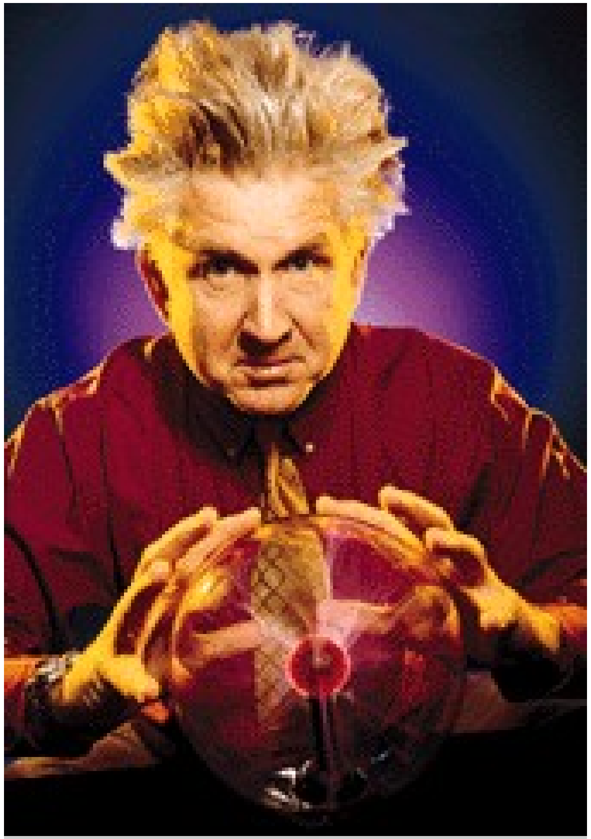
Ethernet

The LAN Killer

“Ethernet works in practice but not in theory.”

Robert Metcalfe



History (1)

- Late 1960s: **Aloha** **protocol University of Hawaii**
- Late 1972: **Robert Metcalfe developed first Ethernet system based on CSMA/CD**
  - **Xerox Palo Alto Research Center (PARC)**
  - **Exponental Backoff Algorithm was key to success (compared with Aloha)**
  - **2.94 Mbit/s**

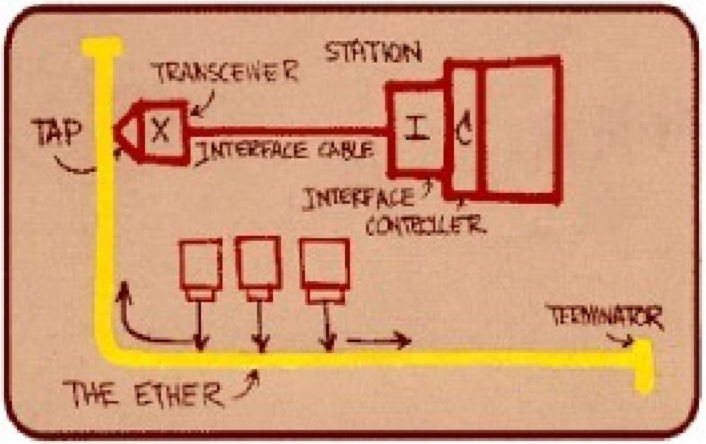
Original Ethernet Frame

S	Destination Address	Source Address	Data	CRC
1	8	8	about 4000 bits	16

History (2)

- 1976: **Robert Metcalfe released the famous paper:**
  "Ethernet: Distributed Packet Switching for Local Computer Networks"

Original sketch



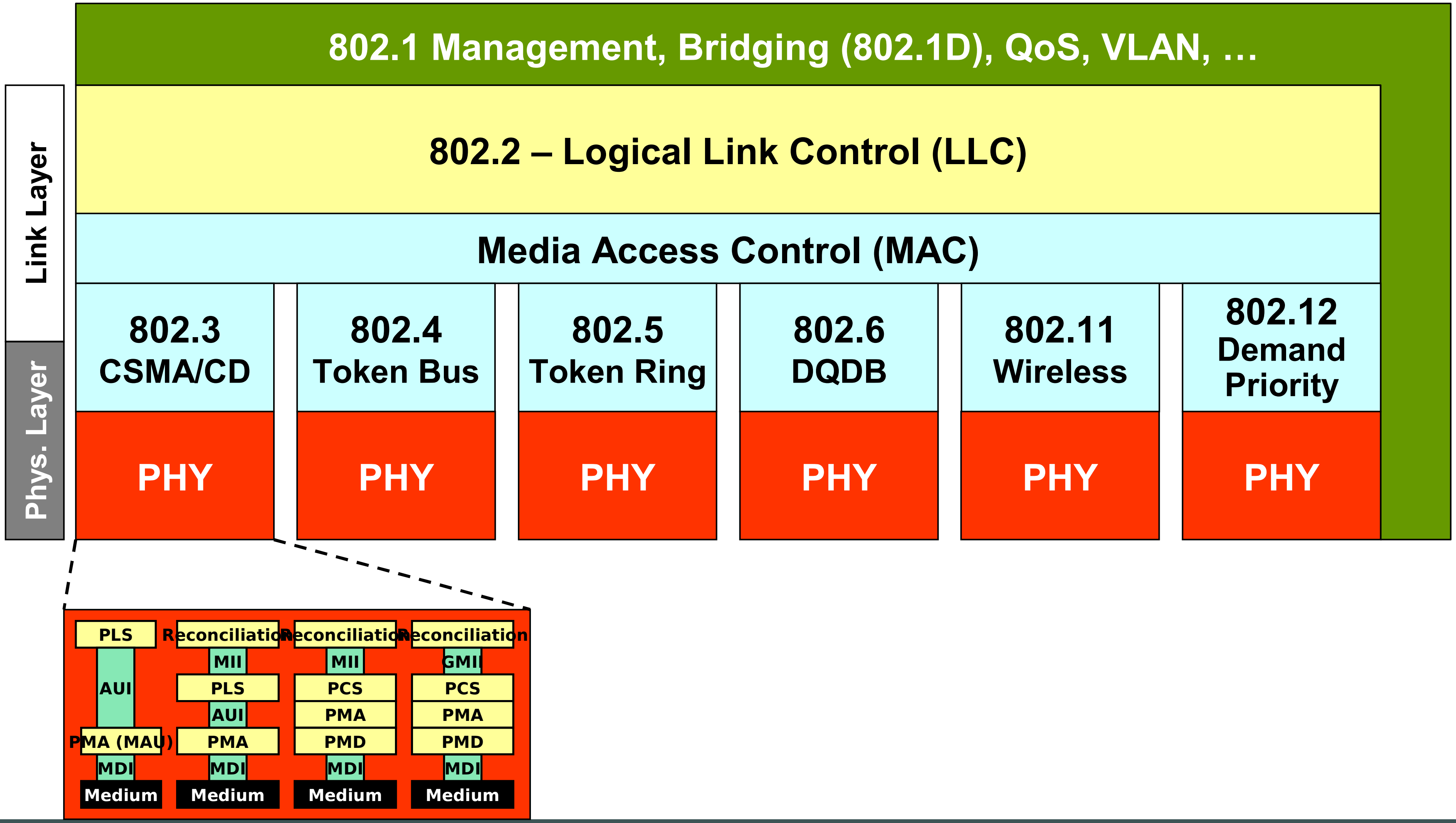
History (2)

- 1978: **Patent for Ethernet-Repeater**
- 1980: **DEC, Intel, Xerox (DIX) published the 10 Mbit/s Ethernet standard**
  - **"Ethernet II" was latest release (DIX V2.0)**
- Feb 1980: **IEEE founded workgroup 802**
- 1985: **The LAN standard IEEE 802.3 had been released**

The IEEE Working Groups

- 802.1 Higher Layer LAN Protocols
- 802.2 Logical Link Control
- 802.3 Ethernet
- 802.4 Token Bus
- 802.5 Token Ring
- 802.6 Metropolitan Area Network
- 802.7 Broadband TAG
- 802.8 Fiber Optic TAG
- 802.9 Isochronous LAN
- 802.10 Security
- 802.11 Wireless LAN
- 802.12 Demand Priority
- 802.13 Not Used — Superstition?
- 802.14 Cable Modem
- 802.15 Wireless Personal Area Network
- 802.16 Broadband Wireless Access
- 802.17 Resilient Packet Ring

IEEE 802 Layer Model



IEEE 802.3/Ethernet

- Since 1984 the IEEE also maintains the DIX Ethernet standard
- Both frame types are supported by "Ethernet NICs"
  - Network Interface Cards

CSMA/CD

- Carrier Sense Multiple Access Collision Detection
  - Improvement of ALOHA
  - "Listen before talk" plus
  - "Listen while talk"
- Fast and low-overhead way to resolve any simultaneous transmissions

1) Listen if a station is currently sending
2) If wire is empty, send frame
3) Listen during sending if collision occurs
4) Upon collision stop sending
5) Wait a random time before retry

Slot Time

- Minimum frame length has to be defined in order to safely detect collisions
- Each frame sent must stay on wire for a RTT duration – at least
- This duration is called "slot time" and has been standardized to be 512 bit-times
  - 51,2 µs for 10 Mbit/s

Slot Time Consequences

- So minimum frame length is 512 bits (64 bytes)
- With signal speed of 0.6c the RTT of 512 bit times allows a network diameter of
  - 2500 meters with 10 Mbit/s
  - 250 meters with 100 Mbit/s
  - 25 meters with 1000 Mbit/s (!)

NOTE:
Only valid on

shared media (!)

Exponential Backoff (1)

- Most important idea of Ethernet !
- Provides maximal utilization of bandwidth
  - After collision, set basic delay = 512 x slot time
  - Total delay = basic delay * rand
  - 0 <= rand < 2^k
    - k = min (number of transm. attempts, 10)
- Allows channel utilization

Exponential Backoff (2)

- After 16 successive collisions
  - Frame is discarded
  - Error message to higher layer
  - Next frame is processed, if any
- Truncated Backoff (k<=10)
  - 1024 potential "slots" for a station
  - Thus maximum 1024 stations allowed on half-duplex Ethernet

Channel Capture

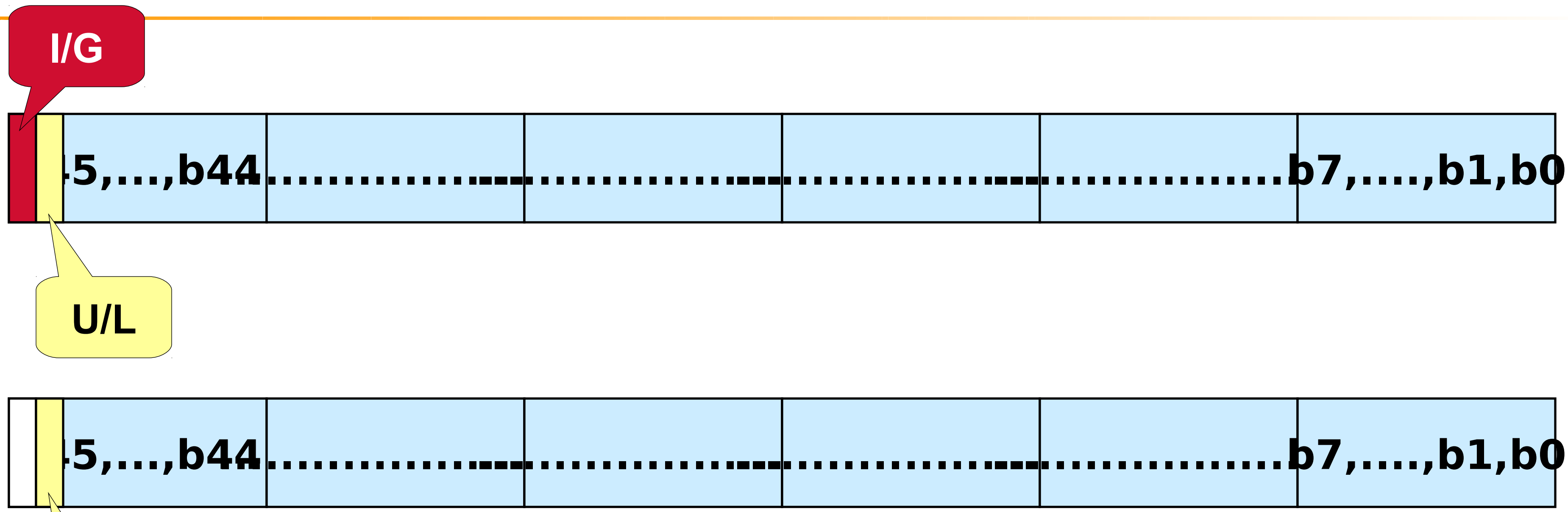
- Short-term unfairness on very high network loads
- Stations with lower collision counter tend to continue winning
- 10 times harder to occur on 100 Mbit/s Ethernet
- Rare phenomena, so no solution against it

But would I choose Ethernet for mission-critical realtime applications…?

Collision Detection

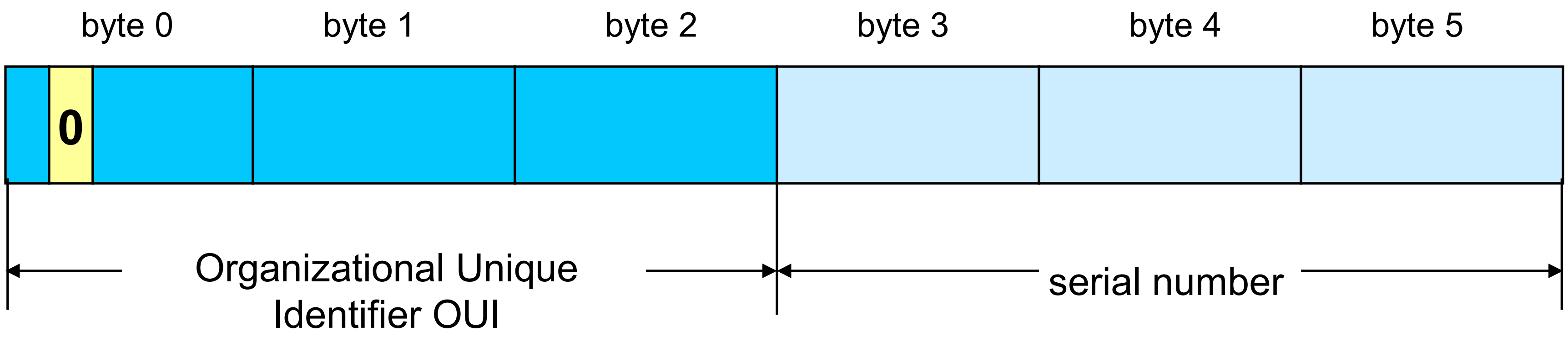
- 10Base2, 10Base5
  - Manchester with –40 mA DC level
  - "high" = 0 mA, "low" = –80 mA
- 10BaseT
  - Manchester with no DC offset
  - Collisions are detected by Hub who sends a "Jam" signal back
  - Similarily at 100BaseT and 1000BaseT

6 Byte MAC Addresses



- **Individual/Group (I/G)**
  - I/G=0 is a unicast address
  - I/G=1 is a group (broadcast) address
- **Universal/Local (U/L)**
  - U/L=0 is a global, IEEE administered address
  - U/L=1 is a local administered address

MAC Address Structure



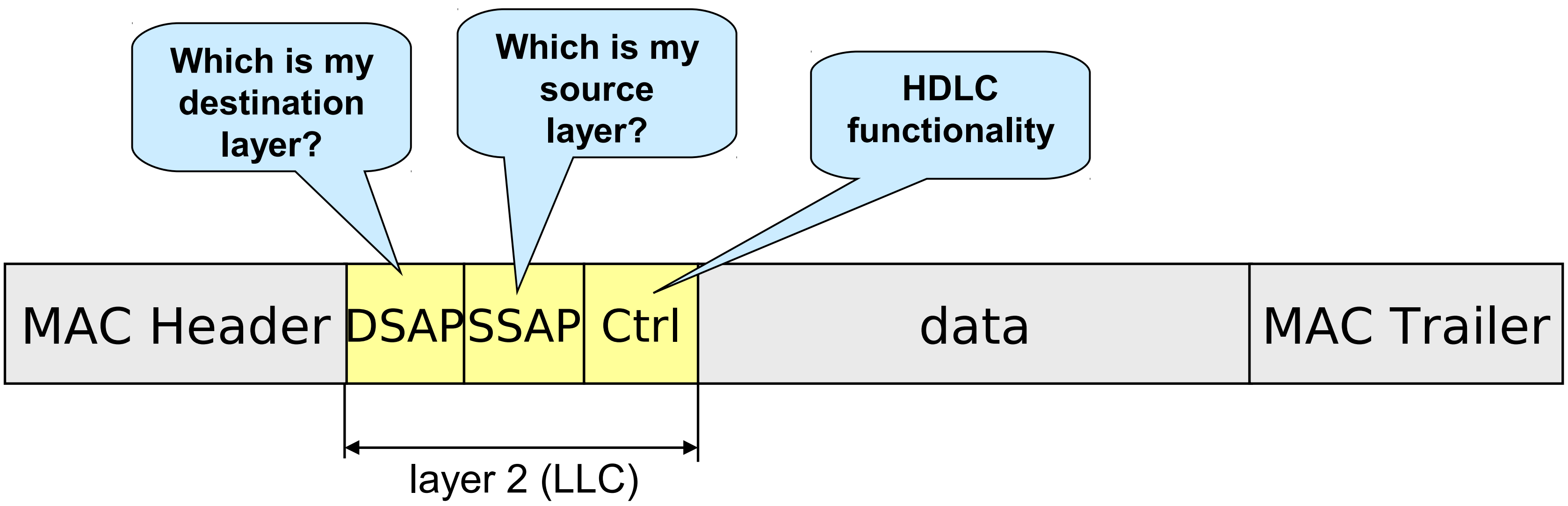
- Each vendor of networking component can apply for an unique vendor code
- Administered by IEEE

Ethernet Frames

- Due to different development branches, there are two different frame types
  - IEEE type: consists of MAC and LLC
  - DIX type: consists of a Type field
- Why using both?
  - Different applications have been defined for either IEEE or DIX

IEEE 802.2 (LLC)

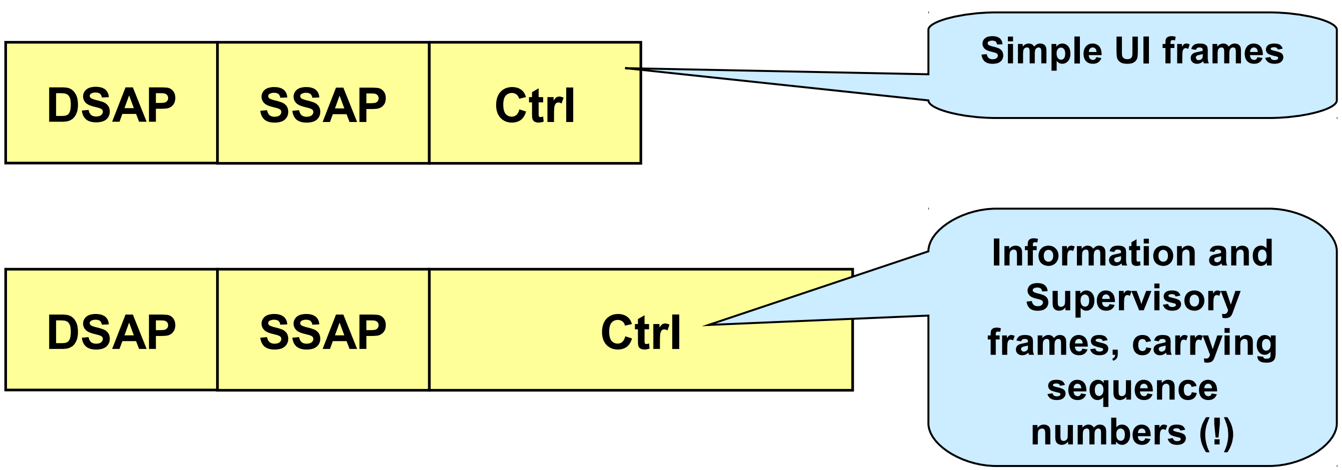
- Every IEEE LAN/MAN protocol carries the Logical Link Control header
  - HDLC heritage



Basic frame format of every IEEE protocol

LLC Details

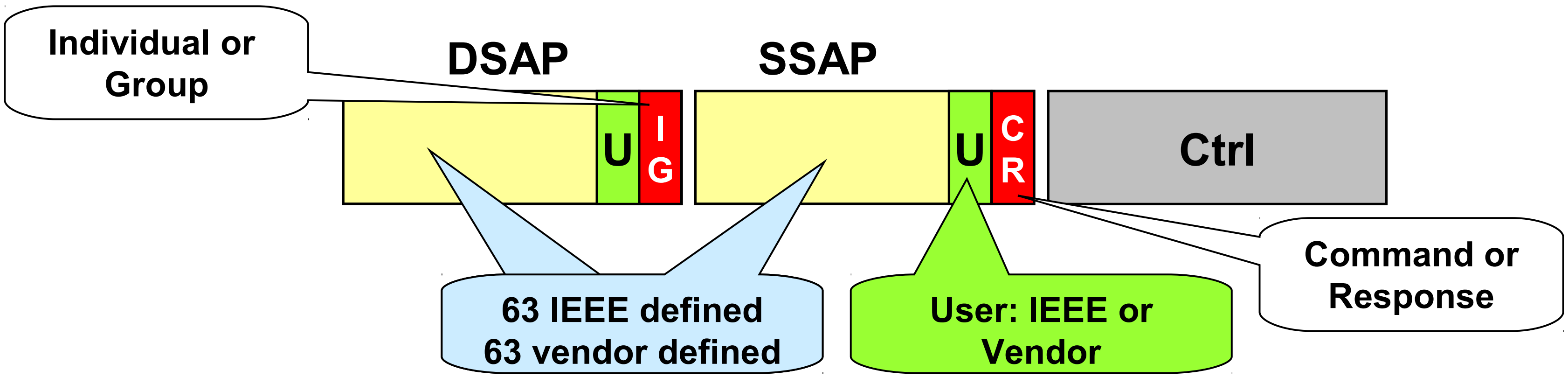
- According sophisticated HDLC functionalities, 4 LLC classes defined
  - Class 1 is most important (UI, no ACKs)



Either 1 or 2 bytes for control field

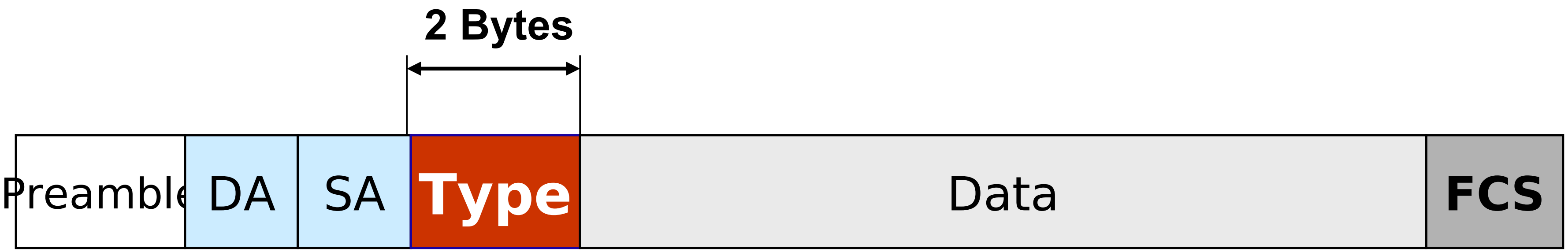
SAP Identifiers

- 128 possible values for protocol identifiers
- Examples:
  - 0x42 … Spanning Tree Protocol 802.1d
  - 0xAA… SNAP
  - 0xE0… Novell
  - 0xF0… NetBios



DIX Type field

- 2-bytes Type field to identify payload (protocols carried)
  - Most important: IP type 0x800
- No length field

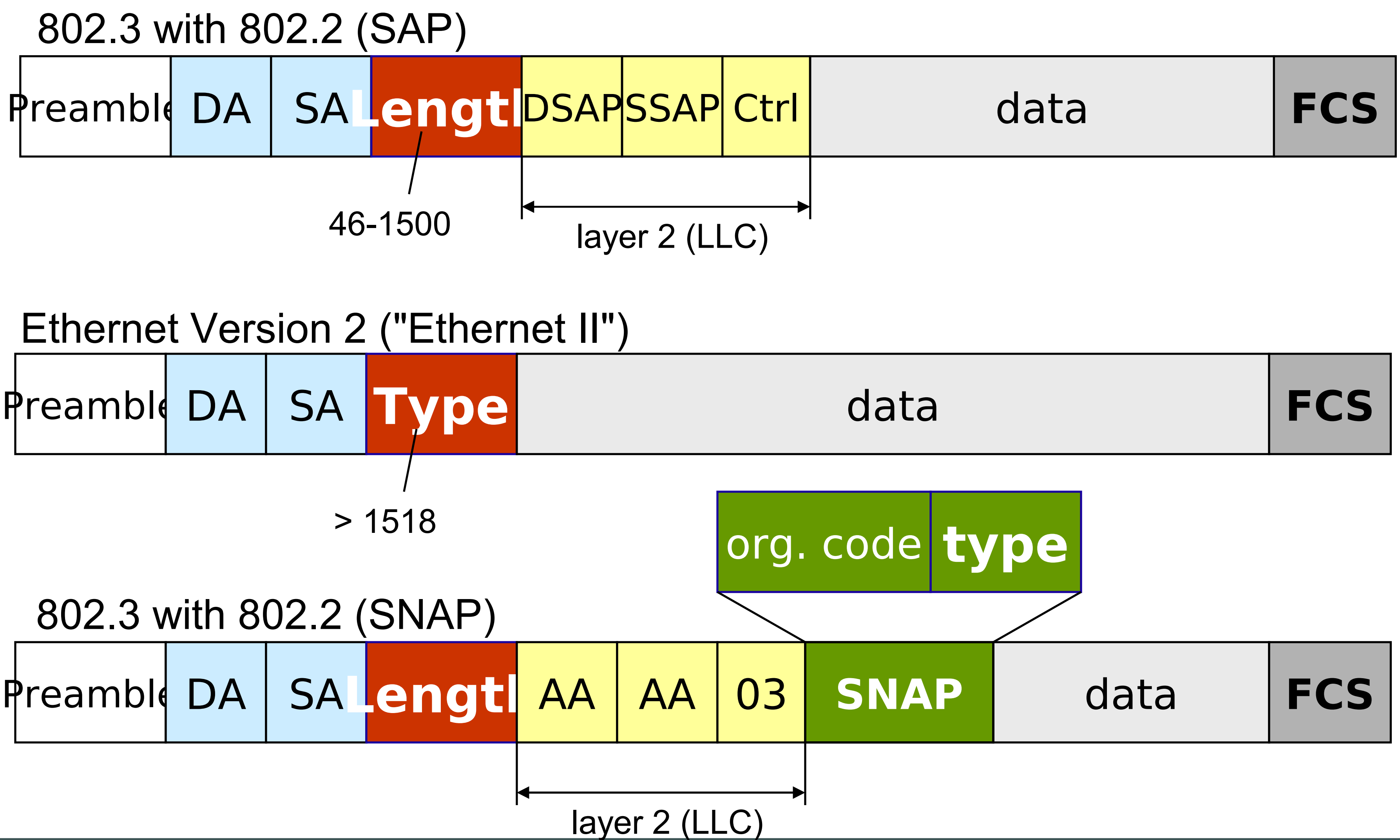


"THE" Ethernet Frame

SNAP

- Demand for carrying type-field in 802.4, 802.5, 802.6, ... also !
- Subnetwork Access Protocol (SNAP) header introduced
  - If DSAP=SSAP=0xAA and Ctrl=0x03 then a 5 byte SNAP header follows
  - Containing 3 bytes organizational code plus 2 byte DIX type field

Frame Types Summary



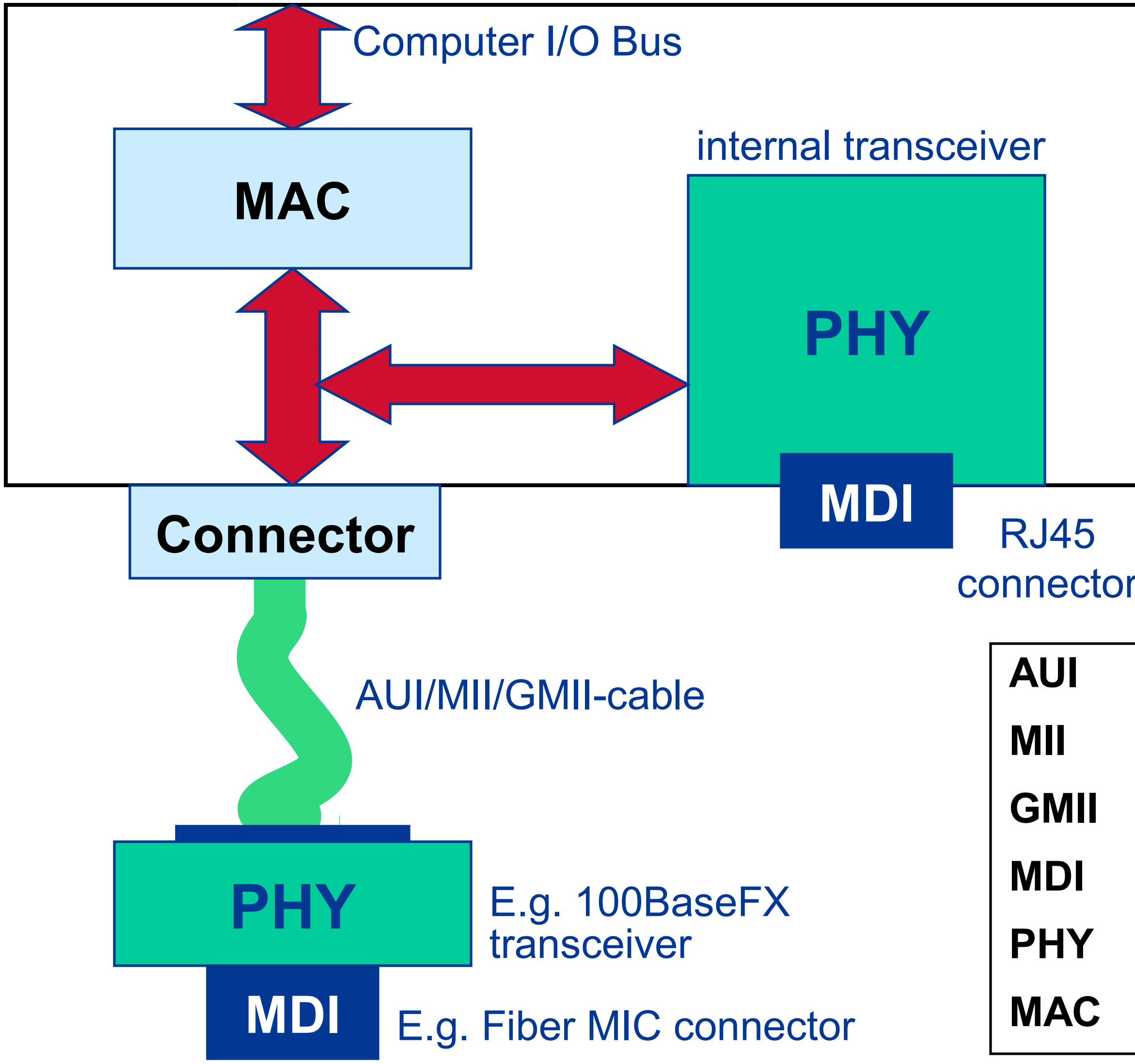
PHY Variants

- 10Base2 (10 Mbit/s, 200 meters)
- 10Base5 (500 meters)
- 10BaseT (star-like cabling, hub needed)
- 10BaseF (fiber)
- 10Broad36 (broadband cable)
- 100BaseT
- 1000BaseT
- 1000BaseX

Twisted Pair Cabling

- Category X cables
  - Cat 3 (Voice grade)
  - Cat 4
  - Cat 5
  - Cat 5e (1000BaseT, unshielded)
  - Cat 6
  - Cat 7
- Category depends on twisting cycles per length unit, isolation, and shielding

Typical NIC Design



AUI	**Attachment Unit Interface**
MII	**Media Independent Interface**
GMII	**Gigabit MII**
MDI	**Medium Dependent Interface**
PHY	**Physical Layer Device**
MAC	**Media Access Control Unit**

Summary

- Successful because simple
- Two frames: DIX (Ethernet2) and IEEE (802.3)
- Shared medium has consequences
  - Collisions ➔ Slot time ➔ Network diameter
  - Unpredictable, bad for realtime
- Increased data rate until today ➔ 10 GE already available (!)

Quiz

- **What is a hub?**
  List typical properties:
  - **Half/full-duplex?**
  - **Different data rates?**
  - **Collision behavior?**
- **What is the canonical addressing format?**
- **What is a jam signal?**
- **What is 802.3u and 803.3z ?**
- **What is a runt? What is the opposite?**