Physical & Link layer

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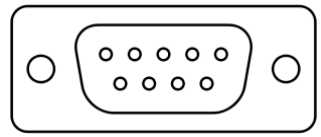
(Wilson Bentley via wikipedia…)

Serial line



- One pin for transmission, one for reception

  This connector is a DE-9, often called DB-9 or RS-232…
- Byte by byte transmission (or groups of 5, 6 or 7 bits)
  - ✓ When idle, the line is in state 1
  - ✓ *start bit* : 0
  - ✓ *stop bit* : 1 (during 1, 1,5 or 2 periods)
- Optional : parity bit (error detection)

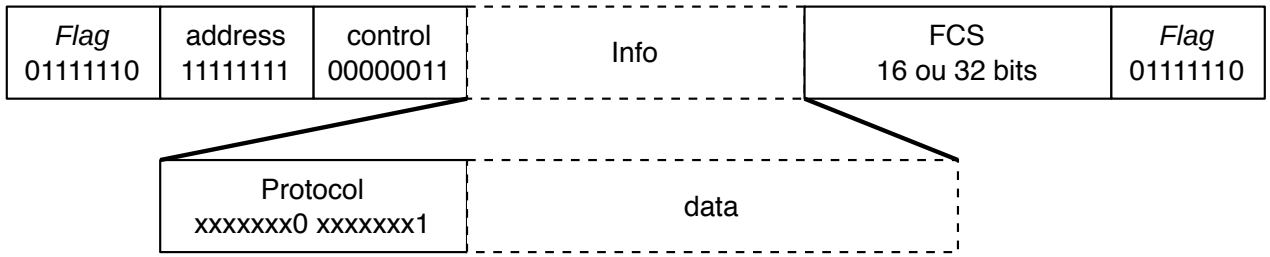
$\Rightarrow$ This is suitable for a console, this is not enough for a data link (PPP or SLIP are mandatory)

The signal is often modulated by a *modem* for long distance transmission $\rightarrow$ other pins carry utility signals.

Serial line data link
PPP (*Point to Point Protocol*) and SLIP (*Serial Line IP*)
What is the purpose of the link layer? (Other than addressing)

- Framing (*framing*) and transparency (sole purpose of SLIP)
- error detection / correction
- PDU data description (eg. IP packet or netbios ?)
- Authentication before link establishment
- Configuration/negociation of layers 2 & 3
- Headers or packet compression

PPP in HDLC framing



- FCS : *frame check sequence*
- *after* FCS computation :
  for byte-stuffing lines:
  - ✓ control bytes escaping in the data :
    `0x7e` → `0x7d, 0x5e` (Flag) ; `0x03` → `0x7d, 0x23`. (Control) ;
    `0x7d` → `0x7d, 0x5d`. (Escape)

  For bit-stuffing lines
  - ✓ between the *flags*
  - ✓ insertion of a zero after any sequence of 5 "1"
  - ✓ Removed upon reception

PPP : associated protocols

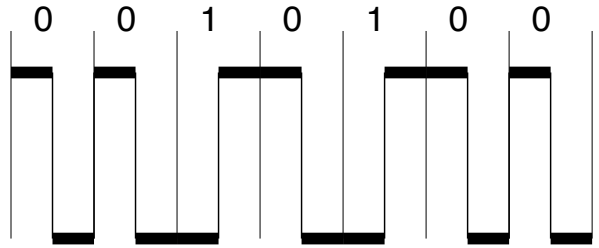
- LCP negociation (*Link Control Protocol*)
  - ✓ Link establishment & control
  - ✓ Connection parameters negociation (for instance: PPP header compression — eg. address field is useless! FCS suppression)
  - ✓ Transparency: avoiding use of bit sequences significant to the PHY layer
- CCP (*Compression…*)
  - ✓ layer 3 headers compression (Similar packets often follow each other)
  - ✓ Whole packet compression (zip-style)
- Authentification, to choose from :
  - ✓ Unix-style login: authentication before PPP starts (see lab session)
  - ✓ PAP (username and password transmission in LCP packets)
  - ✓ CHAP (Cryptography)
- Network layer configuration: NCP protocol family
  - ✓ IPCP Protocol (config. IP)
  - ✓ ATCP (Appletalk config.)

Physical layer
Layer 1

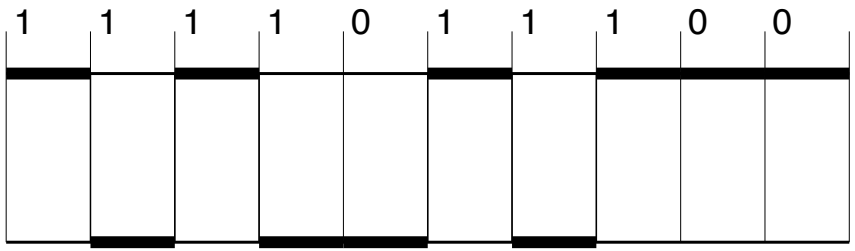
- Transmit bits (represented by physical symbols)
- Establish+maintain synchronization

Ethernet information coding schemes

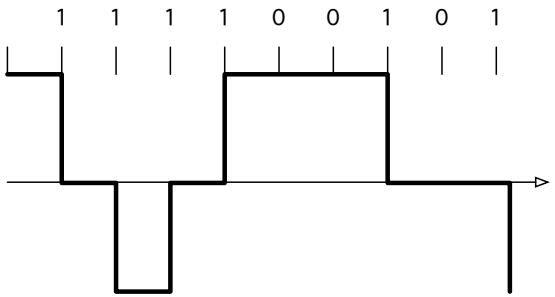
- Manchester coding : one transition per bit



- NRZI : *Non-Return to Zero, Invert on one*



- MLT-3 : *Multi-Level Transitions*



Maintaining synchronization

- Manchester: 1 transition per bit
  - ✓ Ethernet 10Mb/s
- NRZI
  - ✓ At most 1 transition per bit
  - → Bandwidth usage gain
  - → Clock drift :
    A transcoding step introduces transitions

100base-TX : 4B5B → MLT-3

100base-FX : 4B5B → NRZI

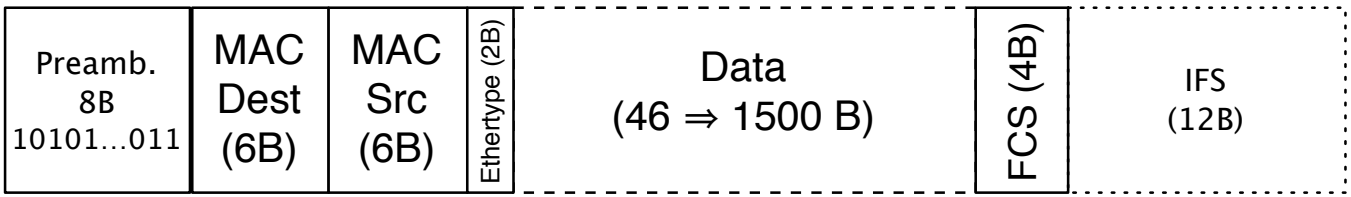
- Scrambling

Why is the preamble useful?

- The sampling point matters!
  - ✓ With manchester coding, a sequence of 1s is very similar to a sequence of 0s

→ A preamble precedes the frame
Sequence of 0, 1, 0, 1…

Ethernet frame:



100base-X

- Only uses 2 twisted pairs (-TX) or 2 fibers (-FX)
- After negociation, the cable is never idle
- 4B5B transcoding creates transitions
  For each group of 4 bits, there is a dictionary lookup
  ex: `0x0 =: 00001 ; OxE =: 11100`
- Start of frame delimiter (`1100010001`)[replaces the first preamble transcoded byte]
  End of frame delimiter `0110100111` [overlaps start of IFS]
- MLT-3 (NRZI-3) (*MultiLevel Transitions*)
  - ✓ Three logical levels : +1 ; 0 ; -1

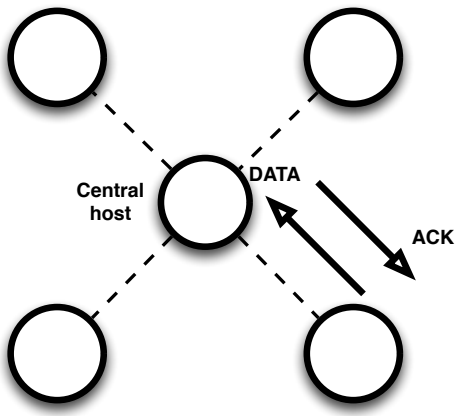
What is a hub ?
A set of wires becomes one layer 2 link

- Repeats from one wire to all others (except in the direction of the incoming signal)
  - → offset attenuation
    - ∗ Inter-connects fiber to copper

      (physical heterogeneity, same speed)
- Detects collisions, generates *jam*
- The Ethernet *hub* is a repeater
  - ✓ The network topology is a star, with possibly sub-stars…

    It's a snowflake!
  - ✓ One uplink and one downlink per interface

Aloha (1972)
The origins of random access




```
i = 1
while (i <= maxAttempts) do
  send packet
 wait for acknowledgement or timeout
  if ack received then
    leave
  wait for random time
increment i
end do
```

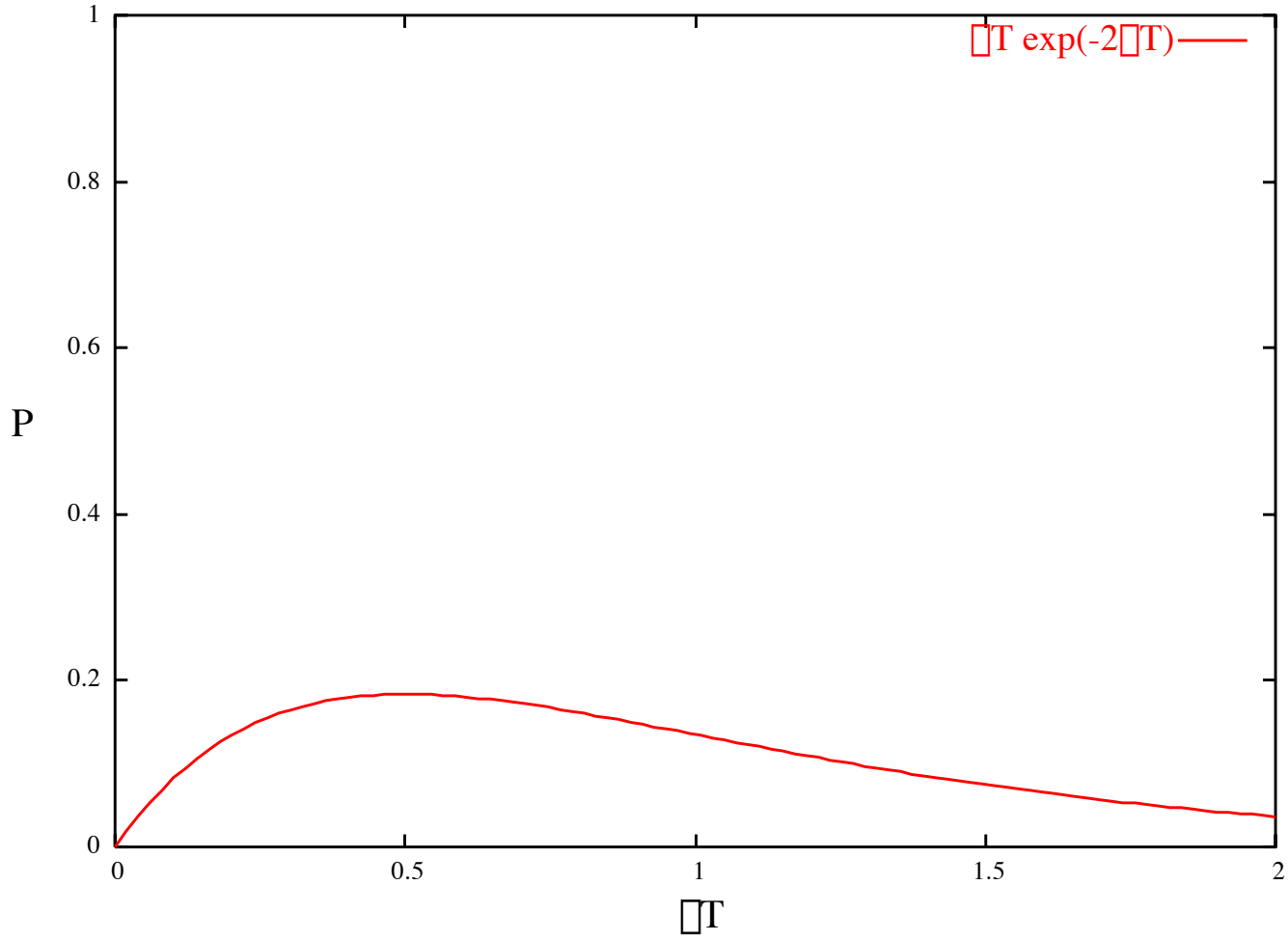
Aloha utilization with Poisson traffic

- A transmission is successful only if a frame does not interfere with an earlier of later transmission
- $\Rightarrow$ For every transmission attempt (which occupy the channel for a fraction $\mu \times$ `frame_duration` of the time) There should be **no other transmission** during $2 \times$ `frame_duration` (D)

$$P[N(t) = n] = \frac{(\mu\ t)^n}{n!} \exp(-\mu\ t) \quad \text{(Poisson process)}$$

$$P[N(2\ D) = 0] = \exp(-2\mu\ D)$$

Aloha utilization with Poisson traffic



CSMA/CD
The Ethernet access method

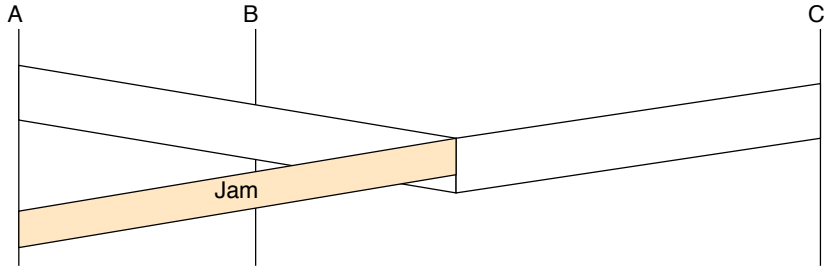
```
i = 1
while (i <= maxAttempts) do
  listen until (channel is idle for interframe_gap)
  transmit and listen at the same time
  wait until (end of transmission) or (collision detected)
  if (collision detected) then
    stop transmitting /* after 32 bits (”jam”)*/
    wait random_time /* picked in [0, CW-1] */
    increment i
  else
    break /* Success! */
end do
```

CSMA/CD
The Ethernet access method (cont.)

- Initially, CW=1 (no random wait), doubles after each collision until CW=2^{10}
- Max number of transmissions attempts: 16 (that's 16 collisions…)
  then the frame is dropped, start from the beginning with fresh frame (and CW=1!)

Frame size, lower limit

- Let's consider an excessively short frame :



- In Ethernet, the «jam» is 32 bits, and should reach back the source before its transmission stops
  - ✓ Typical delay : 4 repeaters + 5 segments (2 $\times$ 100m twisted pair et 3 500m coax.) + 2 stations $\rightarrow 44,4\mu s$
  - ✓ *slot_size* = *bandwidth* $*$ *delay* + *jam_size* + *safety_margin*
    ($\rightarrow$ 512 bits or 64B)
    slot_time = *slot_size*$/(10Mb/s) = 51.2\mu s$
  - $\Rightarrow$ *minimal* size of an Ethernet payload : 46 bytes

$\Rightarrow$ Colliding frames are shortened to at most $\mathrm{slot\_size}$

CSMA/CD, the numbers

- 10Mb/s :
  - ✓ slotTime 512 bit times
  - ✓ interFrameGap 9.6 μs
  - ✓ jamSize 32 bits
  - ✓ maxUntaggedFrameSize 1518 octets ; minFrameSize 512 bits
- 100Mb/s:
  - ✓ slotTime 512 bit times
  - ✓ interFrameGap 0.96 μs
  - ✓ jamSize 32 bits
  - ✓ maxUntaggedFrameSize 1518 octets ; minFrameSize 512 bits
- 1000Mb/s : slotTime 4096 bit times
- propagation speed.
  Thin Coax. and fiber : $\simeq 200.10^6\ m.s^{-1}$; twisted pair : $177.10^6\ m.s^{-1}$

Bridge
An "active" layer 2 device

- Collision-free interconnection
- Allows to extend the Ethernet network further than the largest collision domain
- More than one frame may be crossing the switch at a given moment
- A switch is a multi-interface bridge
  - ✓ Interconnect heterogeneous networks (100Mb/s to 10Mb/s, to wireless…)
  - ✓ **Simple routing**
    - ► If destination unknown, send on all interfaces
    - ► Keep track of source addresses to populate the switching table
- VLANs

Switched Ethernet

- Only the interface towards the receivers gets the frame

$\Rightarrow$ Even better: Ethernet «*Full Duplex*»

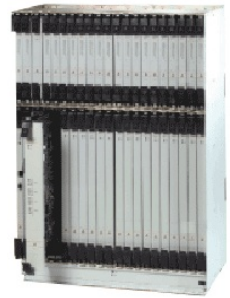
- ✓ If no collision occurs, it is useless to listen while transmitting
  (But then, how do we detect if the wire is unplugged?)
  $\Rightarrow$ Independent use of uplink and downlink
- $\Rightarrow$ Full Duplex Ethernet: **No CSMA/CD**

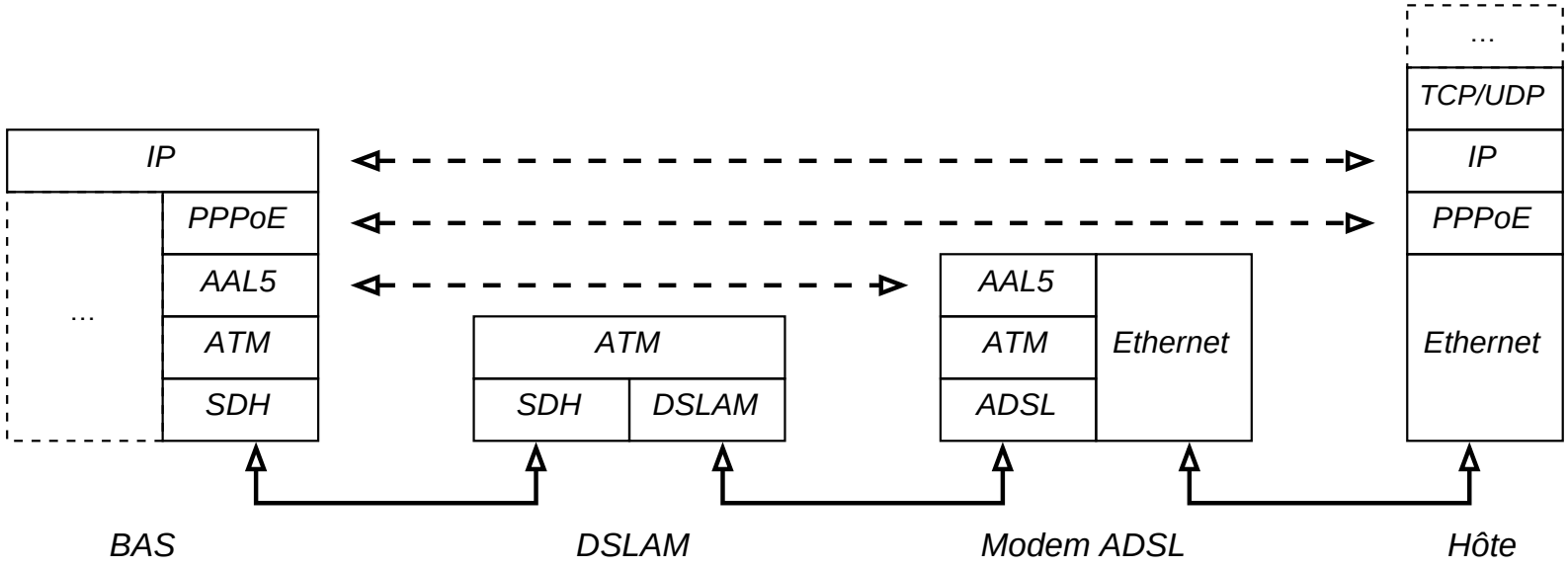
VLANs

- Port-based VLAN: restrict the switching between ports belonging to the same VLAN
- Trunk link: the same link/port belongs to 2 different VLANs
  - ✓ Need to mark the frames

ADSL : architecture

- DSLAM : *DSL Access Module*
- BAS : *Broadband Access Server*

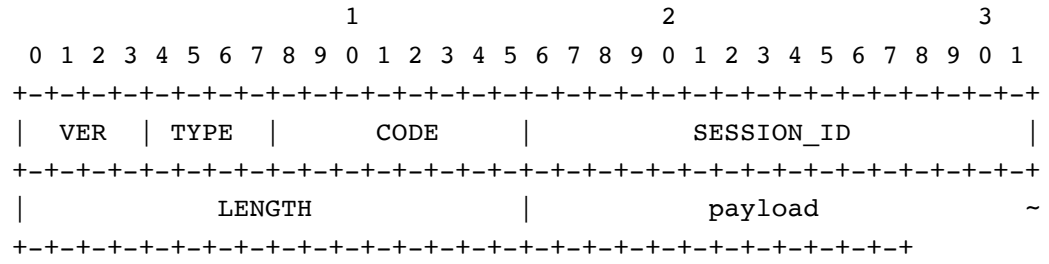




Typical architecture…

PPPoE

- PPPoE : No HDLC framing!
  Ethernet payload:



- PADI, PADO, PADR, PADS, PADT : *PPPoE Active Discovery Initiation, Offer, Request, Session-confirmation, Terminate*
  - ✓ PADI : broadcast, expects a PADO
  - ✓ PADR : The client picks a server
  - ✓ PADS : The server attributes a session #
  - ✓ PADT : Sent anytime

PPPoE (cont.)

- Then LCP packets exchanges, like other PPP variants
  - ✓ The session number lasts for subsequent packets. It identifies the client (useful on shared medium).
  - ✓ The PPPoE payload is a PPP frame:

- **Other architectures** : IP/AAL5/ATM (*BAS* and *DSLAM* is the same entity) or IP/HDLC/ADSL (ADSL2, VDSL)