Ethernet

CSMA/CD, Framing, SNAP,
Repeater, Hub, 10Mbit/s Technology

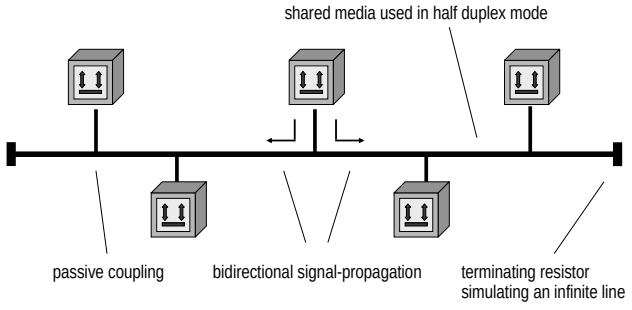
Agenda

- **Introduction**
- **CSMA/CD**
- **Elements and Basic Media-Types**
- **Repeater, Link Segments**
- **Framing**

Origin of IEEE 802.3 (Ethernet)

- bus topology based on coax-cables
  - passive, uninterrupted coupling
  - shared media like the „Ether“ of air
- bidirectional signal-propagation
  - termination resistors avoid signal reflections
- definite transmitting power of network stations
  - limits cable length and number of (receiver-) stations
- two types with baseband transmission with Manchester encoding, 10 Mbit/s
  - 10Base5 "Yellow Cable“
  - 10Base2 "Cheapernet"
- one type with modulation (broadband)
  - 10Broad36 (broadband)

Basic Idea of Ethernet Bus System



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Media Access Control of Ethernet 1

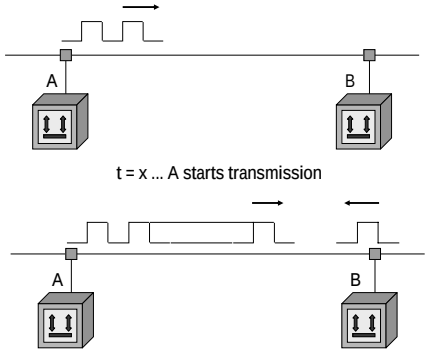
- **CSMA/CD**
  - Carrier Sense Multiple Access / Collision Detection
  - access control based on contention
  - network stations listen to the bus before they start a transmission
  - network stations can detect ongoing transmission (CS) and will not start own transmission before ongoing transmission is over
  - but still simultaneous transmissions (MA) cause collisions (bus conflict)
  - collisions are detected (CD) by observing the DC-level on the medium

Media Access Control of Ethernet 2

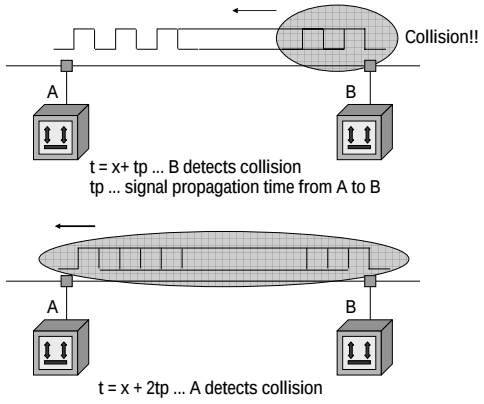
- **conflict resolution**
  - aborting of transmission by all involved stations
  - sending of a JAM-signal (32 bit)
    - to make sure that every station can recognize the collision
    - collision is spread to a minimum length
  - starting a random number generator to create a timeout value

    truncated binary exponential backoff algorithm (the more often a collision occurs the larger is the range for the random number)
  - after timeout expired, station attempts a retransmission
  - number of retransmission-trials is limited to 16
    - after 16 collisions in a sequence a error is signalled to the higher layer

Collision Window / Slot Time 1



Collision Window / Slot Time 2



Collision Window / Slot Time 3

- **worst case**
  - stations have to wait (have to send bits) twice the maximum signal propagation time for reliable collision detection
    - otherwise a collision may not be seen by the transmitting station
  - the maximum allowed time for that in Ethernet transmission system
    - is called collision window or slot time
  - 10 Mbit/s Ethernet defines 51,2 microsecond for the collision window / slot time
    - 10 Mbit/s means 1 bit every 100ns
    - therefore 51,2 microsecond is equal to 512 bits
    - hence the minimal frame length is 64 byte

Collision Window / Slot Time 4

- **there is an interdependence**
  - maximum propagation time (cable and electronic components) or slot time, data rate, cable length and minimum frame size
  - if you choose one parameter, the others will follow
- **the request for reliable collision detection during sending of a frame and the definition of a given Ethernet slot-time**
  - limits the physical distance (network diameter) of Ethernet LANs for 10 Mbit/s
    - around 2500 - 3000 meters
- **the request for fairness**
  - limits the maximum frame size, too
  - 1518 byte is the maximum allowed frame size

Collision Window / Slot Time 5

Technology	Bit-Time (sec)	Collision Window (sec)	Slot Time (bit-times)		Minimum Frame (bit-times / byte)	Distance (m)
10Mbit/s	100ns	51,2µs	512	=	512 / 64	2000-3000
100Mbit/s	10ns	5,12µs	512	=	512 / 64	~200
1000Mbit/s	1ns	0,512µs	512		512 / 64	~10-20
1000Mbit/s	1ns	4,096µs	4096*	≠	512 / 64	200

*** by the usage of carrier extension / frame bursting**

Exponential Backoff Details

- **Provides maximal utilization of bandwidth**
  - After collision, set basic delay = slot time
  - Total delay = basic delay * random
  - 0 <= random < 2^k
    - k = min (number of transmission attempts, 10)
- **After 16 successive collisions**
  - Frame is discarded, error message to higher layer and 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

Collision Detection Details

- **10Base2, 10Base5**
  - Manchester with –40 mA DC level
  - "high" = 0 mA, "low" = –80 mA
  - Two signals at same time: DC Level < -40 mA
- **10BaseT**
  - Manchester with no DC offset
  - Collisions are detected by “Hub” component which sends a "Jam" signal back in case two or more stations start at the same time
  - Similar at 100BaseT and 1000BaseT

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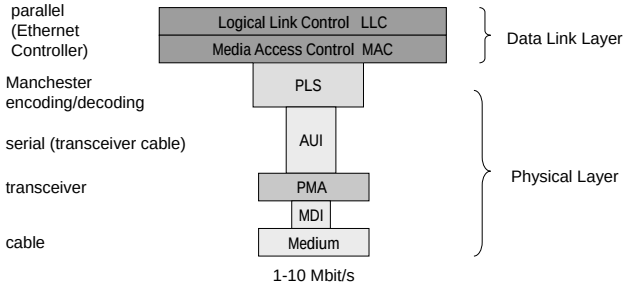
Physical Layer Functions



AUI...Attachment Unit Interface, PLS...Physical Layer Signalling, MDI...Medium Dependent Interface, Interface, PMA...Physical Medium Attachment, MAU...Medium Attachment Unit

PHY Sublayers

- **Physical Layer Signaling (PLS) serves as abstraction layer between MAC and PHY**
- **PLS provides**
  - data encoding/decoding (Manchester)
  - translation between MAC and PHY
    - Using PLS service primitives
  - Attachment Unit Interface (AUI) to connect with PMA
- **Physical Medium Attachment (PMA)**
  - interface between PLS and MDI
- **Medium Attachment Unit (MDI)**
  - specification of the various connectors

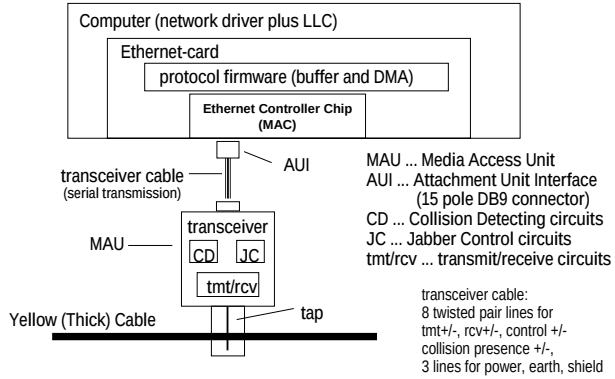
Media-Connection by Transceiver

- **transmitter / receiver**
- **transceiver provides electronic circuits for:**
  - inserting and receiving signal currents
  - collision detection
    - measurement of DC level
    - 10Base5: Level High (1) = 0 mA, Level Low (0) = -80 mA
    - DC of Manchester-encoded signal = -40 mA
    - two signals at same time: DC Level < -40 mA
  - heartbeat function
    - SQE Signal Quality Error
  - jabber control
    - jabber: continuously emitting of frames beyond the maximal frame size

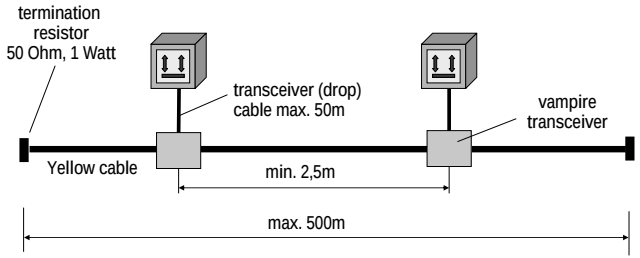
External / Internal Transceiver

- **transceiver types:**
  - 10Base5, 10Base2,
  - FOIRL (Fiber Optic Inter Repeater Link) and 10BaseT, 10BaseF (these types will be handled later in this presentation)
- **external transceiver:**
  - AUI interface (with or without transceiver cable) connects end system and transceiver
  - transceiver powered by end system
- **integrated transceiver:**
  - transceiver is integrated on network card of end system
  - network card provides necessary physical connector
    - BNC (10Base2)
    - RJ45 (10BaseT)
    - ST (10BaseF)

AUI-Connection with 10Base5 Transceiver

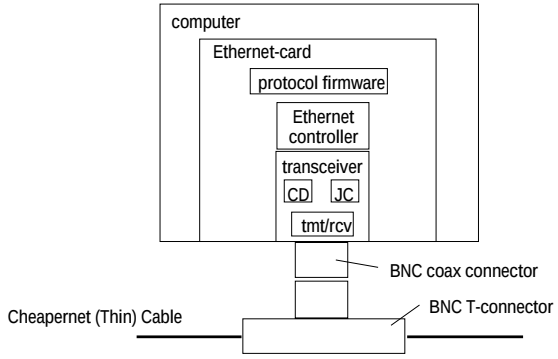


10Base5 Parameter

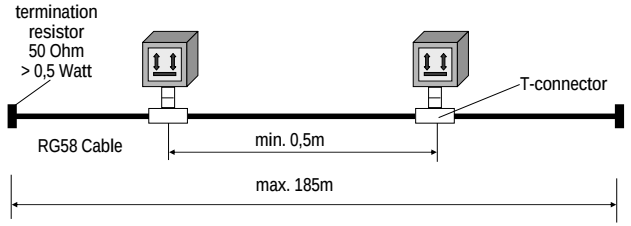


- maximal number of stations: 100
- attachable only at marked points
- cable splitting via coax couplers
- individual cable parts have a length of 23,4m or 70,2m or 117,5m (wave minimum on standing waves due to inhomogeneous media)
- smallest bending radius: 254mm

Integrated Transceiver for 10Base2



10Base2 Parameter



- maximal number of stations: 30
- attachable at any points
- smallest bending radius: 50 mm

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Repeater

- **Repeater is an amplifier expanding the maximal distance of an Ethernet-LAN segment**
  - regenerate signals on the receiving port, amplify them, and send these signals to all connected net segments
  - no buffering, just a short delay, which must be taken into account for the collision window
  - collisions are detected and all other ports are notified by jam-signal
  - optionally auto partition on erroneous ports
- **collision domain**
  - is preserved by repeaters
- **local repeaters directly connect two (coax) segments**
- **remote repeaters are connected by so called link segments**

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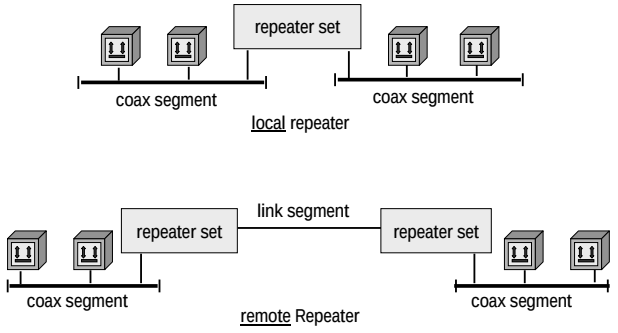
Local / Remote Repeater



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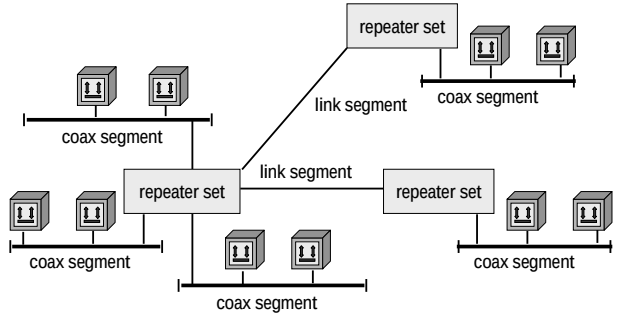
Multiport Repeater - One Collision Domain



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Link Segments for Repeater Interconnection

- **link segment**
  - first implementation for repeater interconnection only
  - point-to point connection
    - only two devices are connected by a physical cable
  - several types were defined
    - fibre based
    - copper based
  - FOIRL (Fibre Optic Inter Repeater Link)
    - maximal length 1000m
    - first FO specification
    - repeater - repeater

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Link Segments for Repeater Interconnection

- **types cont.**
  - 10BaseFL (Fibre)
    - asynchronous
    - maximal length 2000m
    - repeater - repeater, end system - multiport repeater
  - 10BaseFB (Fibre)
    - synchronous (idle signals during communication pauses)
    - maximal length 2000m
    - for repeater - repeater links only
    - developed to overcome limitation based on repeater rules by defining a repeater less backbone infrastructure
  - 10BaseFP (Fibre)
    - passive hub, no active repeater function (remark: active means electrically powered)

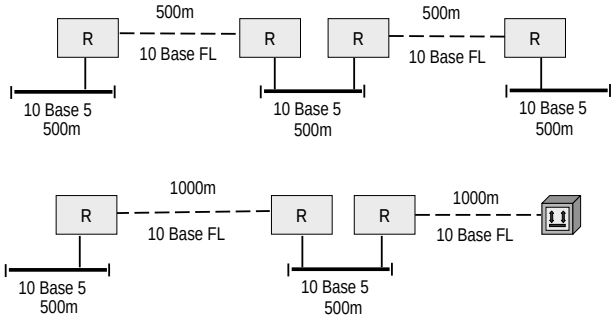
Repeater-Rules 1

- **collision domain of an Ethernet LAN is limited**
  - collision window of 51,2 microsecond
- **topology of repeaters must obey**
  - maximal 5 segments over 4 repeater-sets are allowed, in this case 2 segments have to be link-segments (rest arbitrary), length of fibre optic link segments must not exceed 500m each

    -> results in a maximum diameter of 2500m
  - on 4 segments with 3 repeater-sets, the length of a fibre optic link segment must not exceed 1000m, the segments may be mixed in any desired way

    -> results in a maximum diameter of 3000m

Repeater-Rules 2



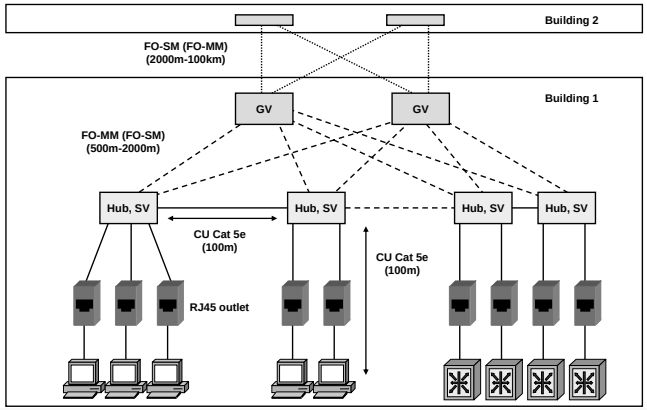
Link Segments for End Systems 1

- **link segment**
  - was later also defined for connection of a network station (end system) to a multiport repeater
    - using a dedicated point-to-point line
  - reason for that:
    - Ethernet was originally based on coax cabling and bus topology
    - later an international standard for **structured cabling** of buildings was defined
      - star wired to a central point(s)
      - based on twisted pair cabling
    - that excellently fits to Token ring cabling
    - Ethernet had been adapted to that in order to survive

Structured Cabling (LAN)

- **Physical Wiring**
  - Should follow the principle of structured cabling
  - Primary
    - End system to first “Hub” (Repeater or nowadays a L2 Switch)
      - “Stockwerkverteiler”
    - CU-UTP, Category 5e or better
    - FO for extreme conditions only
  - Secondary
    - Hubs to central functions
      - “Gebäudeverteiler”
    - FO-MM (FO-SM)
  - Tertiary
    - Interconnections of buildings
    - FO-MM (FO-SM)

Structured Cabling (LAN)



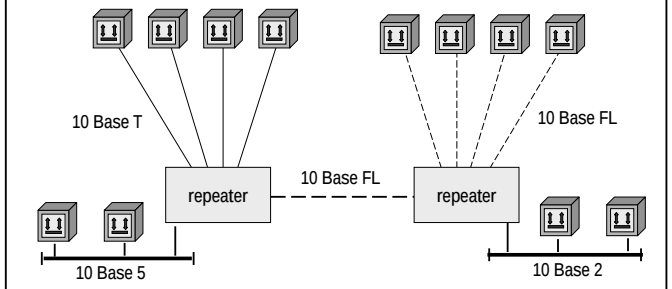
Link Segments for End Systems 2

- **link segment (cont.)**
  - 10BaseT (unshielded twisted pair)
    - maximal length 100m
    - 2 lines Tmt+-, 2 lines Rcv+-, RJ45 connector
    - Manchester-Code with no DC offset
      - collisions are detected by hub, if two or more signals are received at the same time, hub produce Jam signal on all ports, hence collision is recognized if signals are on the tmt and rcv line at the same time
    - during transmission pause
      - “Start of Idle” signal followed by periodic link test pulses (LTP) to check the link state
      - every 16ms a 100ns lasting LTP is sent by LAN devices, no signal on the wire means disconnected
    - repeater - repeater, end system - multiport repeater,
    - end system - end system via cross-over cable

Link Segments for End Systems 3

- **link segment (cont.)**
  - 10BaseFL (Fibre)
    - asynchronous,
    - maximal length 2000m
    - repeater - repeater, end system - multiport repeater
- **repeater with more than two segments and different physics**
  - multiport repeater
- **end-systems and multiport repeater in a star like topology**
  - repeater is called a “Hub”
    - be careful using this expression because also used for L2 Ethernet-Switch
  - main usage for 10BaseT in today's Ethernet networks

Multiport - Repeater



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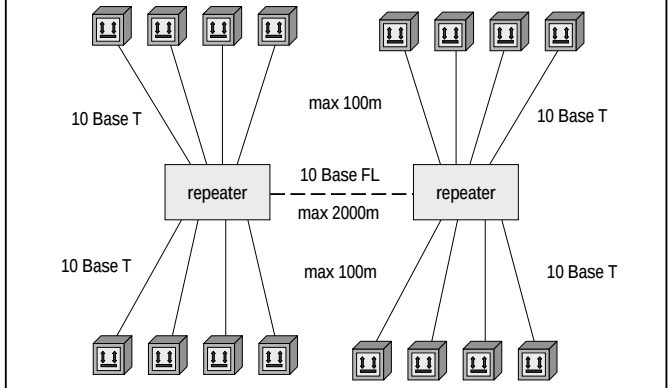
Multiport Repeater as „Hub“



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IEEE 802.3 Frame Format

preamble	DA	SA	length	LLC	data	FCS

preamble ..... for clock synchronization (64 bit)
(62 bits 10101.....01010 + 2bits 11 as SD,
bit synchronization within 18 bit times)
DA ..... Destination MAC-address (48 bit)
SA ..... Source MAC-address (48 bit)
length ..... of IEEE 802.3 frame (16 bit)
= octets following without CRC (46-1500)
data ..... payload
FCS ..... Frame Check Sequence (32 Bit)
parameters: interframe gap 9.6 microsecond
jam size 32 bit
slot time 512 bits, minimal frame length 64 Byte
(6+6+2+46+4, FCS counted, preamble not counted)
-> at maximum 14880 frames per second
maximal frame length 1518 byte (6+6+2+1500+4)

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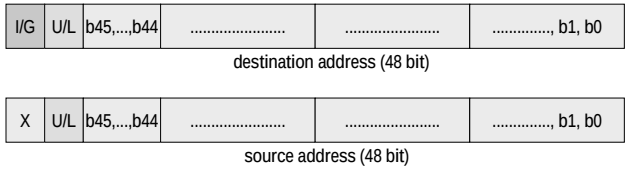
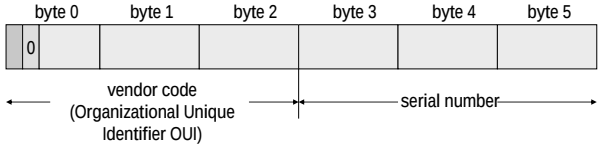
IEEE-MAC-Address Format



- I/G Individual / Group (only for DA):
  I/G = 0 individual address, I/G = 1 group broadcast
  (broadcast for a group is called multicast)
  address with all bits set to 1 .... broadcast-address
  hex FFFF FFFF FFFF (note: U/L is set to 1)
- U/L Universal / Local:
  U/L = 0 global address, administered by IEEE
  U/L = 1 local administered address
  bit 47 (x) not used for source address

IEEE Administered Addresses (U/L = 0)



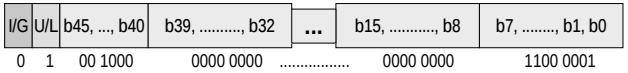
IEEE assigns each vendor of network components an unique vendor code (OUI, byte 0, 1, 2)

vendors use byte 3, 4 and 5 for numbering their network components (serial number)

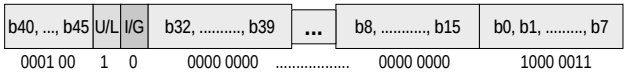
called "Burned In" Address (BIA)

Storage Format of 802.3 MAC-Address

- **basic rule:**
  - I/G bit must be the first bit on the medium, so the transmitted address must have the following format:



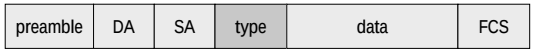
  - 802.3 sends the least significant bit of each octet at first
  - so 802.3 must store each octet in memory in reverse order:
    - also called "Canonical" Format



IEEE 802.3 <-> Ethernet Version 2

- **IEEE 802.3 relies on LLC (802.2) and SAPs**
  - the protocol-type is indicated by SSAP and DSAP (LLC)
- **Ethernet Version 2 uses a protocol-type-field instead of the length field**
  - there is no need for an additional sub layer (like LLC) in order to implement connectionless services only
  - layer 3 is directly attached on Ethernet V2
- **some values for the protocol-type-field (Ethertype):**
  - 0x0800 IP, 0x806 ARP, 0x8035 RARP, 0x814C SNMP
  - 0x6001/2 DEC MOP, 0x6004 DEC LAT, 0x6007 DEC LAVC, 0x8038 DEC Spanning Tree
  - 0x8138 Novell

Ethernet Version 2 (DEC, Intel, Xerox -> DIX)

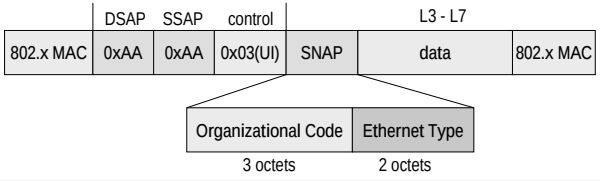


preamble ..... for clock synchronization
DA .....Destination Address (48 Bit)
SA .....Source Address (48 Bit)
type .....protocol-type field (16 Bit)
(Ethernet Version II frame)
Data ..... payload
FCS ..... Frame Check Sequence (32 Bit)

• Ethernet V2 and 802.3 can coexist on the same cable, but each associated sending and receiving station must use the same format.
• Fortunately all type-field values are larger than 1518 (max frame length), so any incoming frame can be recognized and handled properly.

Ethernet Type over LLC with SNAP

- **SNAP (Subnetwork Access Protocol)**
  - convergence protocol to transport Ethernet V2 type information over IEEE LANs
  - reason: LLC SAP-fields (length 8 bit) can not carry some already defined Ethernet V2 protocol types (length 16 bit)
  - note: some IEEE LANs require the usage of LLC
    - e.g. Token Ring, FDDI



SAP, SNAP, Ethernet V2 - SUMMARY