Physical Layer Standards

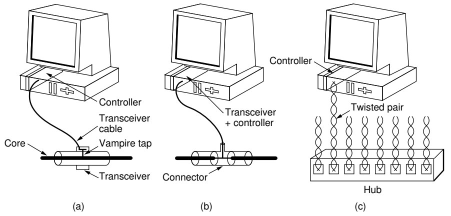
- Physical layer: concern with transmission of raw bit stream over **physical medium**
- A physical layer "protocol" or standard deals with mechanical, electrical and procedural characteristics to access physical medium
- Parts of a physical layer are completely related to the medium and others are independent of the medium → useful thinking physical layer as two sublayers
  - "**Medium dependent** sublayer": specifies the medium, physical connectors, related mechanical and electrical characteristics
  - "**Medium independent** sublayer": covers line coding – how to transmit 0 and 1 bits; synchronisation – sender and receiver clocks must be synchronised to know the start/end of a bit, usually by organising block of bits into a frame; other issues not directly linked to the medium

Do not confuse layer-1 framing with framing in layer-2: It is really concerned with how to reliably transmit bit stream (timing), while layer-2 framing includes some other higher functional purposes

IEEE 802.3 Ethernet

- A bus LAN, "medium dependent" part of physical layer specifies things related to the medium:

name	(a) 10Base5	(b) 10Base2	(c) 10Base-T
medium	thick coax cable	thin coax cable	twisted pair
max. length	500 m	200 m	100 m
nodes	100	30	1024
data rate	10 Mbps	10 Mbps	10 Mbps

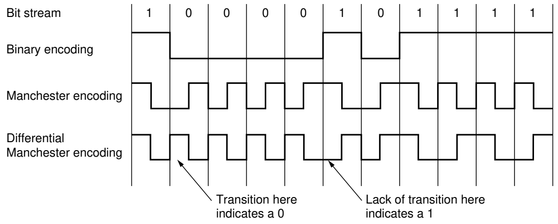


- "Medium independent": the Manchester encoding is used for the line coding – A 1 bit is transmitted as a half-width positive pulse followed by a half-width negative pulse, and a 0 bit is another way round

  This line coding is simple:

  ⇑ DC balanced (on average DC is zero), always has lots of transitions for synchronisation

  ⇓ baud rate is twice of data rate, and the required bandwidth is doubled



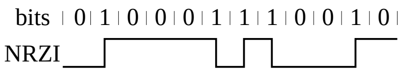
Fiber Distributed Data Interface

- FDDI is 100 Mbps fiber optics LAN standard based on timed token ring, used as backbone
- Physical layer medium dependent (PMD) specifies optical components: fiber, connector, transmitter, receiver and light pulses → depending on media, many standards and two examples:

	Multimode Fiber PMD	Single mode Fiber PMD
Window:	1300 nm	1300 nm
Fiber:	multimode graded-index, 62.5/125 μm	single mode, 8.7/125 μm
Transmitter:	LED, wavelength 1270–1380 nm	laser sources
Receiver:	PINs	PINs
Fiber cable:	upto 2 km	upto 40–60 km

  A window is the range of wavelength used for communications, denoted by its centre wavelength
- Physical layer medium independent (PHY) defines algorithms to overcome clock rate differences, detect errors and encode data bits
- **Line coding**: uses nonreturn to zero inverted (NRZI) with 4b/5b encoding

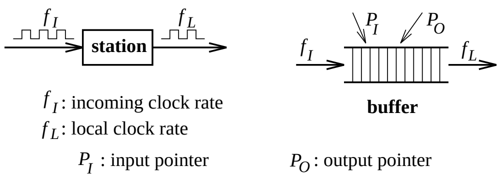
  In NRZI, 1 bit: a signal transition and 0 bit: no transition → If many 0 bits occur in a row, signal level remains unchanged, clock information may lose



  With 4b/5b coding, 4-bit data are encoded as 5 code bits, and code bits are chosen such that data stream never have more than three zeros in row

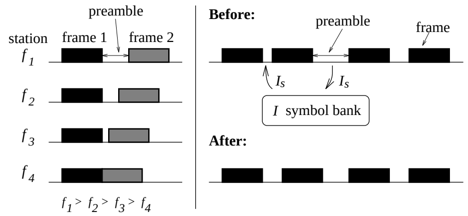
FDDI (continue)

- FDDI baud rate is 125 Mbps due to this encoding. Encoding also provides error detection capability and special bit pattern for frame delimiter
- **Elasticity buffer**: alleviates clock differences between neighboring stations. Clock difference means number of in and out pulses may not be the same. If more bits are received, bits in the interframe gap are deleted by re-centering the FIFO buffer at the end of the frame. If fewer bits are received, additional bits are transmitted after the end of the frame



- **Smoother**: ensures sufficient interframe gap. If a series of station clocks is skewed such that their elasticity buffers chew away the whole gap, next station will be forced to delete bits from the frames

  Smoother counts the number of "idle" symbols in the preamble. If the preamble is shorter than a minimum, it adds an idle symbol and keeps a count of added symbols. It refills its supply of idle symbols when it finds a longer preamble by shortening it

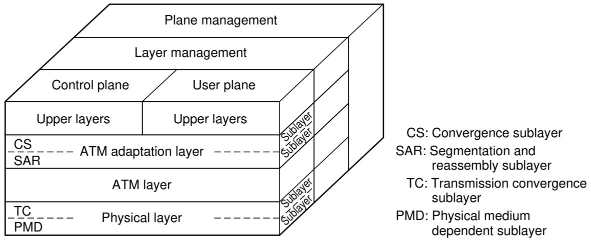


Broadband-ISDN

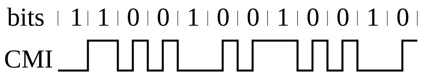
- B-ISDN is based on ATM whose protocol architecture:

  ATM is very fast packet-oriented and uses fixed-length cells with 5-byte header and 48-byte information field

  Physical layer defines two interface rates: 155.52 Mbps and 622.08 Mbps, and the medium is usually fiber



- Physical medium dependent sublayer (PMD): includes physical medium-dependent functions and is responsible for transmitting/receiving a continuous flow of bits with associated timing
  - Line coding: coded mark inversion (CMI)



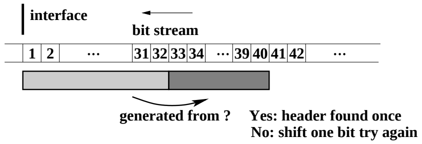
  - 0 bit: half-width negative pulse followed by a half-width positive pulse; 1 bit: full-width negative pulse or a full-width positive pulse in such a way that the polarity alternates for successive 1 bits
  - CMI is DC balanced and provides easy clock recovery, but baud rate is twice of data rate (with fiber, bandwidth is not too much a concern)

B-ISDN (continue)

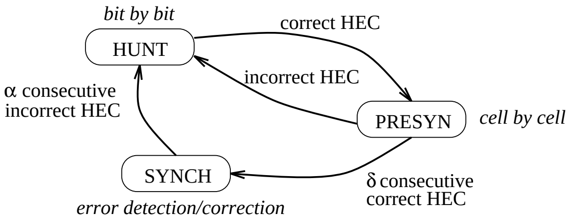
- Transmission convergence sublayer (TC): some of its functions belong to layer-2
  - Transmission frame generation and recovery: generating and maintaining the frame structure appropriate for a given data rate
  - Transmission frame adaptation: packaging ATM cells into a frame, and two alternative frame structures are the cell-based and SDH-based
  - Cell delineation: maintaining the cell boundaries so that cells can be recovered at the destination
  - HEC sequence generation and verification: generating and checking HEC code (1-byte checksum in the header called header error control)
  - Cell rate decoupling: insertion and suppression of idle cells in order to adapt the rate of valid ATM cells to the payload capacity of the transmission systems
- **SDH-based physical layer**: stream of ATM cells are mapped into payload of STM-1 (synchronous transport module level 1) frame of SDH (synchronous digital hierarchy)
- The SDH provides extensive framing for synchronisation, and the receiver knows the start of a cell
- **Cell-based physical layer**: no framing structure and the interface consists of continuous streams of ATM cells
- For the cell-based physical layer, no framing is imposed → how synchronisation is achieved ? or how to locate cells at receiver?

Locating ATM Cells

- The 5-th byte of 5-byte header, HEC, is generated from the rest of header according to known coding rule, and this forms the basis of cell reception



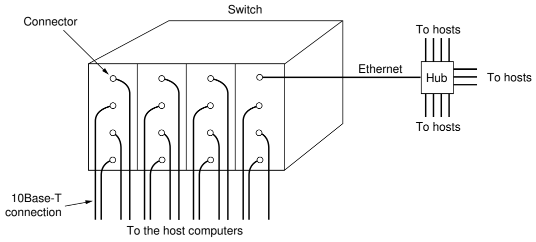
- Cell reception algorithm:
  1. **HUNT**: a cell-delineation algorithm is performed bit by bit to determine if HEC coding law is observed. Once a match is achieved, it is assumed that one header has been found
  2. **PRESYN**: a cell structure is now assumed. Cell-delineation algorithm is performed cell by cell until encoding law has been confirmed δ times consecutively
  3. **SYNCH**: HEC is used for error detection and correction. Cell delineation is assumed to be lost if HEC coding law is recognised as incorrect α times consecutively



Fast Ethernet

- Fast Ethernet (IEEE 802.3u): keeps all things of Ethernet and thus compatible to existing Ethernet, but bit period is reduced from 100 ns to 10 ns → **100 Mbps** data rate
- It is based on wiring design similar to 10Base-T and uses hubs and switches
  - Ethernet **switch**: high-speed backplane for 4 to 32 plug-in line cards, each having 1 to 8 connectors. Each connector typically has a (10Base-T) twisted pair connected to a single host

    When a station transmits a frame, it outputs it to the switch. The plug-in card getting frame checks it to see if it is for a station connected to the same card. If so, the frame is copied there. If not, the frame is sent over high speed backplane to the destination's card. Backplane runs at Gbps



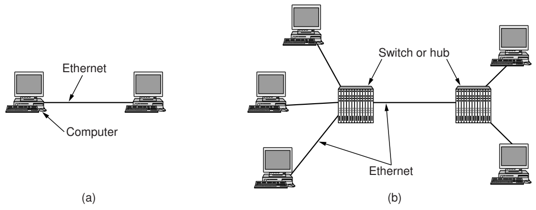
  - Ethernet **hub**: acts like Ethernet, i.e. frames arriving at a hub contend for 802.3 LAN in usual way (CSMA/CD). Hubs are cheaper than switches
  - Fast Ethernet wiring: 100Base-T4, twisted pair, 100 m, uses category 3 UTP; 100Base-TX, twisted pair, 100 m, full duplex at 100 Mbps (cat 5 UTP); 100Base-FX, fiber optics, 2000 m, full duplex at 100 Mbps

Fast Ethernet (continue)

- **100Base-T4**: four twisted pairs, each with signalling speed of 25 MHz (UTP-3)
  - One is always to hub, one always from hub, and the other two are switchable so that there are always 3 twisted pairs for the current transmission direction
  - Manchester encoding cannot be used (you never get 200 MHz baud rate) → Line coding is ternary (three levels)
  - 3 twisted pairs plus ternary: 27 symbols → possible to transmit 4 bit per symbol with some spare. Transmitting 4 bits in 25 MHz → 100 Mbps in forward channel
  - Reverse channel (one twisted pair) has capacity of 33.3 Mbps
  - This scheme is terrible, but telephone wiring has four twisted pairs per cable
- **100Base-TX**: with signalling speed of 125 MHz (UTP-5), two twisted pairs per station for full duplex, one to hub and one from hub
  - Line coding is compatible to FDDI, 4b/5b encoding with baud rate 125 Mbps
- **100Base-FX**: uses two standard multimode fibers, one for each direction, to achieve full duplex 100 Mbps data rate

Gigabit Ethernet

- Gigabit Ethernet (IEEE 802.3z): 1 Gbps data rate and is compatible to existing Ethernet, but it uses **point-to-point** configuration: each Ethernet cable has exactly two devices on it
- Two modes: full duplex and half duplex for computer-switch (no contention) and computer-hub (collision possible) links



- Gigabit Ethernet wiring:
  - Manchester encoding is definitely not on card: 2 GHz bandwidth for 1 Gbps is too much wasteful

Name	Cable	Max. segment	Advantages
1000Base-SX	Fiber optics	550 m	Multimode fiber (50, 62.5 microns)
1000Base-LX	Fiber optics	5000 m	Single (10 μ) or multimode (50, 62.5 μ)
1000Base-CX	2 Pairs of STP	25 m	Shielded twisted pair
1000Base-T	4 Pairs of UTP	100 m	Standard category 5 UTP

  - Line coding is 8b/10b encoding with following properties: no codeword has more than 4 identical bits in a row and no codeword has more than 6 0s or 6 1s → to allow sufficient signal transitions and make DC as low as possible
  - 1000Base-T uses a different encoding: with 125 MHz each pair and four pairs for each direction, 5-levels line coding is used → allow to transmit at 2 bits per symbol and this gives exactly 1 Gbps at each direction ($2 \times 4 \times 125$ Mbps)

10 Gigabit Ethernet Over Copper

- **10GBASE-T**: 4-pair UTP-6 or better, 4×2.5 Gbps, quad DX

  Standard approved on 21 July 2006
- Definitely point-to-point and no collision (not use CSMA/CD)
- Sophisticated line signalling and signal processing
- See **talk** by Gottfried Ungerboeck at NEWCOM-ACoRN Joint workshop, Vienna, Sept.20-22, 2006

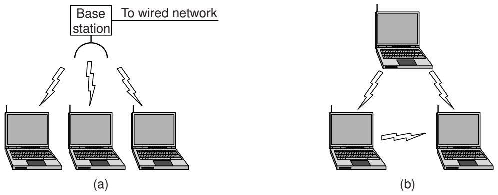
  which can be downloaded from

  http://www.ecs.soton.ac.uk/∼sqc/EL336/

Wireless LANs

- Wireless LAN can have a base station called **access point** or without a base station called **ad hoc network**
- IEEE 802.11 **WIFI** physical layer defines five permitted transmission techniques

  ISM: industrial, Scientific, Medical bands



  - 802.11 Infrared: two speeds are permitted, 1 Mbps and 2 Mbps. This is not a popular option
  - 802.11 FHSS (frequency hopping spread spectrum): uses 79 channels, each 1 MHz bandwidth, starting at the low end of 2.4-GHz ISM band
  - 802.11 DSSS (direct sequence spread spectrum): is also restricted to 1 or 2 Mbps. Chip rate is 11 times of bit rate and uses Baker sequence
  - 802.11a OFDM (orthogonal frequency division multiplexing): delivers up to 54 Mbps in the wider 5-GHz ISM band. The number of subcarriers is 52: 48 for data and 4 for synchronisation. This is compatible to HIPERLAN
  - 802.11b HR-DSSS (high rate DSSS): supports data rates 1, 2, 5.5, and 11 Mbps, and uses Walsh/Hadamard codes
  - 802.11g OFDM: an enhanced version of 802.11b, operates in the narrow 2.4-GHz ISM band and theoretically is up to 54 Mbps

Summary

- Physical layer functions overview

- Physical layer standard or design

  medium dependent: defines medium used and physical hardware

  medium independent: specifies issues independent of medium such as line coding, and synchronisation (timing)

- Examples of physical layer discussed:

  Ethernet, FDDI, B-ISDN (notice scale: LAN $\rightarrow$ WAN)

  Fast Ethernet, Gigabit Ethernet, wireless LANs