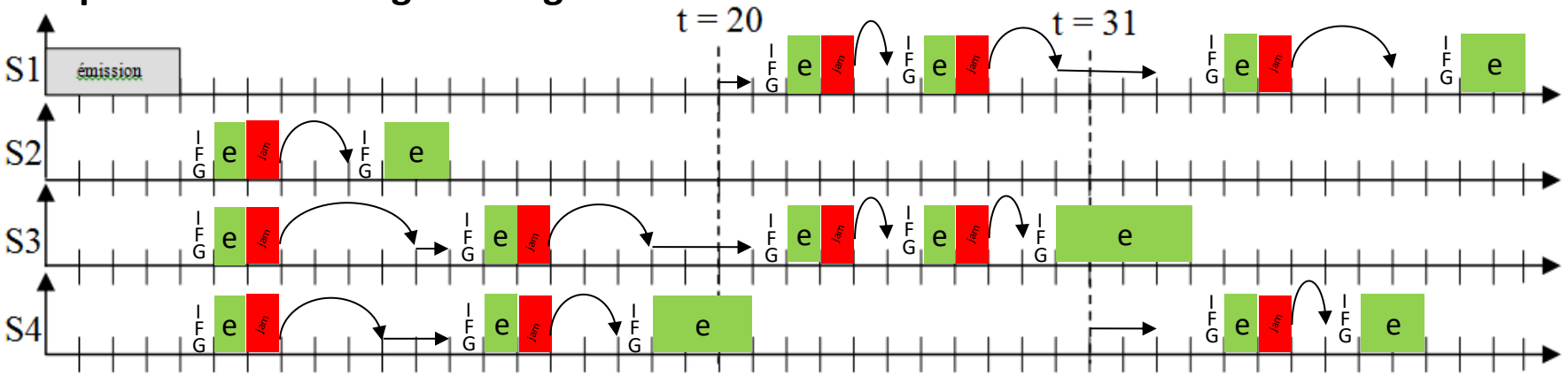
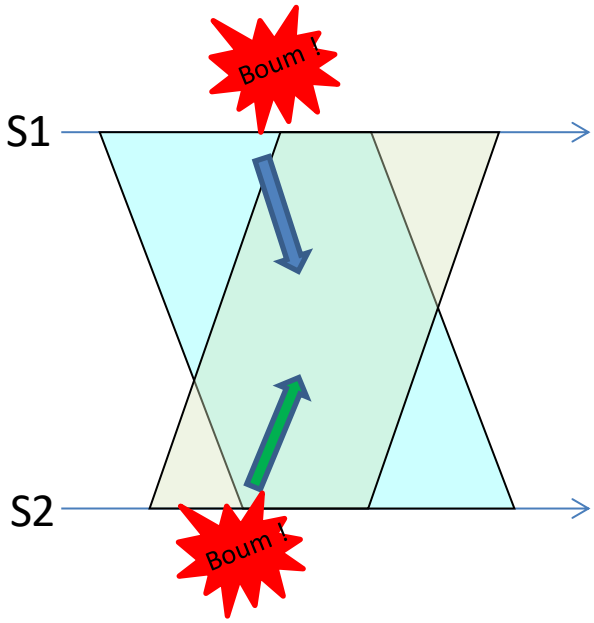
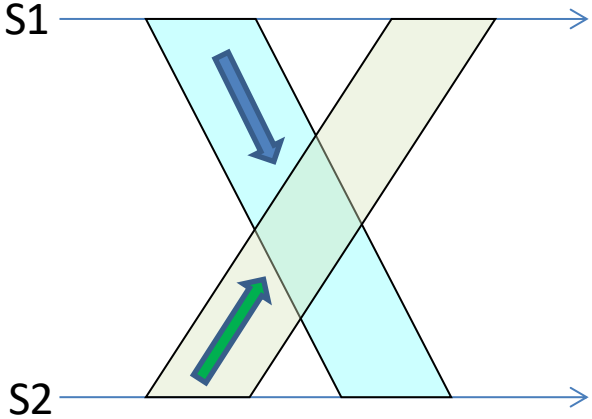
Complete the following chronogram



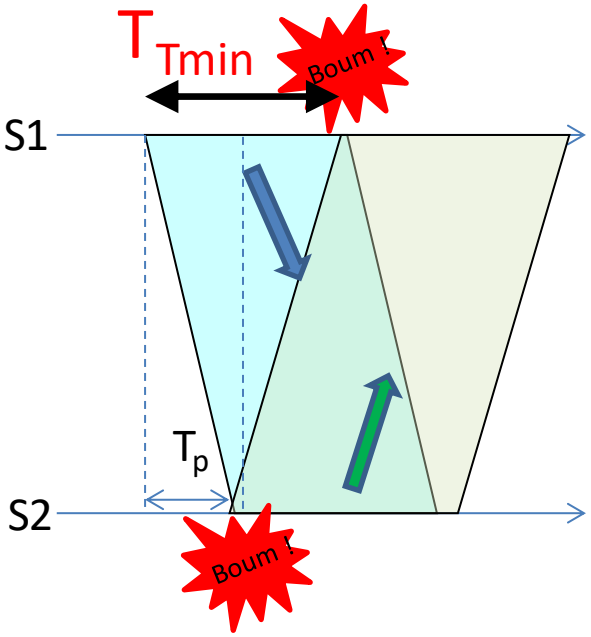
Problem : propagation time can't be negligted !



Collision detected !



Collision not detected !



At the limit ….

$$T_{Tmin} \geq 2T_{pmax} = T_s$$

The frames minimum size is such that their transmission time exceeds 2 time the propagation time between the most distant stations

$2T_{pmax}$ is called « *slot time* » (T_s)

The Binary Exponential Backoff (BEB)

- The backoff is chosen randomly in an interval whose width increases with the number of attempts :
- $[0, 2^i \times T_s]$
  - with :
    - i : number of sending attempt
    - T_s : slot time = $2T_{pmax}$
  - Maximum sending trys : 16

$[0, 2T_s]$

$[0,\ldots\ldots\ldots 4T_s]$

$[0,\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots 8T_s]$

$[0,\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots 16T_s]$

…

IEEE 802.3 frames format

PRE	SFD	DA	SA	LEN	Data + padding	FCS

Bytes : (7 + 1 + 6 + 6 + 2 + n +if necessary + 4) ≥ 64

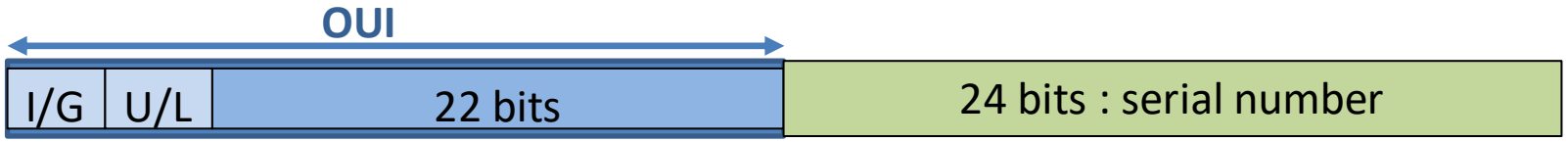
- PREamble = 10101010…10101010 (56 bits)

The clock

- Start Frame Delimiter = 10101011

- DA, SA : Destination and Source Addresses
- LENgth : of the data (n)
  - Nowadays, « LEN » is replaced by « Protocol Type »
    - Because with the IP (20 bytes) and TCP (20 bytes), the frame is long enough
    - Ex : Protocol Type = $(0800)_{16}$ when IP over Ethernet
- Padding : if necessary, to fill the frame up to 64 bytes
- Frame Check Sequence

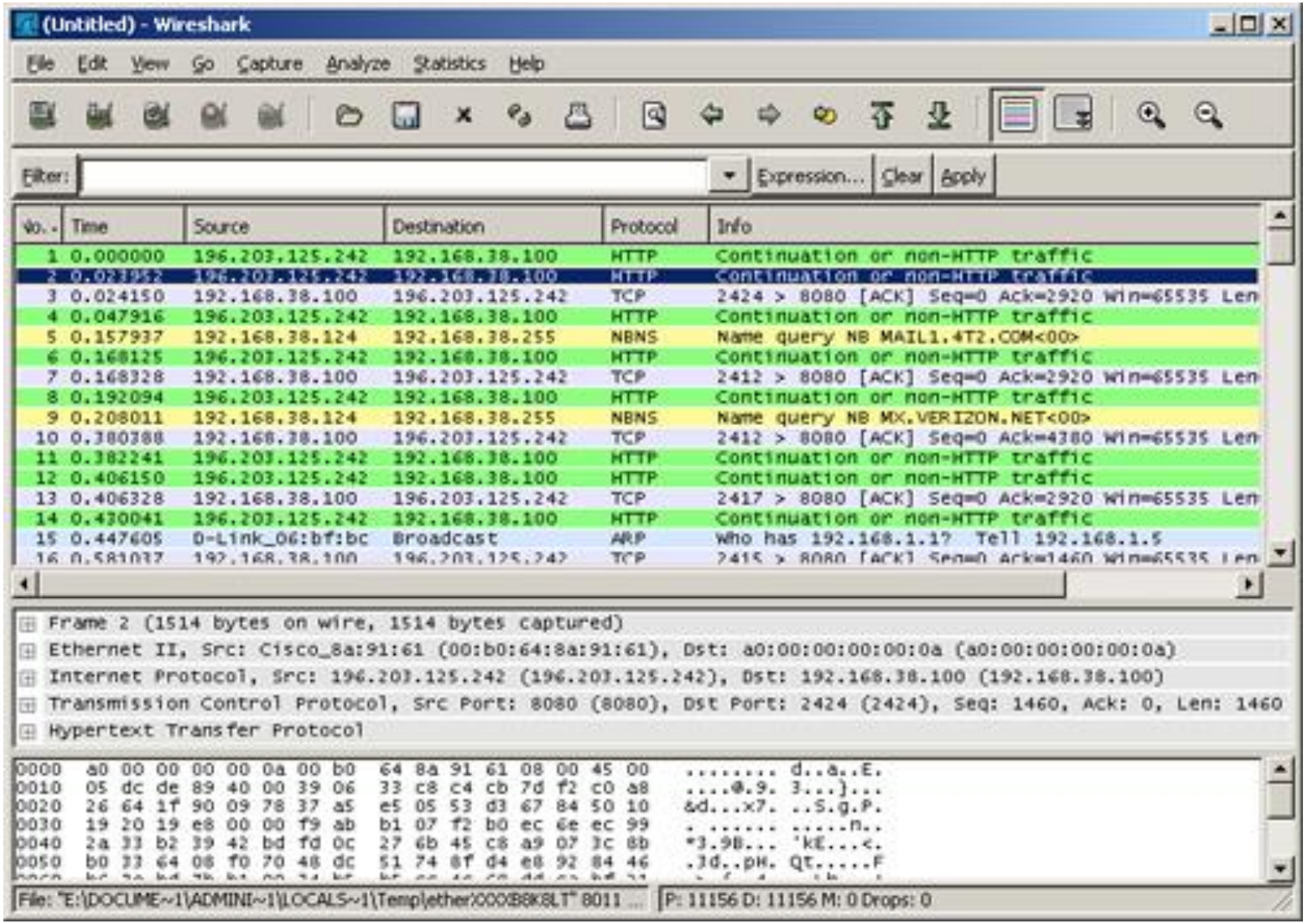
Addresses format



- 3 bytes coding the manufacturer
  - OUI : *Organizationally Unique Identifier*, given by the IEEE
  - Ex :
    - 00-B0-64 (hex) CISCO SYSTEMS, INC (among others)
    - 00-04-75 (hex) 3 Com Corporation (created by Bob Metcalfe in 1979)
    - 00-1E-0B (hex) Hewlett-Packard Company
- 3 bytes for the serial number
- The 2 MSB :
  - Bit I/G :
    - 0: individual address, for an unique device (unicast)
    - 1 : group address (multicast)
      - FF-FF-FF-FF-FF-FF is the broadcast address
  - Bit U/L :
    - 0 : universal address in conformance with the IEEE format,
    - 1 : local address (this address is locally managed)

Example

- A frame analyser : wireshark

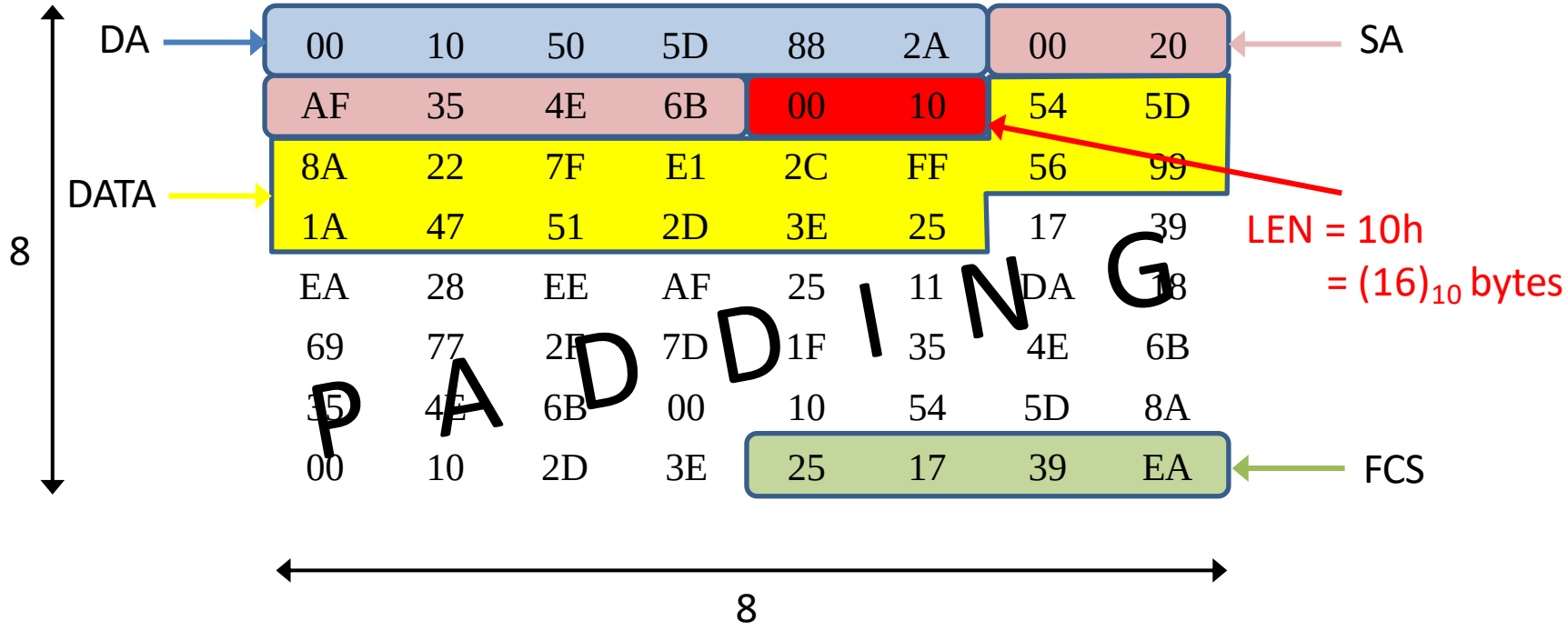


Padding : an example

PRE	SFD	DA	SA	LEN	Data + padding	FCS

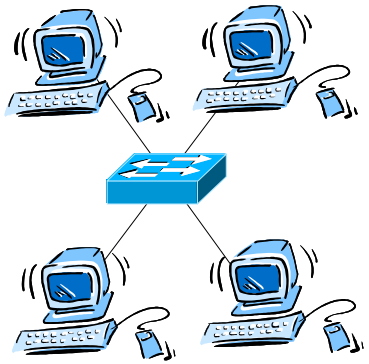
Bytes : (7 + 1 + 6 + 6 + 2 + n + if necessary + 4) ≥ 64

PREamble and Start Frame Delimiter are not displayed

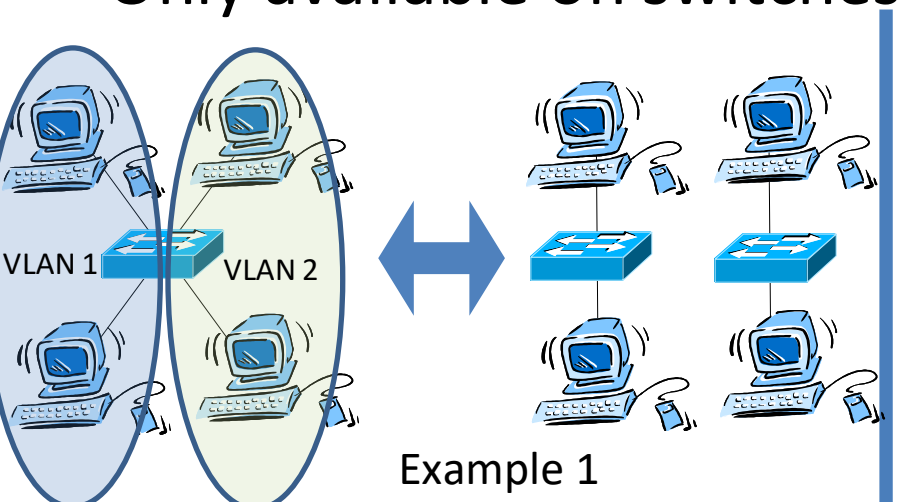


VLANs

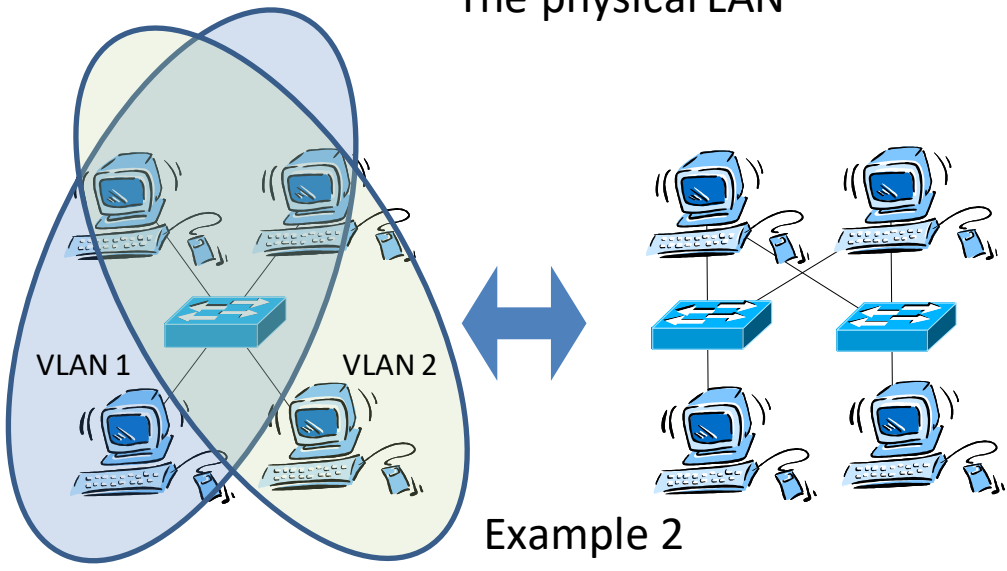
- Virtual LANs
- Several VLANs (logical) on an unique physical LAN
  - Creation of multiple broadcast domains
  - Creation of mutually isolated domains
- Interests :
  - Simple and flexible (regarding wiring)
  - Security, confidentiality
- Only available on switches



The physical LAN



Example 1



Example 2

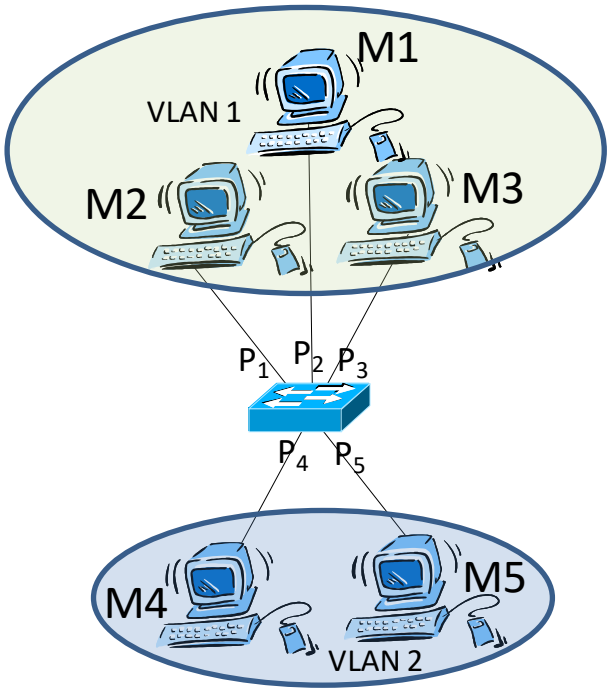
VLANs

- Several techniques
  - Level 1 VLAN : based on the switch ports
    - High security (only the admin has rights on the switch management) 🙂
  - Level 2 VLAN : based on stations MAC addresses
    - Interresting for mobile stations 🙂
    - Heavy management for the network admin who have to know all MAC @ 🙁
    - Low security (the user can modify its MAC @) 🙁
  - Level 3 VLAN : based on stations IP addresses
    - Easy for the network administrator 🙂
    - Low security (the user can modify its IP @) 🙁
- This defines in all cases the belonging of each port to one or several VLANs

VLANs

- Port-based VLAN
  - Association of a VLAN number to each switch port
  - The switch records :

Port	VLAN
P_1	1
P_2	1
P_3	1
P_4	2
P_5	2



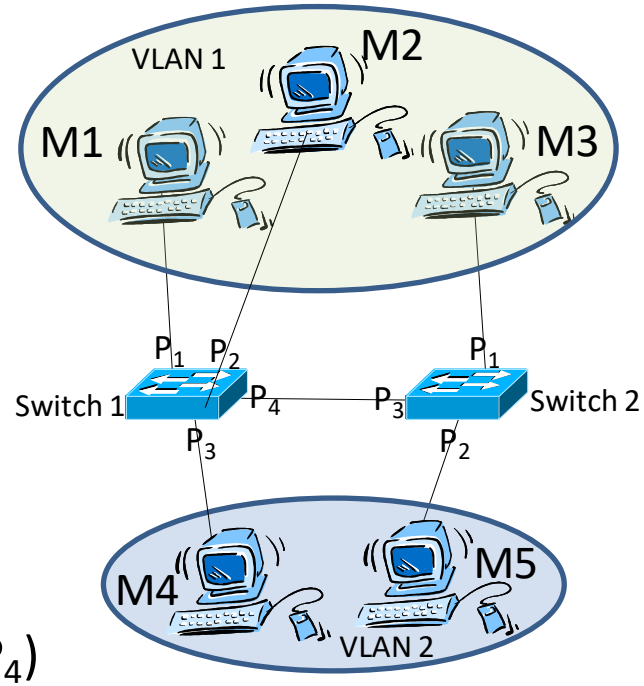
  - Ping (M4 on M1) : no response …
    - Because ARP request is only broadcasted on VLAN 1

VLANs

- Let us consider this configuration :

Switch 1	
Port	VLAN
P_1	1
P_2	1
P_3	2
P_4	1, 2

Switch 2	
Port	VLAN
P_1	1
P_2	2
P_3	1, 2



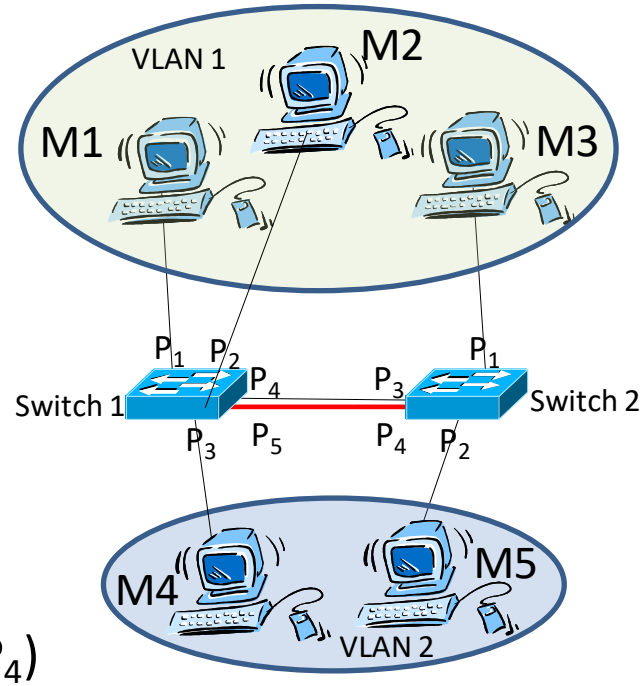
  - Ping (M1 on M3) :
    - ARP request is broadcasted on VLAN 1 (on P_2 and P_4)
    - But how switch 2 knows on which port forwarding this request ?
      - P3 is associated to both the VLANs

VLANs

- Let us consider this configuration :

Switch 1	
Port	VLAN
P_1	1
P_2	1
P_3	2
P_4	1, 2

Switch 2	
Port	VLAN
P_1	1
P_2	2
P_3	1, 2



– Ping (M1 on M3) :
  - ARP request is broadcasted on VLAN 1 (on P_2 and P_4)
  - But how switch 2 knows on which port forwarding this request ?
    – P3 is associated to both the VLANs

– Solutions :
  - 1 : a second physical link between the 2 switches :
  - 2 : the frame includes the VLAN number in its header : « tagged » VLAN (IEEE 802.1Q)

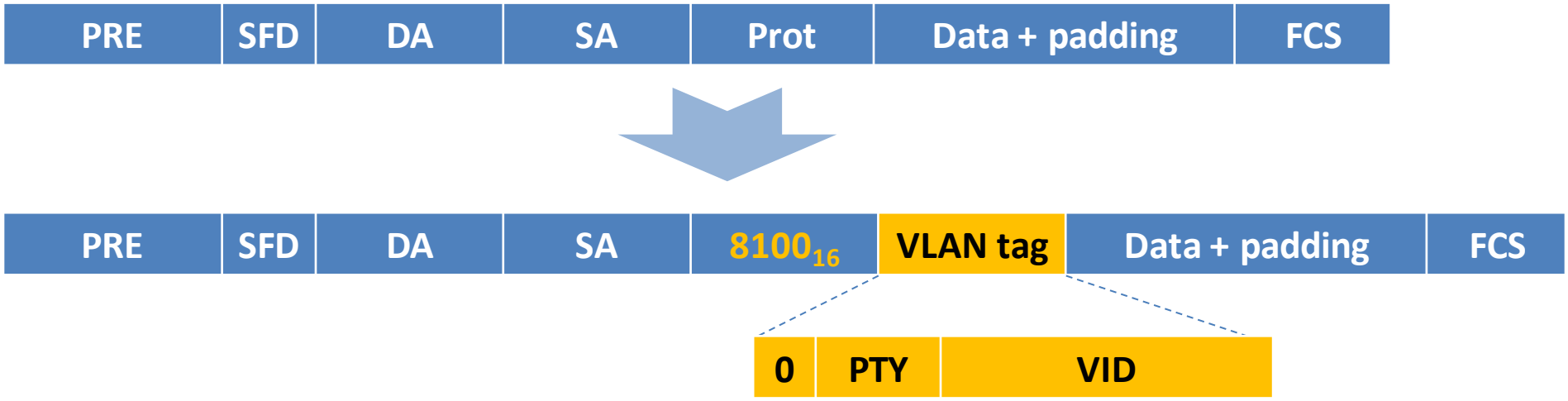
Switch 1	
Port	VLAN
P_1	1
P_2	1
P_3	2
P_4	1
P_5	2

Switch 2	
Port	VLAN
P_1	1
P_2	2
P_3	1
P_4	2

Solution n° 1

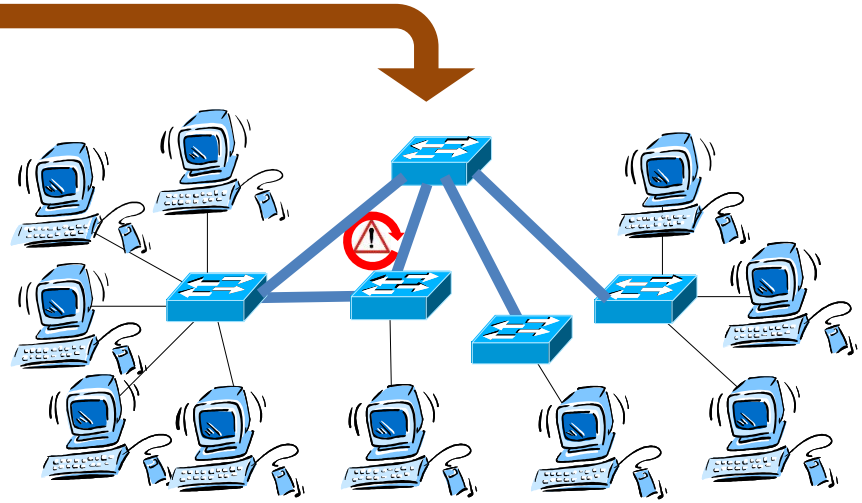
VLANs

- From IEEE 802.3 to IEEE 802.1Q frame format
  - 2 bytes are added to the 802.3 frame
    - Signaled by Prot Type = 8100_{16}



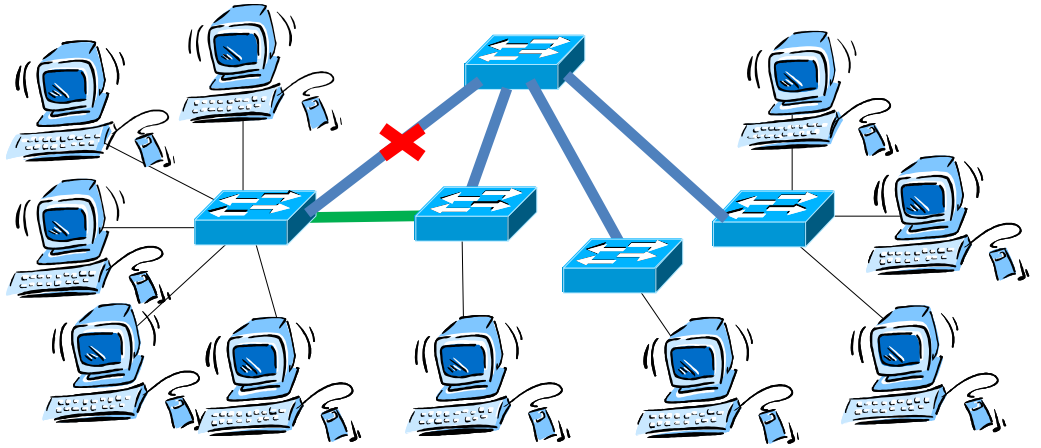
- PTY : 3 bits : Priority for CoS (between 0 and 7)
- VID : 12 bits : VLAN Identifier

The Spanning Tree Protocol



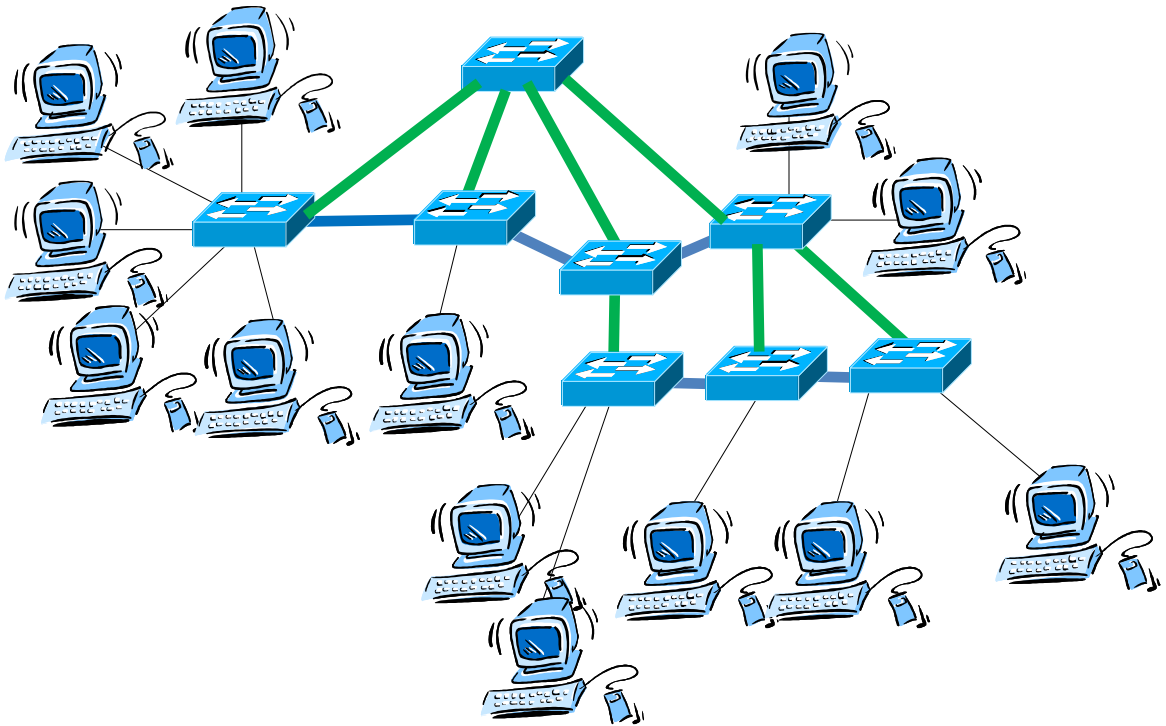
- Aim :
  - To avoid loops
    - Infinite frames repetition
    - Desactivation of some switch ports
  - Reconfiguration of the network in case of :
    - Switch port failure
    - Link failure

    through redundant link activation



The Spanning Tree Protocol

- STP is standardized as IEEE 802.1D
- Principle :
  - Building a tree enabling to reach all stations
  - Avoiding multi-pathes



The Spanning Tree Protocol

- How to build the tree ?
  - Bridges (switches) periodically send BPDU
    - Bridge Protocol Data Unit
  - There are three types of BPDUs:
    - Configuration BPDU (CBPDU), used for Spanning Tree computation
    - Topology Change Notification (TCN) BPDU, used to announce changes in the network topology
    - Topology Change Notification Acknowledgment (TCA)
  - BPDUs are exchanged regularly (every 2 seconds by default) and enable switches to keep track of network changes

The Spanning Tree Protocol

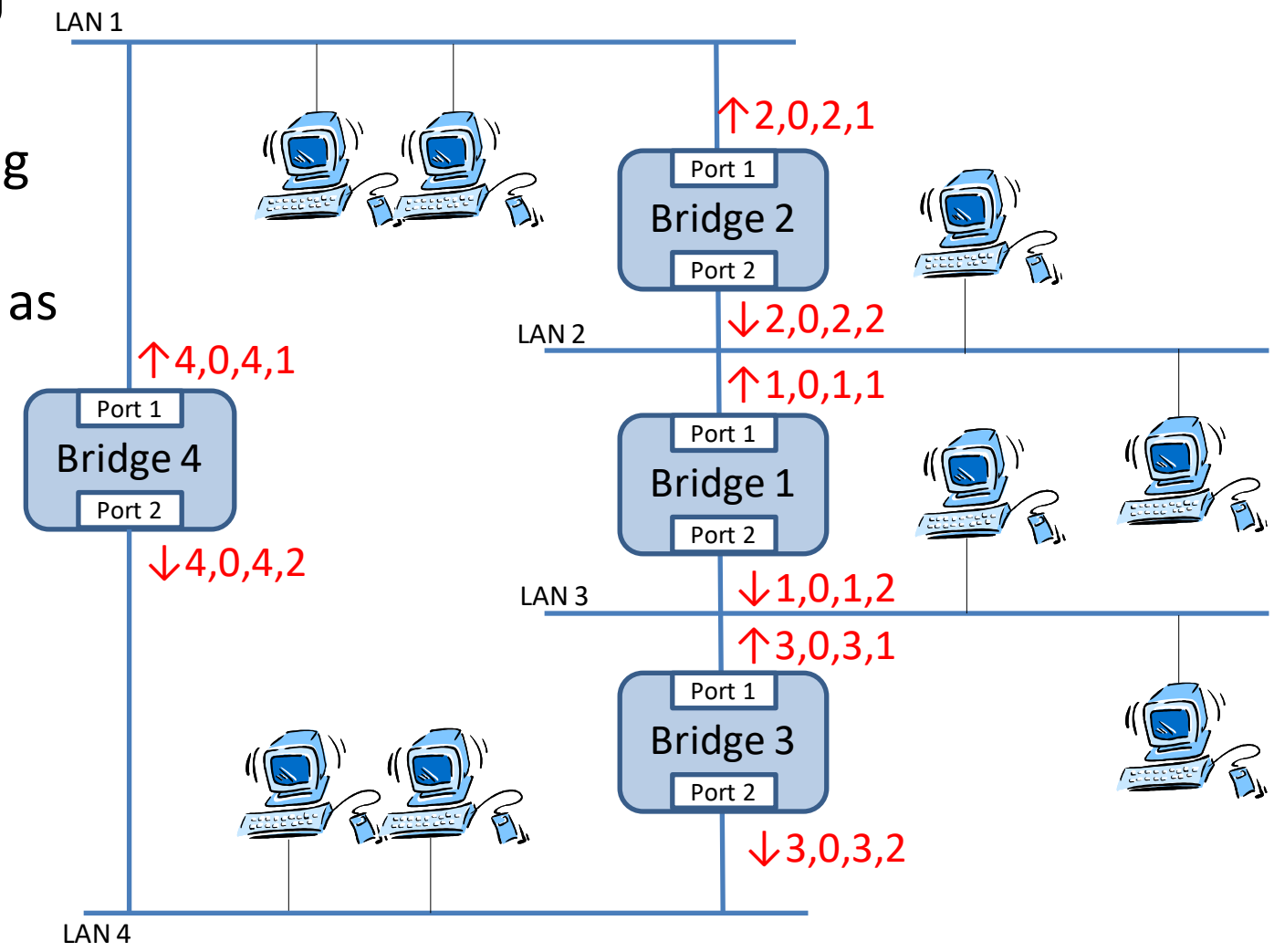
- CBPDU :
  - (root / cost to the root / bridge / port)
    - Root : the MAC address of the supposed root
    - Cost to the root :
      - Number of hops to the root
      - Time to reach the root
      - Average bit rate to the root
      - ….
    - Bridge : the MAC address of the CBPDU sender
    - Port : the port number on which the CBPDU is sent

The Spanning Tree Protocol

- CBPDU : (root / cost to the root / bridge / port)
- Each bridge compares sent and received CBPDU and updates the configuration that seems best
- A CBPDU is better than another if (in the order) :
  - The root ID is lower
  - The cost to the root is lower
  - The bridge ID is lower
  - The port number is lower

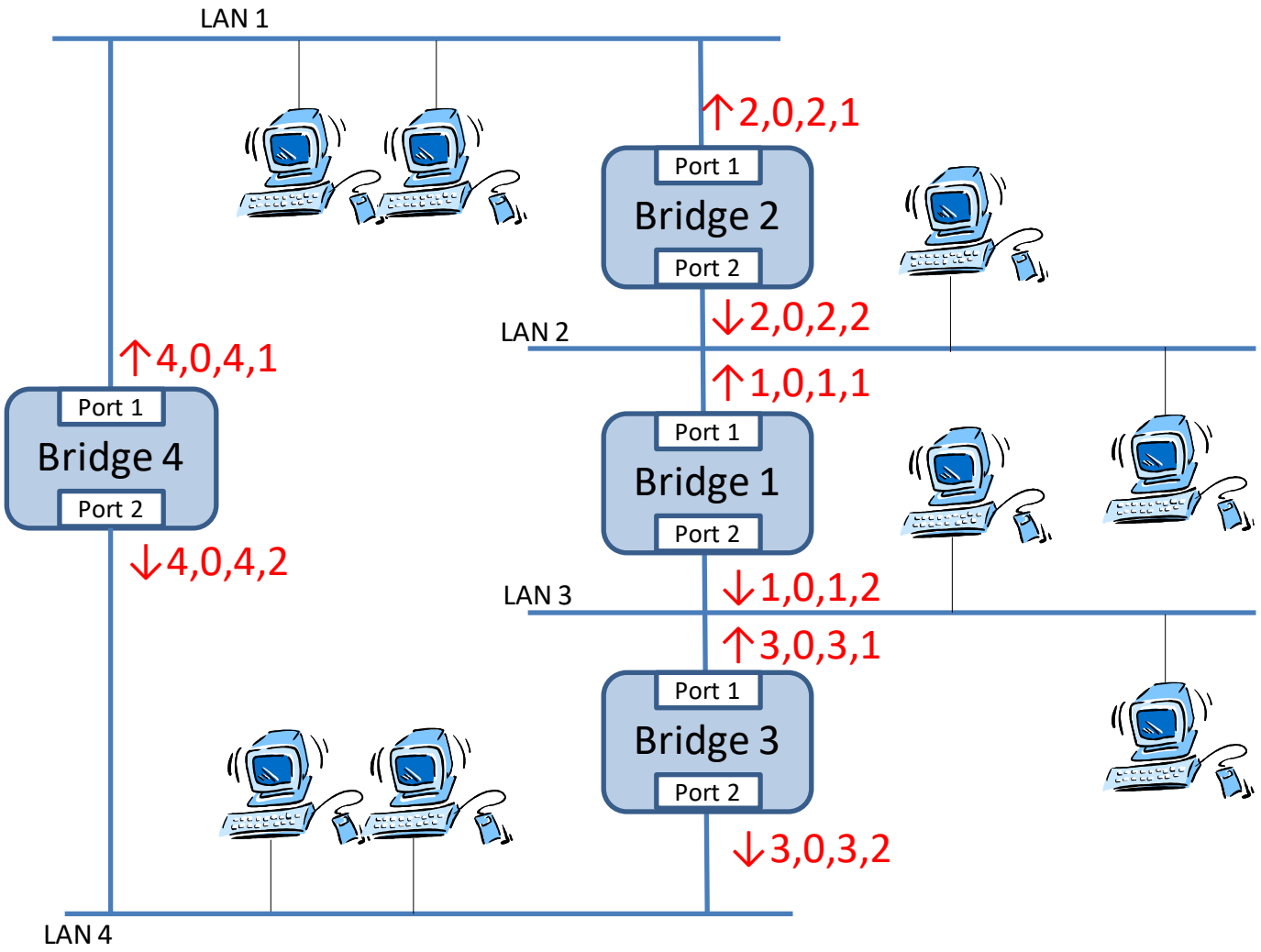
The Spanning Tree Protocol

- Example :
  - ✓ 1st step: CBPDU sending
  - ✓ At the beginning each node considers itself as the root



The Spanning Tree Protocol

- Example :
  - ✓ 2nd step :
  - ✓ 1 compares :
    - 1,0,1,x (sent)
    - 2,0,2,2 (received)
    - 3,0,3,1 (received)
    - It remains the root
  - ✓ 2 compares :
    - 2,0,2,x (sent)
    - 1,0,1,1 (received)
    - 4,0,4,1 (received)
    - the root becomes 1
  - ✓ 3 compares :
    - 3,0,3,x (sent)
    - 1,0,1,2 (received)
    - 4,0,4,2 (received)
    - the root becomes 1
  - ✓ 4 compares :
    - 4,0,4,x (sent)
    - 2,0,2,1 (received)
    - 3,0,3,2 (received)
    - the root becomes 2



The Spanning Tree Protocol

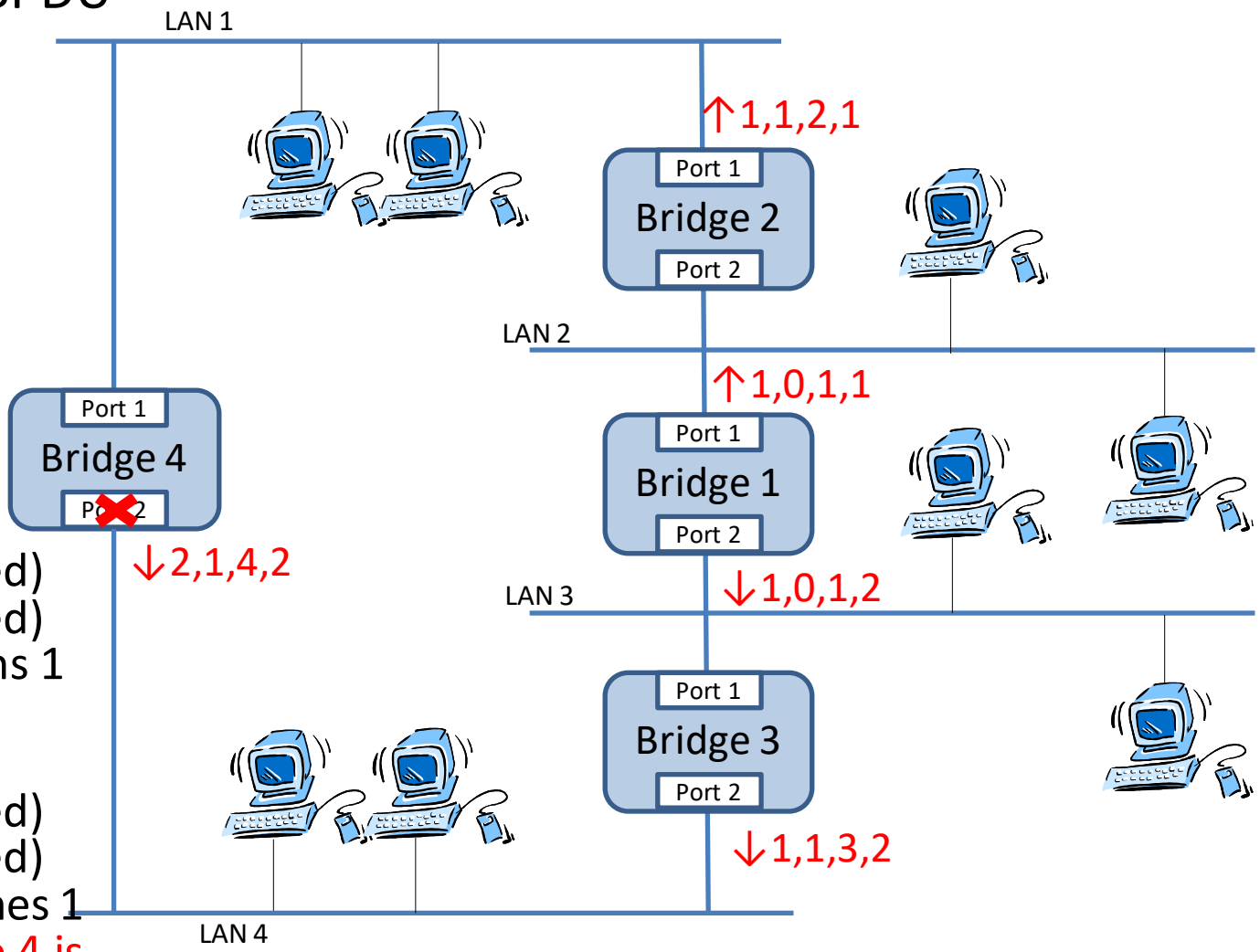
- Example :

✓ 3rd step: new CBPDU sending

- ⚠ Only on the non- root ports
- With the updated roots and costs

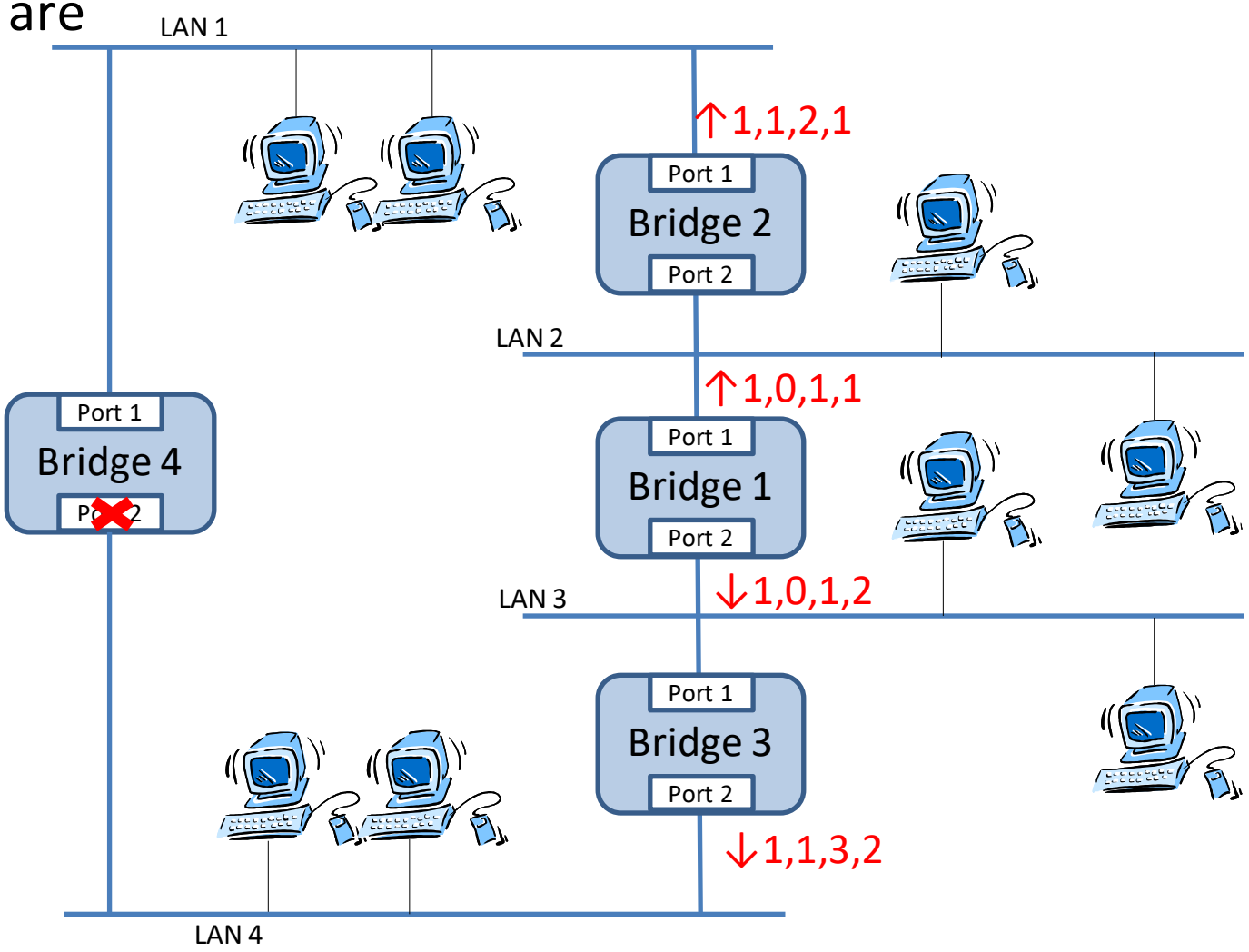
✓ 4th step :

- 3 compares :
  - ✓ 1,1,3,2 (sent)
  - ✓ 1,0,1,2 (received)
  - ✓ 2,1,4,2 (received)
  - ✓ the root remains 1
- 4 compares :
  - ✓ 2,1,4,2 (sent)
  - ✓ 1,1,2,1 (received)
  - ✓ 1,1,3,2 (received)
  - ✓ the root becomes 1
  - ✓ Port 2 of Bridge 4 is desactivated



The Spanning Tree Protocol

- Example :
  - ✓ 5th step: CBPDU are sent every 2 s
    - ⚠ Only on the non-root ports

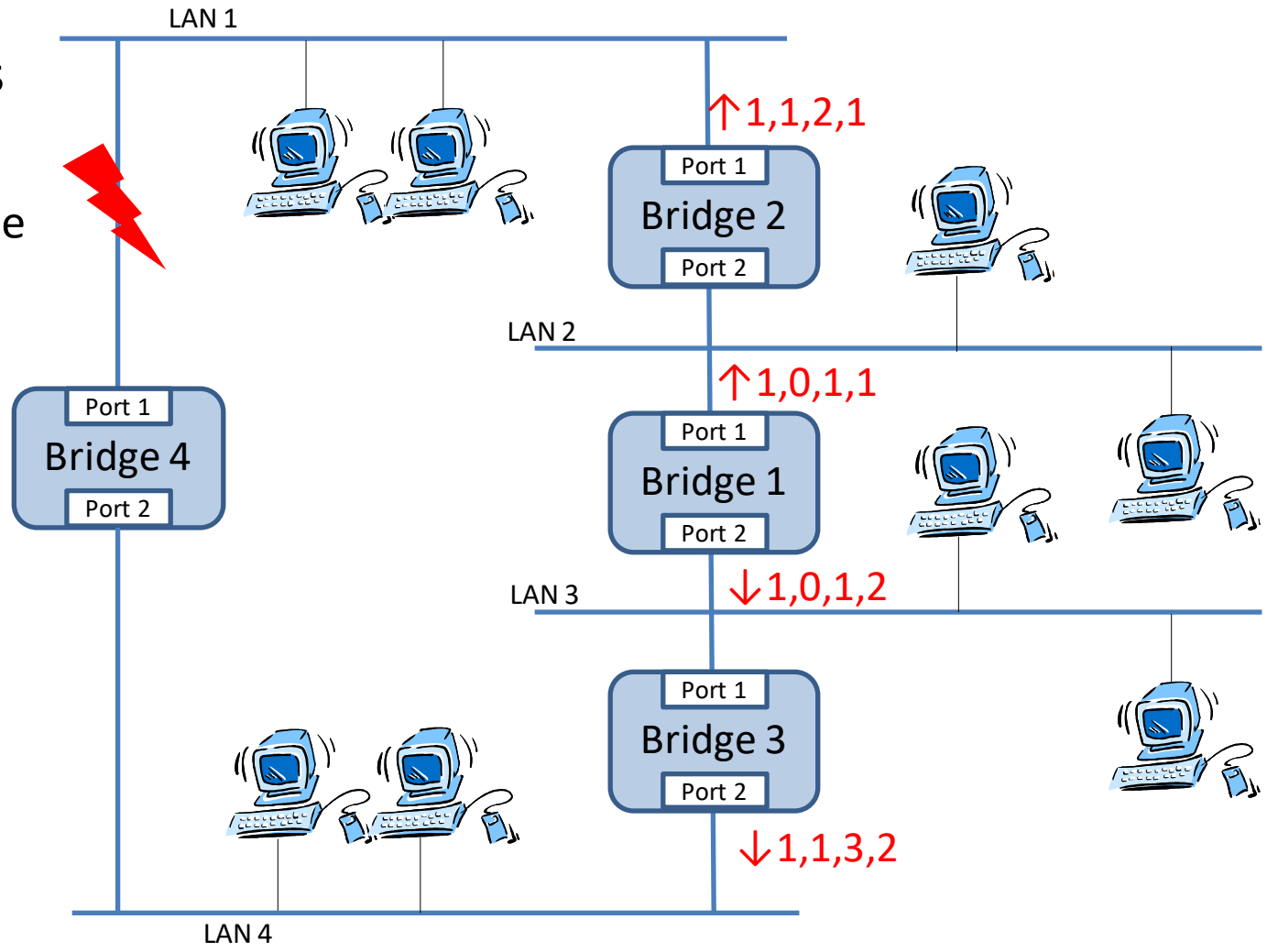


The Spanning Tree Protocol

- Example :

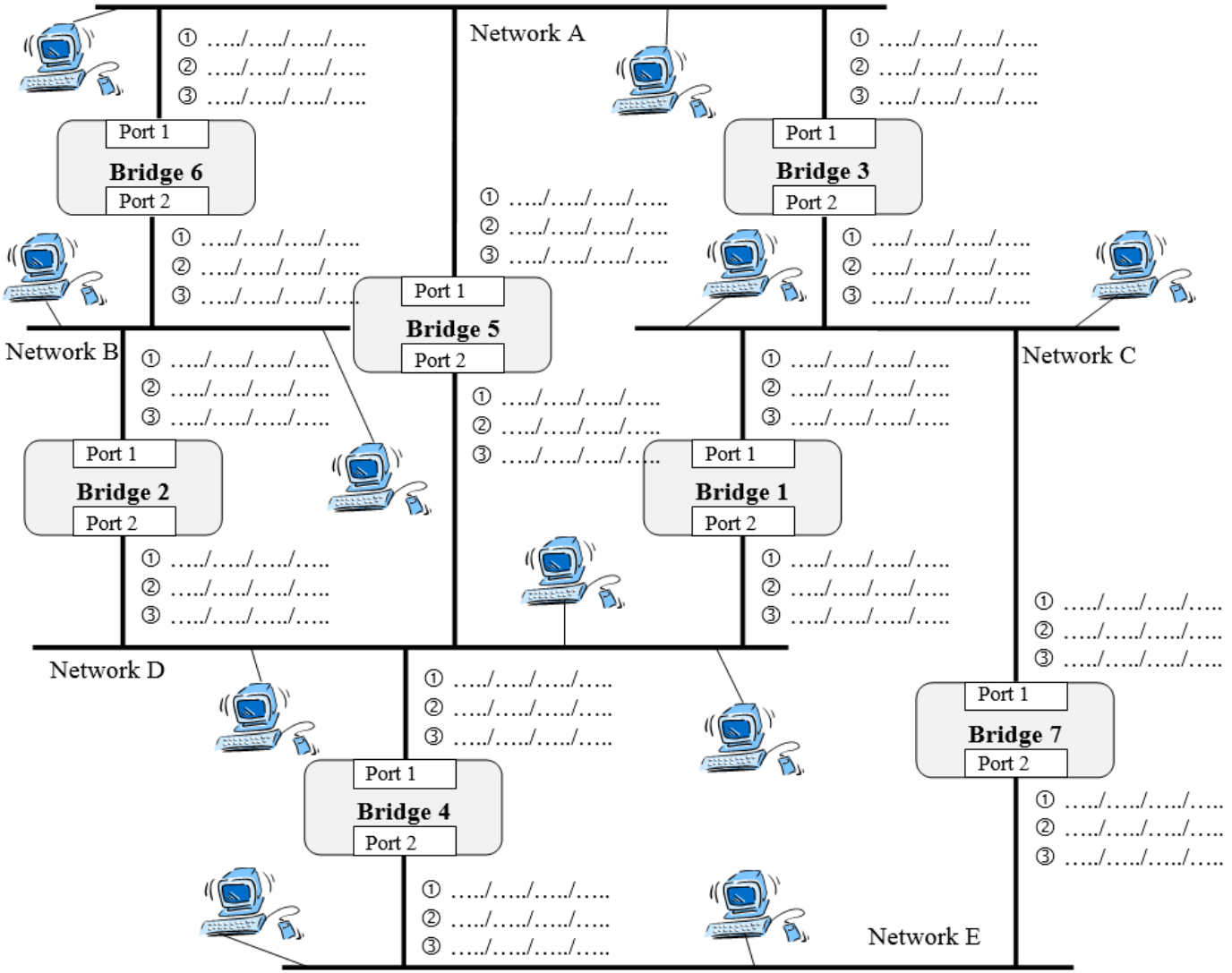
✓ How a reconfi-guration process is launched ?

- ✓ 4 do not receive CBPDU from 2
- ✓ After 30s, it enables again its port 2



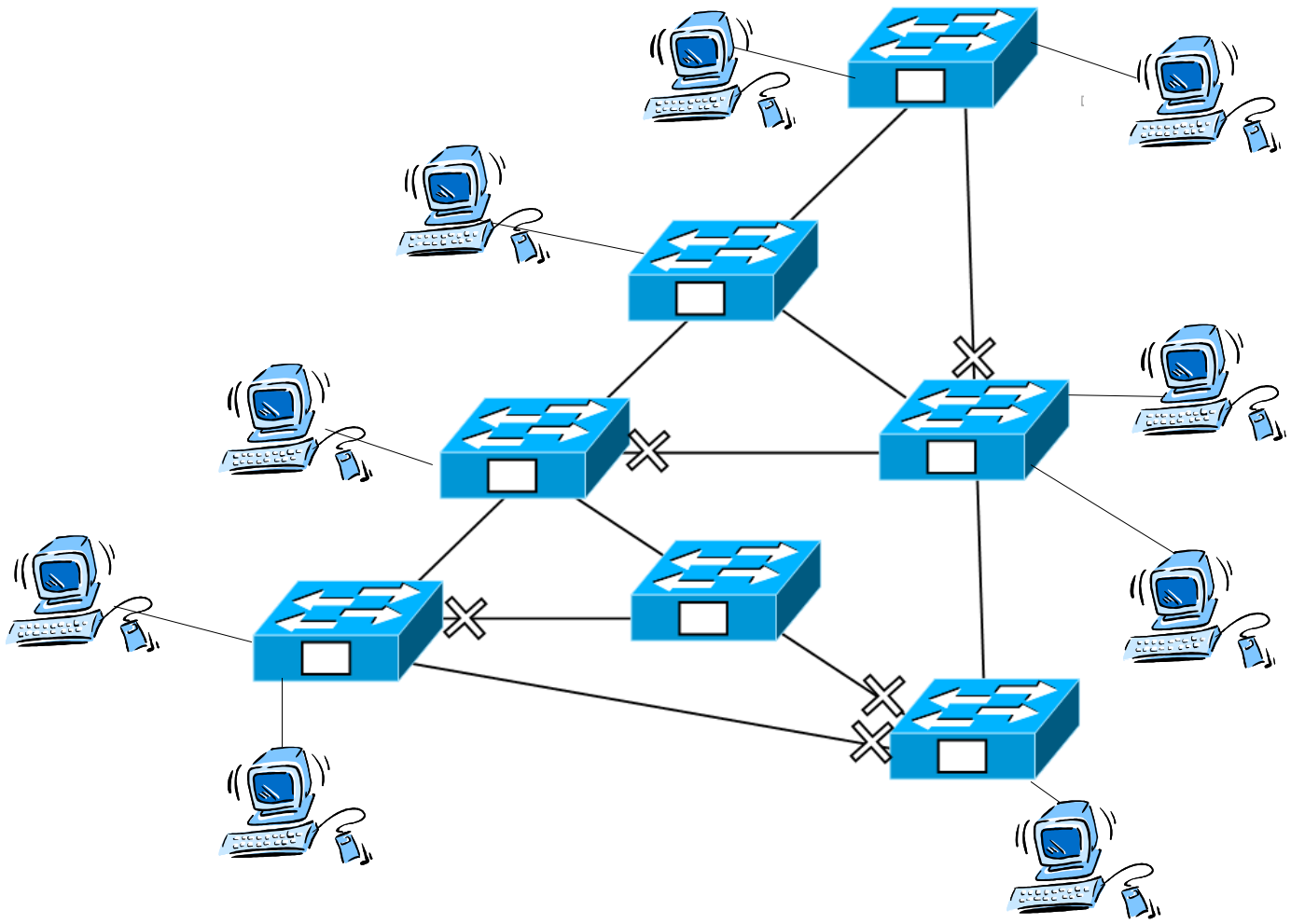
Exercise 1

For each bridge, write all the CBPDU sent on its ports
(root / cost to the root / bridge / port)



Exercise 2

Propose switch Ids (1 to 7), in order the Spanning Tree Protocol desactivates marked ports



Ethernet evolution

- 2006 : a new IEEE 802.3 working group
  - Energy Efficient Ethernet (EEE)
  - Standardized in sept 2010 : 802.3az
- Where energy consumption is comming from ?
  - Data transmission,
  - Continuous transmission of an auxiliary signal called IDLE
    - For 100 Mb/s and higher data rates (up to 10 Gb/s)
    - To keep transmitter and receiver clocks aligned
  - The growth of bitrates implies the increase of the energy consumption
    - Ex : 1000BAS-T physical layer tranceiver : 0,5W

      10GBAS-T physical layer tranceiver : over 5W

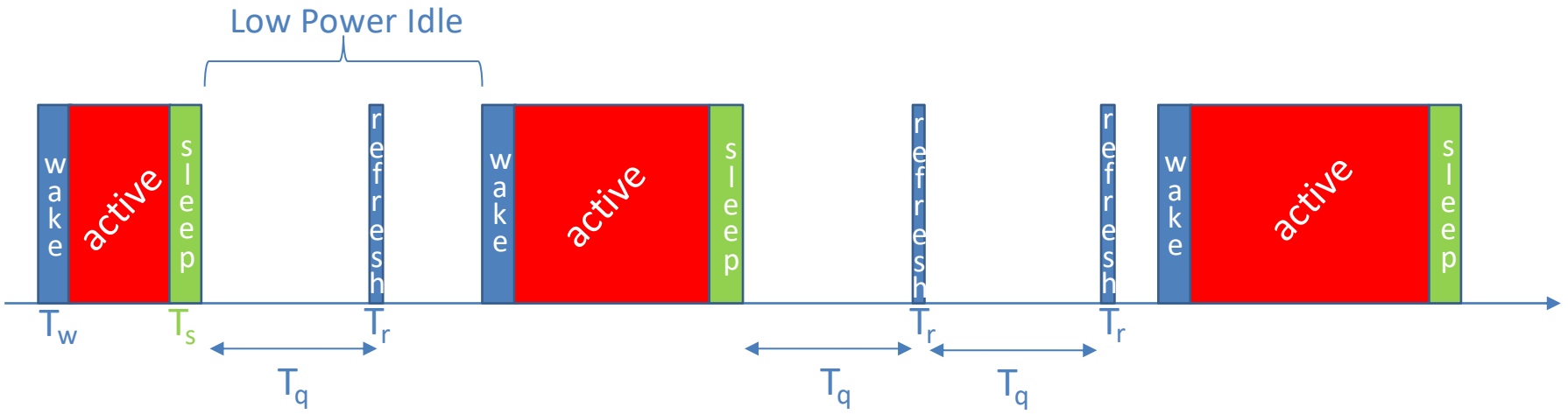
Ethernet evolution

- Principle :
  - A *Low Power Idle* mode to reduce the energy consumption of a link when no packets are being sent.
  - A *Adaptive Link Rate* strategy has been considered but not retained : low speed during periods of low link utilization
- Expected savings :
  - $1 billion per year worldwide !
  - [Christensen 2010]

Christensen K and al., « IEEE 802.3az : the road to Energy Efficient Ethernet », IEEE Communications Magazine, Nov. 2010

Ethernet evolution

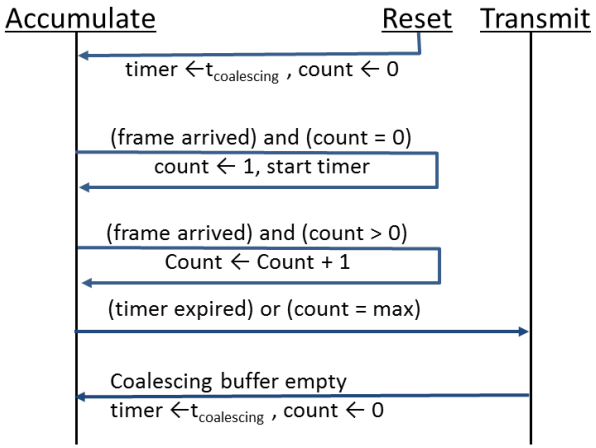
- Transitions between the *active* and *low power* modes
  - *Low Power Idle* instead of *continuous Idle*



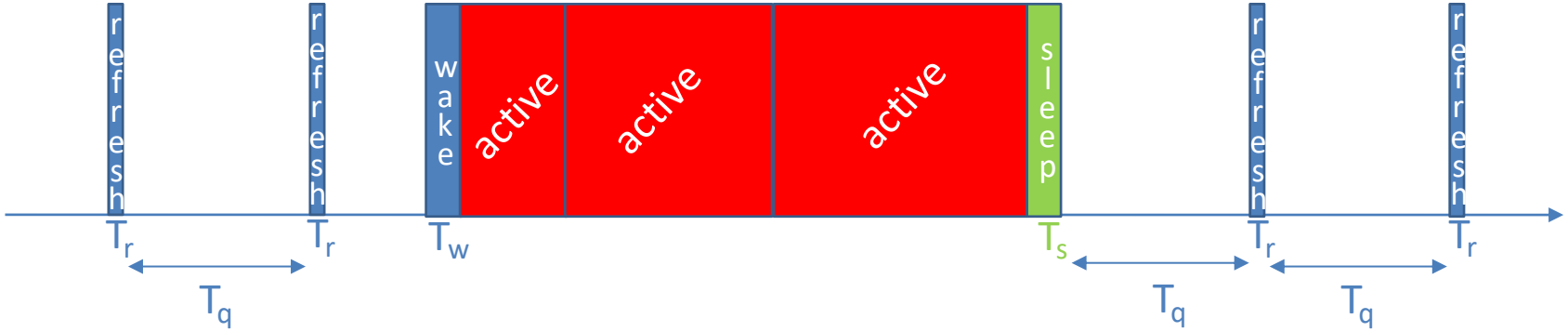
  - Consumption (Low Power Idle) ≈ Consumption (active)/10
  - Consumption (wake or sleep) ≈ Consumption (active)/2
  - For 10 Gb/s :
    - T_w = 4,48 µs, T_s = 2,88 µs, T_{Tmax} = 1,2 µs (1500 bytes)

Christensen K and al., « IEEE 802.3az : the road to Energy Efficient Ethernet », IEEE Communications Magazine, Nov. 2010

Ethernet evolution



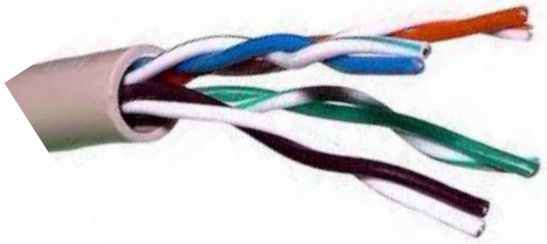
- Improvement :
  - Frames coalescing (aggregation)
  - To minimize the number of (T_w,T_s) couples



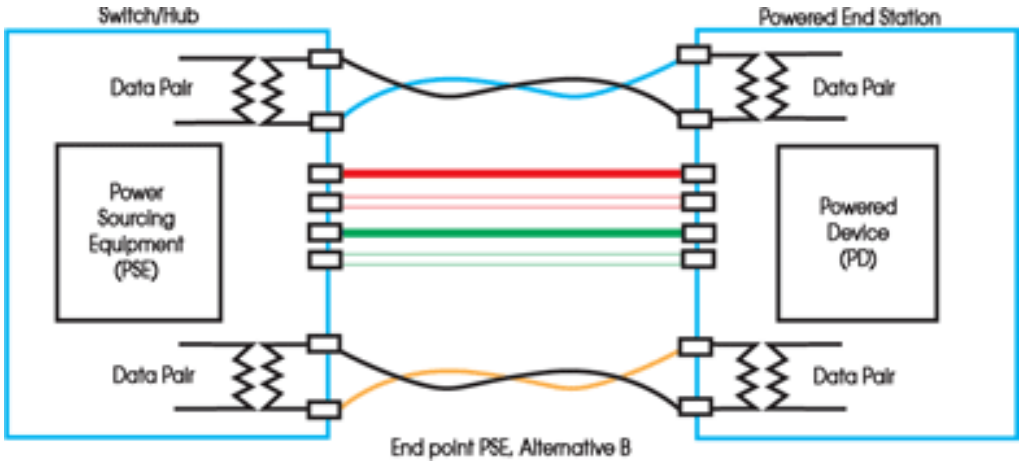
  - More energy saved 🙂
  - First frames have to wait before transmission 🙁
  - Rq : same mechanism in IEEE 802.11n (high speed wifi)

Christensen K and al., « IEEE 802.3az : the road to Energy Efficient Ethernet », IEEE Communications Magazine, Nov. 2010

Ethernet evolution



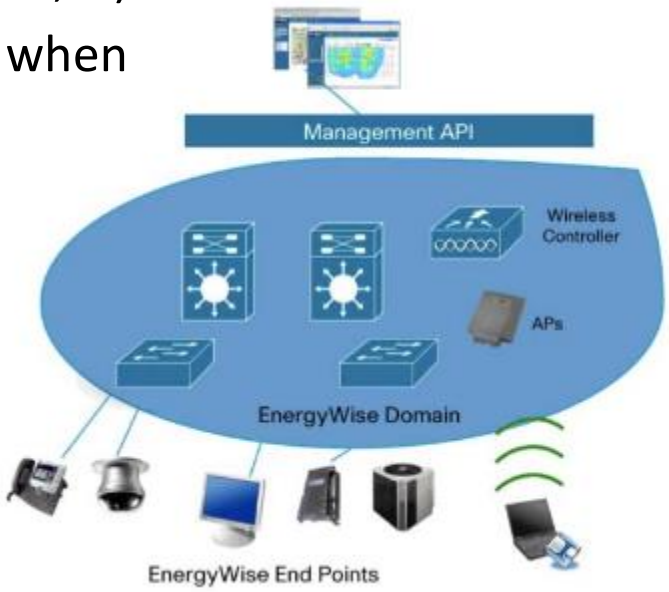
- PoE : Power over Ethernet
  - IEEE 802.3af (2003)
    - 48V (350 mA max & 15,4 W max) over 1 or 2 UTP pairs
    - The required power is negotiated between :
      - The PoE equipments
      - The switches
    - « Electrical budget »
      - 3 classes :
        - » Class 1 : 4W
        - » Class 2 : 7W
        - » Class 3 : 15,4W



  - 2018 :
    - IEEE 802.3bt : up to 100 W !

Ethernet evolution

- Cisco EnergyWise
  - Energy monitoring and optimization
    - Devices discovery
    - PoE negociation
    - Planning
      - Power off during the night (PC, telephones, …)
      - On demand power on (of the telephone when a new client arrives in his hotel room)
    - Monitoring and reporting
      - Statistics
      - Advices
      - …



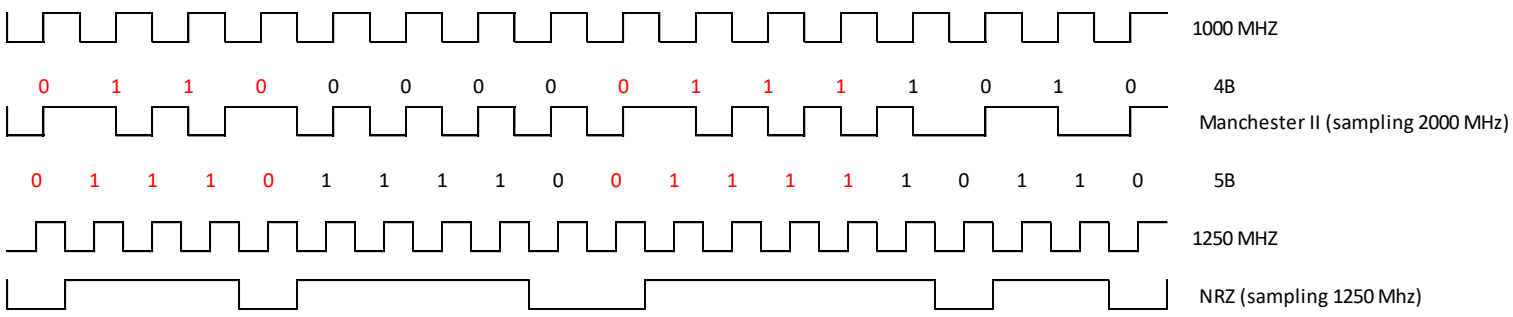
Ethernet evolutions

- Gigabit Ethernet
  - Only on switched architectures
    - Point to point links
  - 1000BASE-T : IEEE 802.3ab (on twisted pair)
    - 100 m max
  - 1000BASE xX, … : IEEE 802.3z (on optical fiber)
    - Mono or multimode
    - Up to 100 km
  - And also :
    - 10 Gb/s (IEEE 802.3ae), 40 Gb/s, 100 Gb/s (IEEE 802.3ba) !
    - The today's technology for the providers backbones
  - Terabit Ethernet or TbE : >100 Gb/s.
    - IEEE P802.3bs approved on December 6, 2017

Ethernet evolutions

- Gigabit Ethernet
  - 2 ways to deal with high bitrate problems :
    - Using simultaneously 4 pairs of the UTP cable;
      - Only 250 Mb/s on each pair
    - Using specific encoding :
      - Example : 4B/5B enabling to use NRZ instead of Manchester II (not suitable because too high frequency generated signal)
      - No long 0 or 1-series
      - Necessitates a 1250 MHz clock, instead of 2000 Mhz ! (for 1 Gb/s real bitrate)

Data Input	Data Output
0000	11110
0001	01001
0010	10100
0011	10101
0100	01010
0101	01011
0110	01110
0111	01111
1000	10010
1001	10011
1010	10110
1011	10111
1100	11010
1101	11011
1110	11100
1111	11101



Ethernet evolutions

- TSN : Time sensitive Networking (2012 ->)
  - Gathers several amendments :
    - IEEE 802.1AB, AS, ASbt, AQ, CB, Qca, Qaz, Qat, Qav, Qbv, Qch, Qci, Qbu, Qcc, Qbp, Qbz
  - Real-time features :
    - Delays and jitter control, synchronization, …
    - 1 ns latency
  - Applications :
    - Audio/video streaming, industrial control, embedded systems (cars, …)

Wi-Fi :
the most famous wireless LAN protocol

History

802.11 network standards

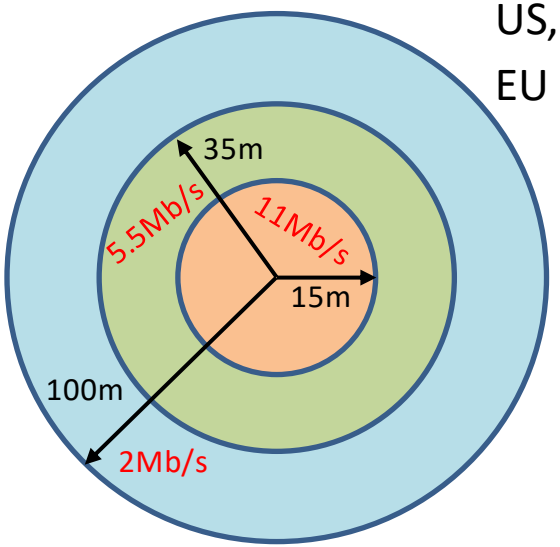
802.11 protocol	*Release*	*Freq. (GHz)*	*Bandwidth (MHz)*	*Data rate (Mbit/s)*	*Modulation*	*Approximate indoor range (m)*	*Approximate outdoor range (m)*
—	Jun 1997	2.4	20	1, 2	DSSS, FHSS	20	100
a	Sep 1999	5	20	6, 9, 12, 18, 24, 36, 48, 54	OFDM	35	120
b	Sep 1999	2.4	20	1, 2, 5.5, 11	DSSS	35	140
g	Jun 2003	2.4	20	6, 9, 12, 18, 24, 36, 48, 54	OFDM, DSSS	40	140
n	Oct 2009	2.4	20	7.2, 14.4, 21.7, 28.9, 43.3, 57.8, 65, 72.2	OFDM	70	250
		5	40	15, 30, 45, 60, 90, 120, 135, 150		70	250

Some physical considerations

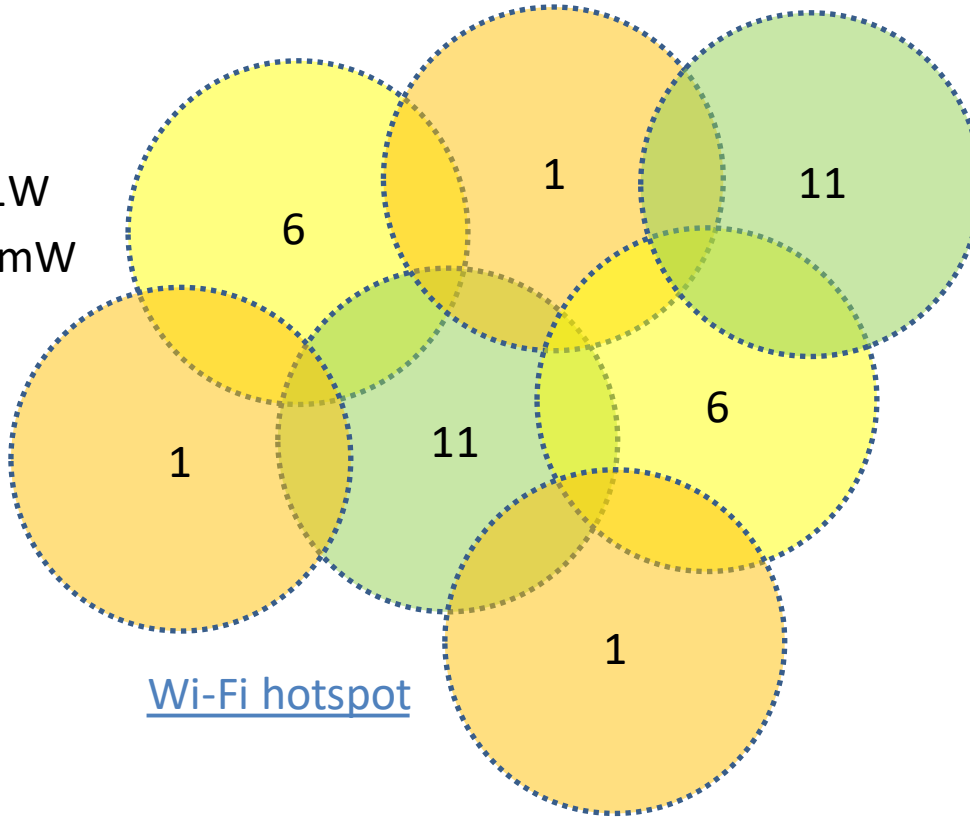
- 802.11b

US, Jp : P_{max} = 1W

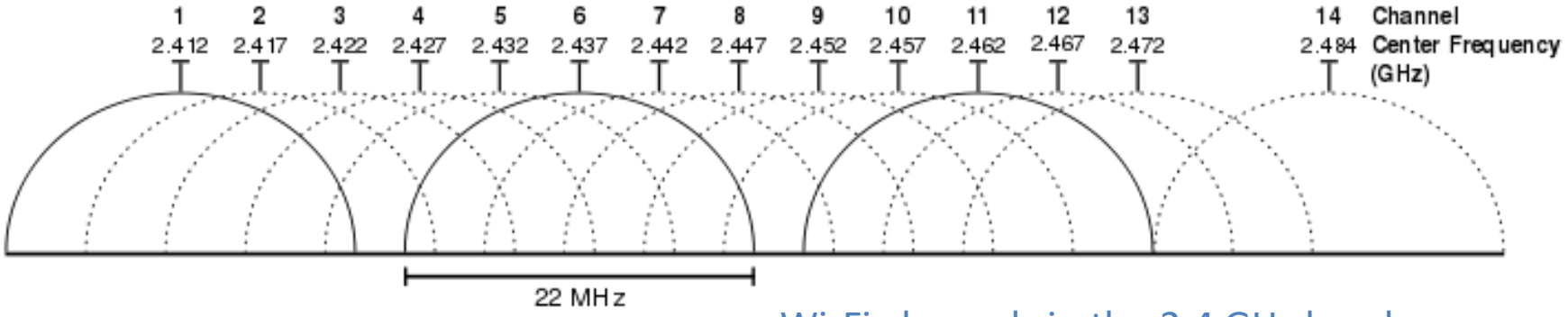
EU : P_{max} = 100mW



Range and rates



Wi-Fi hotspot



Wi-Fi channels in the 2.4 GHz band

CSMA/CA : why ?

- is a bus !
  - A shared medium
    - CSMA/CD should have been considered
- But 2 problems :
  - ① Through an antenna, it is impossible to simultaneously transmit and receive

or

mute if listening, deaf if emission

CSMA/CA : why ?

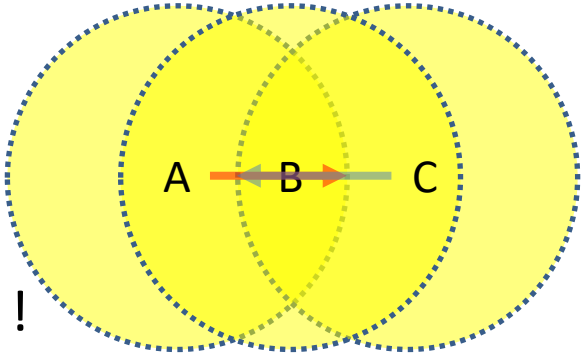
② The « hidden station problem » …

Collisions may be not detected !

- So not corrected …

Consequences :

- The transmitter can't be sure that no collision occured !



- A transmits to B
  - Its signal doesn't reach C
- C transmits to B
  - Its signal doesn't reach A
- There is a collision in B
  - Not detected by A
  - Not detected by C

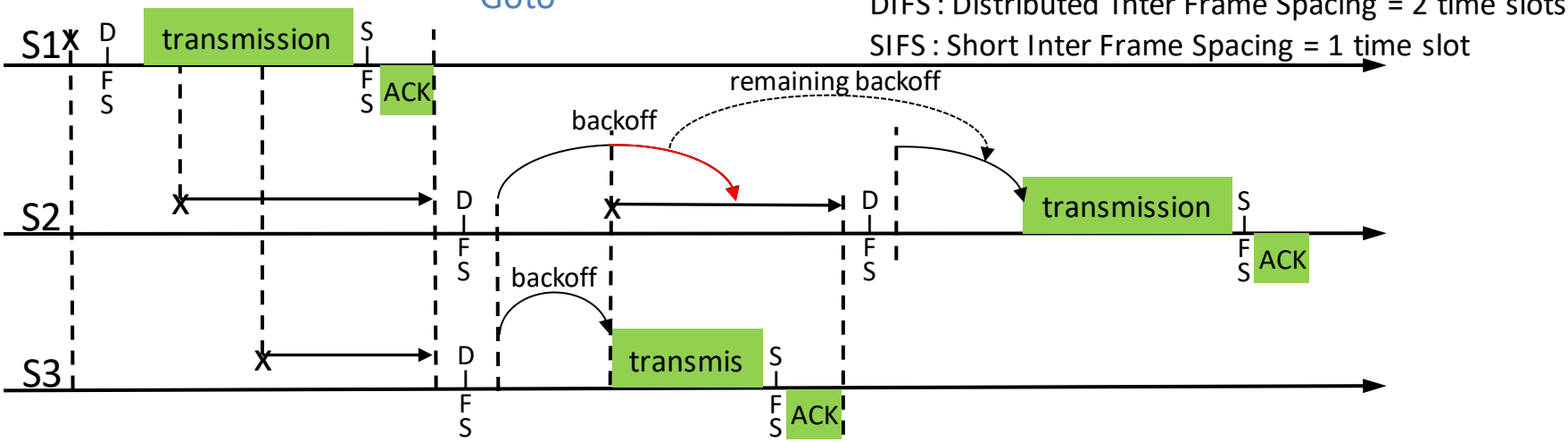
All transmission have to be acknowleged

⟶ Because collision detection is not guaranteed, we'll will try to avoid them ! (CSMA/CA$_{voidance}$)

How to avoid a collision ?

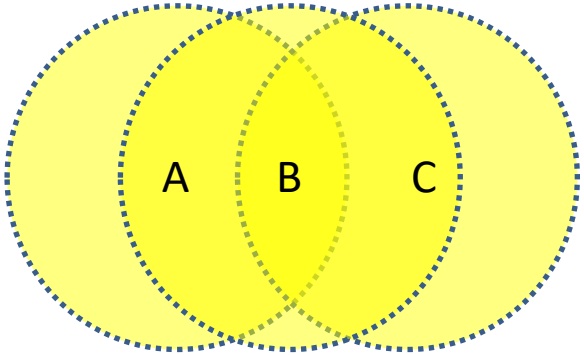
- Roll the dice before !
  - DCF mode (Distributed Coordination Function)

Want to transmit : listen to the medium
free : transmission after DIFS
wait for ACK reception
busy : wait for the end of active transmission (ACK)
DIFS, then random backoff in [0, 7xtime slot]
*listen to the medium
free : transmission
wait for ACK reception
busy : wait for the end of active transmission (ACK)
DIFS, then remaining backoff
Goto *



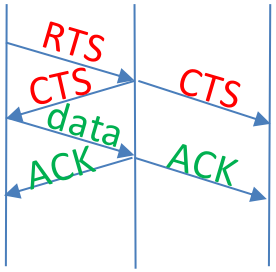
How to reserve the medium ?

- The RTS/CTS mechanism:
  - Request To Send / Clear To Send



A wants to reserve the medium

A transmits to B



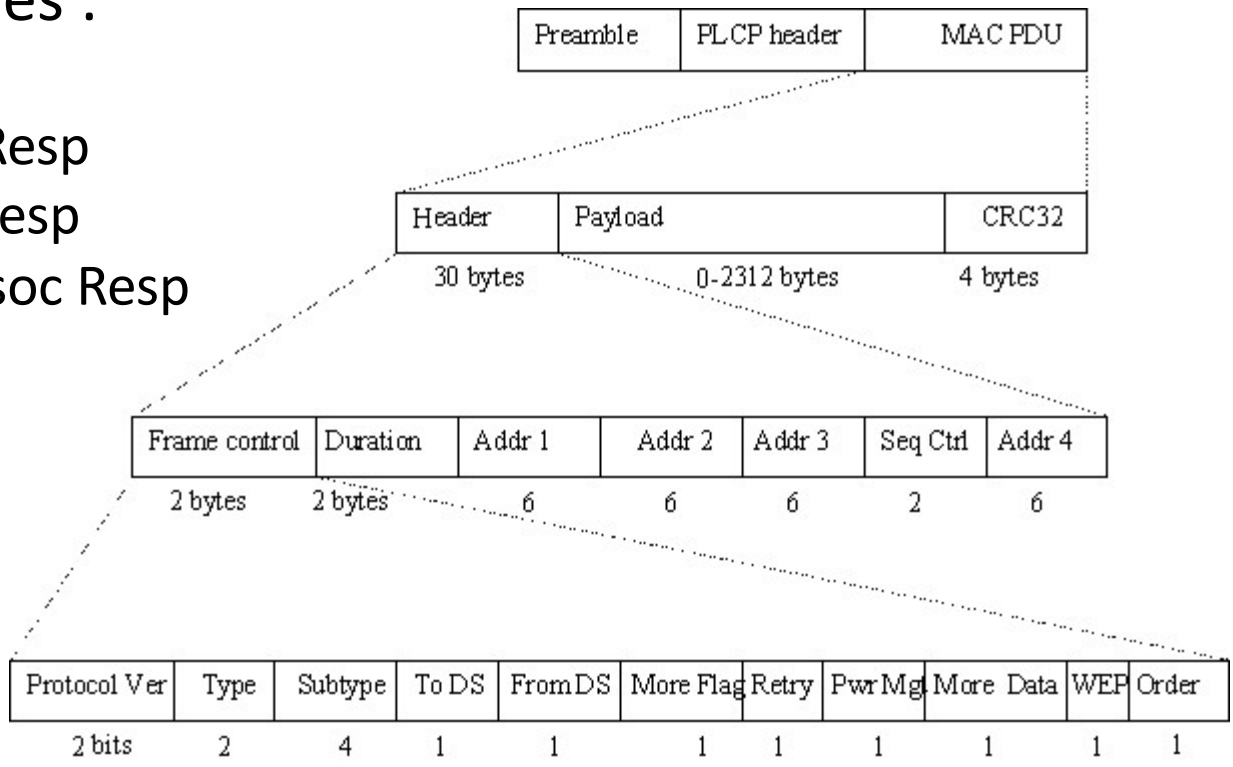
C understands that a hidden station wants to transmit to B. It keeps mute

C understands that the transmission is over The medium is available again.

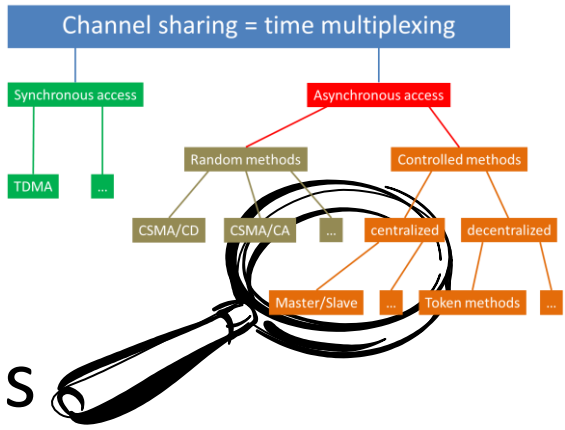
802.11 frames

- 3 types of MAC frames :
  - Control Frames :
    - RTS, CTS, ACK
  - Data Frames
  - Management Frames :
    - Beacon
    - Probe Req, Probe Resp
    - Assoc Req, Assoc Resp
    - Reassoc Req, Reassoc Resp
    - Disassociation
    - Authentication
    - Deauthentication

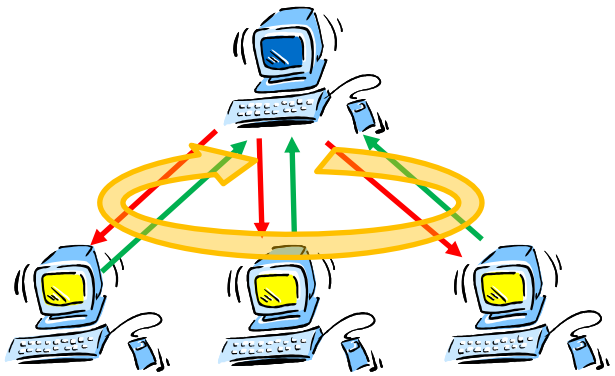
Example :
ACK : type = 01
subtype = 1101



Centralized controlled methods

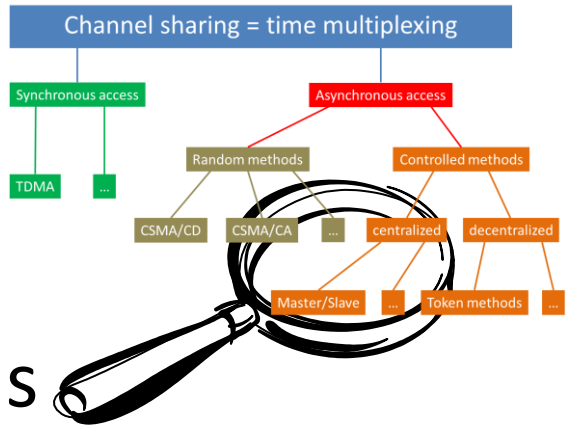


- Also named "master/slaves" methods
  - The master asks sequentially the slaves to know if they want to transmit :
    - Yes : the slave can transmit during a limited maximum time T_{max}
    - No, the master asks the next slave
  - The method works on any topology

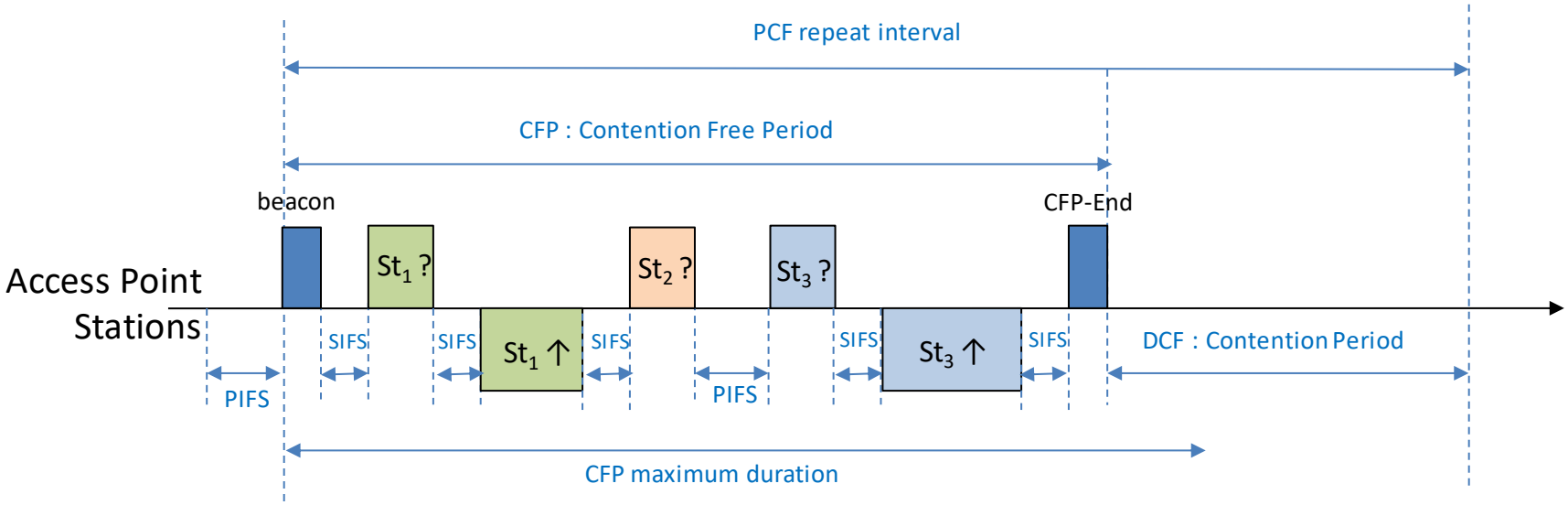


  - The method is deterministic :
    - In the worst case, how much time a slave has to wait for transmission ?
    - $(N-1)xT_{max}$ (with N the number of slaves)

Centralized controlled methods

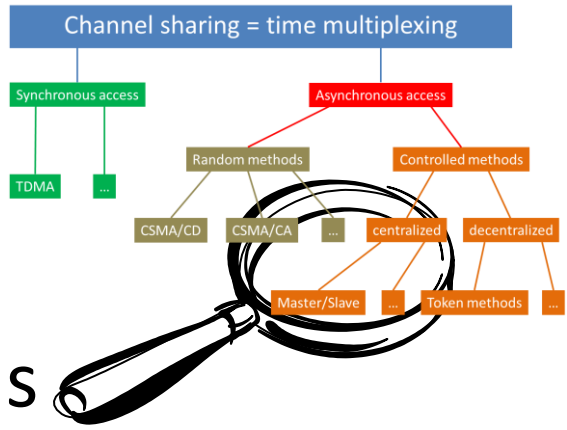


- Also named "master/slaves" methods
  - Also used in wireless protocols
    - Ex : 802.11 PCF mode (Point Coordination Function)
      - The Access Point is master

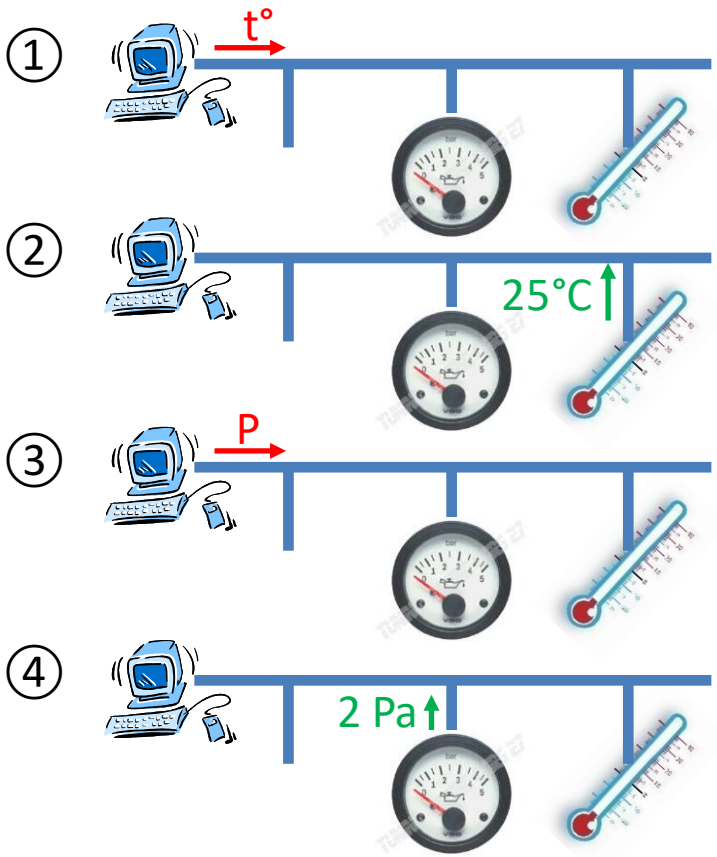


    - Bluetooth also implements a Master/slave protocol

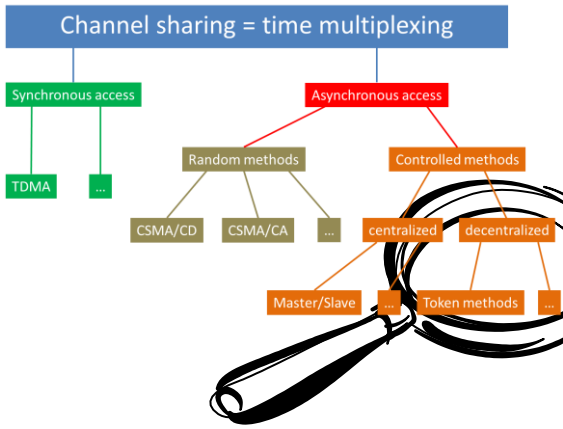
Centralized controlled methods



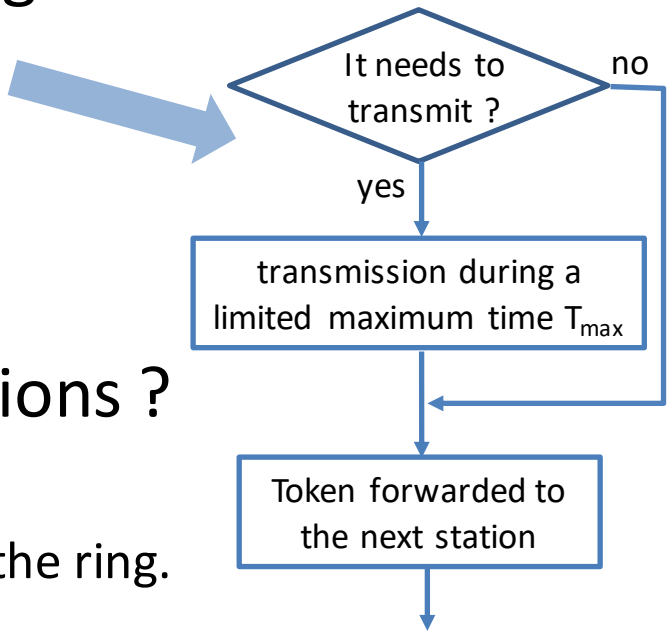
- Also named "master/slaves" methods
  - An other method used in the FIP network (bus topology)
    - Field Information Protocol
    - Producer/consumer model
    - The bus arbitrator periodically broadcasts a variable name
    - The station which produces this variable broadcasts its value
    - The bus arbitrator schedules the variables broadcasting
    - Ex : t° every 5 ms, and P, 10 ms



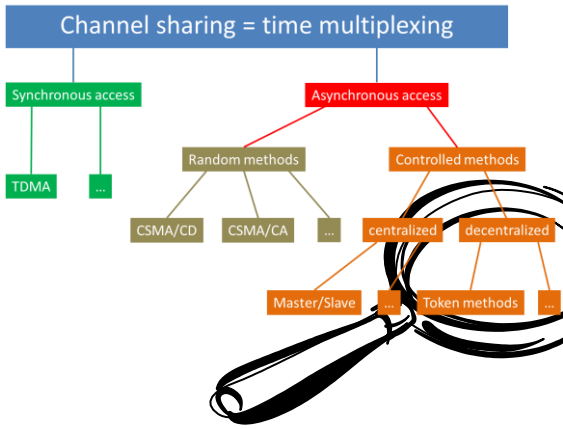
Decentralized controlled methods



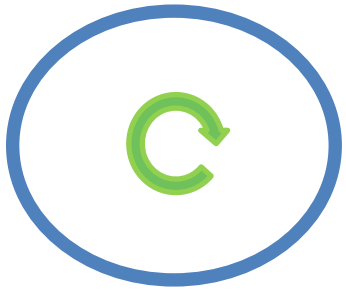
- Also named "token" methods
  - The token represents an exclusive right to transmit
  - When a station receives the token :
- Deterministic methods !
- Question :
  - How the token turns around all stations ?
    - Token Ring (IEEE 802.5)
      - The next station is the physically next on the ring.
      - IBM
    - Token Bus (IEEE 802.4)
      - The next station is the one of immediate lower MAC address



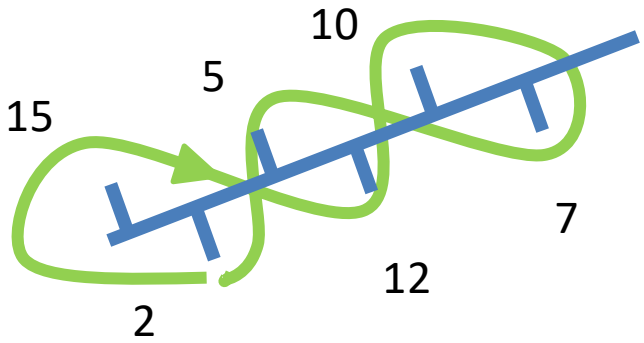
Decentralized controlled methods



- Token management problems :
  - Token Ring (IEEE 802.5)
    - The next station is the physically next on the ring.
    - The transmiting stations waits for the frame to come back before forwarding the token : what happens if not ?
    - And if this station disappears during this time? (with the token)

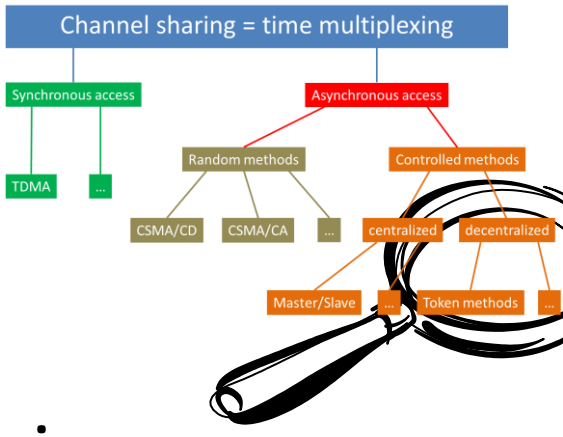


  - Token Bus (IEEE 802.4)
    - The next station is the one of immediate lower MAC address
    - How to manage the logical ring ?
      - » New stations insertion,
      - » Stations disappearance



- Complicated !

Decentralized controlled methods



- Futhermore, token methods are not in conformance with economical and ecological criteria !
  - There is always traffic, even if no user data have to be transmitted….
  - The token turns around stations indefinitely …