Computer Networks

Lecture on

Computer Serial Links

Plan of This Lecture

- Common computer wired interfaces
- Transmission media
- Data representations on a transmission line
- Bit error correcting code
- Framing
- Point-to-Point Protocol

Common Computer Wired Interfaces

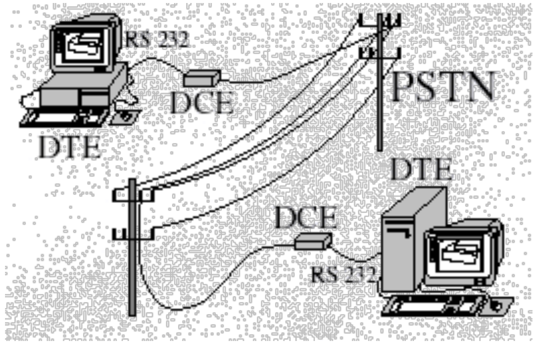
Ethernet	Thunderbolt	USB	FireWire (IEEE 1394)
0.1 1 10 40 100 400 Gb/s	10 20 40 Gb/s	1.5 12 480 Mb/s 5 10 20 Gb/s	100 200 400 800 Mb/s 3.2 Gb/s
100 m - CAT5 100 km - fiber	copper 3 m fiber 30, 100 m	5 m; can be 50 m - CAT5 10 km - fiber	4.5 m; can be 100 m also fiber and coax

- Ethernet is dominant for any distance communication
- Any older interfaces can be find in data centers
- VPN over Internet is the cheapest solution to set a new link between remote devices

- Modems over PSTN are still in use for:
  - dialup remote control

    PSTN – Public Switched Telephone Network

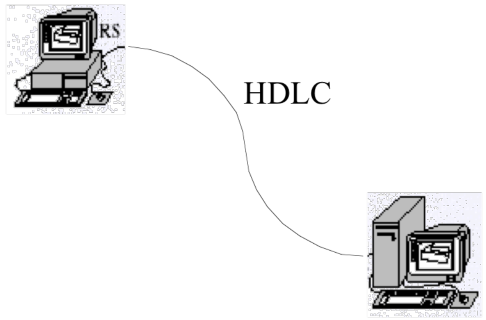
Asynchronous commuted lines



- Synchronous HDLC over telephone leased lines are still in use for:
  - backup communication

    HDLC – High-Level Data Link Control

Synchronous leased lines



- xDSL technologies are widely used
  - DSL modem can be built in the home router
  - or connected via USB or Ethernet

    DSL – Digital subscriber line

- Optical cables replace copper cables – Ethrnet interfaces are dominant

Transmission Media

Cable media:

- Unshielded Twisted Pair (UTP) & Shielded Twisted Pair (STP)

Category	Bandwidth
3	16 MHz
5e	100 MHz
...	...
8.2	2000 MHz

- Coaxial Cable
  - Wide standards range
  - Higher attenuation than twisted pairs
- Optical Fibre
  - Single-mode fibre core 8-10 μm

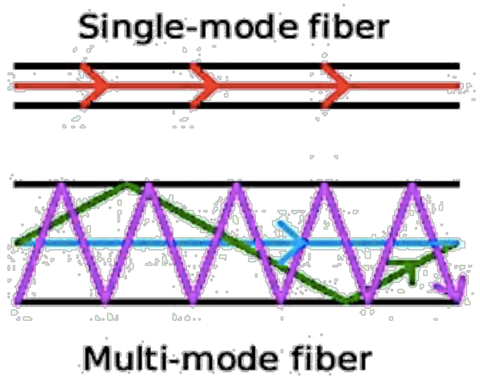
No degradation of signal	Manufacturing and handling is difficult
Low dispersion	Higher price
Well suited for long distance	Coupling light into the fibre is difficult

Used in MANs and WANs

  - Multi-mode fibre core 50-200 μm

High attenuation	Manufacturing and handling is easy
High dispersion	Lower price
Well suited for short distance	LED transmitters can be used

Used in LANs and inside devices



Why do fibre cables replace copper ones?

- Insensible for electromagnetic noises
- Junctions are humidity resistant
- Enable much higher transmission speed
  which is limited by electro-optic interfaces
- Enables much longer transmission distances without signal amplifiers
- Optical cables weight less than copper cables
- Installations are less expensive

Non-cable transmission media:

- Radio waves
- Visible light
- Infrared light
- Ultrasound waves

Data Representations on a Transmission Line

There is huge number of line codes

Prominent examples are:

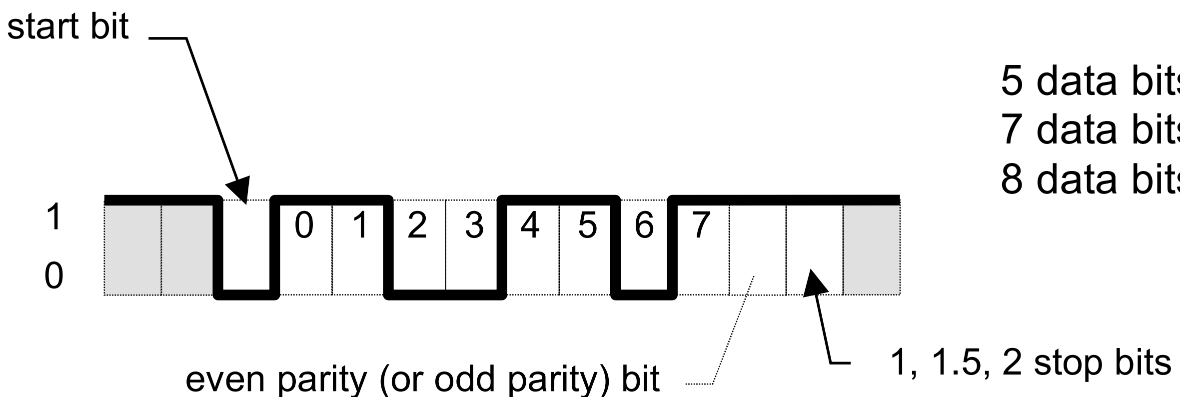
- Asynchronous transmission schema
- Manchester code aka. Phase Encoding
- Miller code aka. Modified Frequency Modulation
- MLT-3 *Multi-Level Transmit*
- 4B5B
- 8b/10b
- 64b/66b

Expected features of line codes

- clock recovery
- special symbols e.g. start of frame
- DC-balance – no direct current
  - non-galvanic coupling possible – no risk of ground loop courent
- lower bandwidth

Asynchronous Transmission

The signal carries only data bits

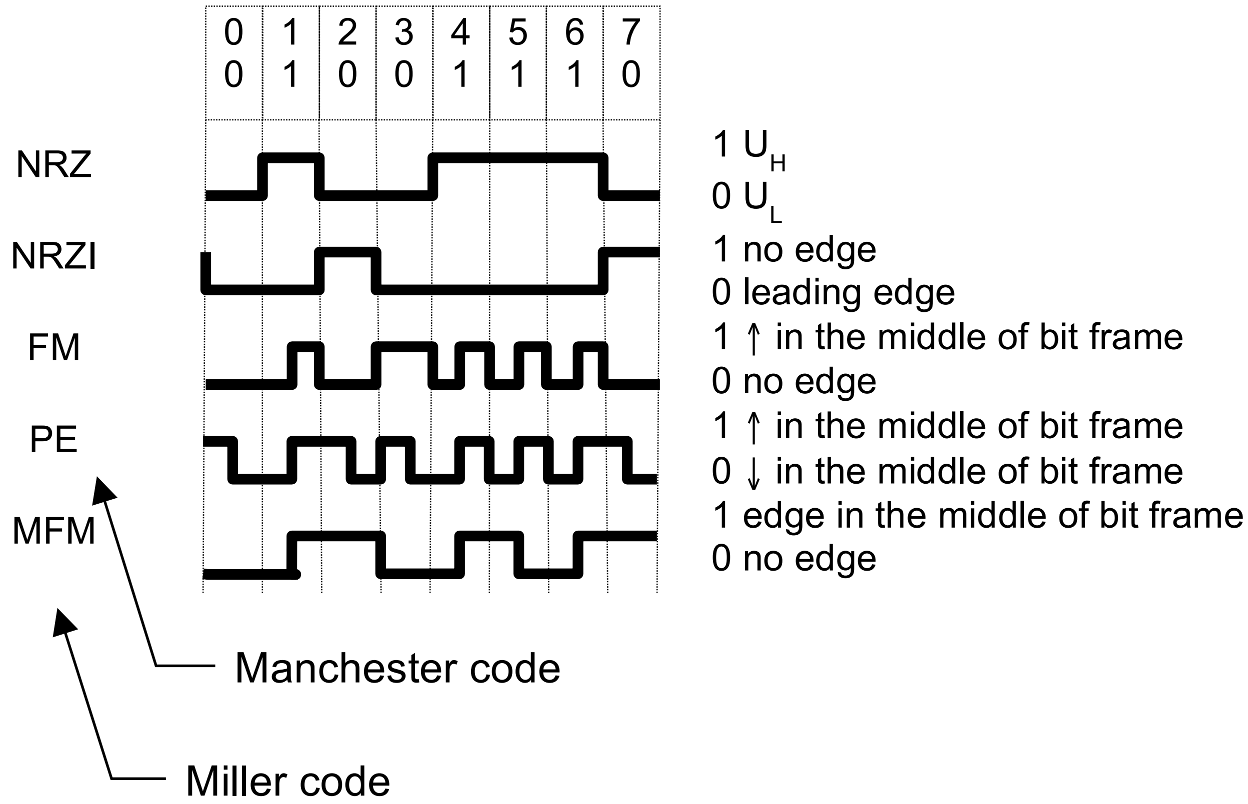


5 data bits – teletypewriter code
7 data bits – ASCII code
8 data bits – for octet stream

‘0’ for 20 ms it is a brake signal

Synchronous Transmission

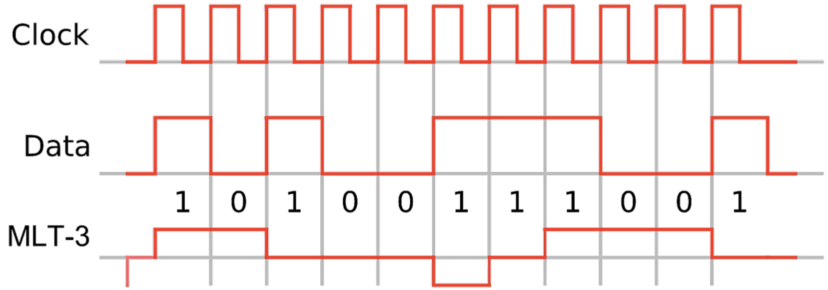
The signal carries clock and data bits



MLT-3 encoding

Multi-Level Transmit

- cycles sequentially through −1, 0, +1, 0



4B5B encoding

- Used in FDDI, Fast Ethernet and others
- There are 16 special purpose codes
  - e.g. start of the frame
- On optical fiber is NRZI encoded
- On copper is MLT-3 encoded

Data (Hex)	Data (Binary)	4B5B code	Data (Hex)	Data (Binary)	4B5B code
0	0000	11110	8	1000	10010
1	0001	01001	9	1001	10011
2	0010	10100	A	1010	10110
3	0011	10101	B	1011	10111
4	0100	01010	C	1100	11010
5	0101	01011	D	1101	11011
6	0110	01110	E	1110	11100
7	0111	01111	F	1111	11101

8b/10b encoding

- Used in DVI, HDMI, USB 3.0 and others

64b/66b encoding

- Used in 10, 100 Gigabit Ethernet and others

Cyclic Redundancy Check (CRC)

Bit error-detecting code

- is based on the remainder of a polynomial division
- has proved efficiency of detecting strength
- is simple to implement in binary hardware

A binary polynomial:

$$X=10011011 \quad \rightarrow \quad w(X)=x^7+x^4+x^3+x+1$$

Popular divisors

CRC-16 (BISYNC)	$x^{16}+x^{15}+x^2+1$
SDLC (IBM, CCITT)	$x^{16}+x^{12}+x^5+1$
CRC-16 reverse	$x^{16}+x^{14}+x+1$
SDLC reverse	$x^{16}+x^{11}+x^4+1$
LRCC-16	$x^{16}+1$
CRC-12	$x^{12}+x^{11}+x^3+x^2+x+1$
LRCC-8	x^8+1
ETHERNET CRC	$x^{32}+x^{26}+x^{23}+x^{22}+x^{16}+x^{12}+x^{11}+x^{10}+x^8+x^7+x^5+x^4+x^2+x+1$

How it works:

```
frame s(x) = w(x).FCS                          – Frame Check Sequence
FCS = reminder of polynomials division  2^G * w(x) : g(X)
s(x) = 2^G * w(x) : g(X) + r(x)
                                                CRC code
```

e.g.. G=3 w(x)= 0111

```
2^3 * w(x)      g(X)
0111000 : 1011 = 0110     ← '0' if shift, '1' if subtraction modulo-2
 1011
  1010          ← exor
  1011
   0010         ← exor

    010 = r(x)   =>   s(x) = 0111 010
                CRC
```

See: http://www.ee.unb.ca/cgi-bin/tervo/calc.pl

Mathematically proved efficiency

e.g. for CRC-16 and frame length ≤ 32 767 bits

- All detected errors
  - single bit
  - two bit
  - three bit
  - all odd bits
- Probability of detection of serial bit errors
  - 100% for ≤ 16 consecutive bits
  - 99,997 % for 17 consecutive bits
  - 99,998 % for 18 consecutive bits

Bit Error Correction Codes

There are many such correction codes

Hamming codes are widely used

- simple implementation
- can correct one-bit error

m – message length
r – number of parity bits
n – number of transmitted bits $n = m + r$
Condition of one bit correction $m + r + 1 \leq 2^r$

m	16	32	64	128	…
r	5	6	7	8	…

How it works:

Bit position		1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	
Encoded data bits		p1	p2	d1	p4	d2	d3	d4	p8	d5	d6	d7	d8	d9	d10	d11	p16	d12	d13	d14	d15	
Parity bit coverage	p1	✗		✗		✗		✗		✗		✗		✗		✗		✗		✗		
	p2		✗	✗			✗	✗			✗	✗			✗	✗			✗	✗		...
	p4				✗	✗	✗	✗					✗	✗	✗	✗					✗	
	p8								✗	✗	✗	✗	✗	✗	✗	✗						
	p16																✗	✗	✗	✗	✗	

P = 0 then no error, otherwise P is the number of bit to be corrected

Hamming codes with additional parity allow

- to detect and correct a single error
- and at the same time detect (but not correct) a double error

Framing – Protocols Using Asynchronous Links

- BISYNC (IBM) - based on ASCII characters

SYNC	SOH	**Header**	STX	**Payload**	ETX	CRC	SYNC	SOH

- Other methods:
  - SOH and ESC injection
  - min/max delays between frames and characters in a frame
- DDCMP (DEC) - for binary data
  - fixed length header carries payload counter

Protocols Using Synchronous Links

- SDLC (IBM)
  - synchronization byte: 01111110
  - after every 5 ones a zero bit is injected/removed
  - silence byte: 11111111
  - ring release byte: 11111110

- Token Ring (IBM)
  - coding disturbance: J and K symbols in Manchester code

- HDLC - High Level Data Link Control (ISO) - for binary data

- <u>HDLC subsets:</u>
  - LAP Link Access Procedure X.25
  - LAPB Link Access Procedure Balanced, X.25
  - LAPD Link Access Procedure, D-channel, ISDN
  - LAPX LAPB extended, teletex
  - LAPM ITU V.24 for modems
  - LLC LOGICAL Link Control IEEE 802

Serial Line IP (SLIP)

- RFC 1055 A Nonstandard for Transmission of IP Datagrams over Serial Lines

  "SLIP END" = 192 (219 220) → 192

  "SLIP ESC" = 219 (219 221) → 219

  - no means for control information
  - no bit error detection, correction, nor compression mechanisms
  - no means for dynamic IP address assignment
  - no authorization mechanisms
  - can carry bytes of any protocol (up to 1006 octets)

- CSLIP *Compressed SLIP* RFC 1144

  IP header 20 B + TCP header 20 B → 3-5 octets

  - can handle up to 16 connections

Point-to-Point Protocol (PPP)

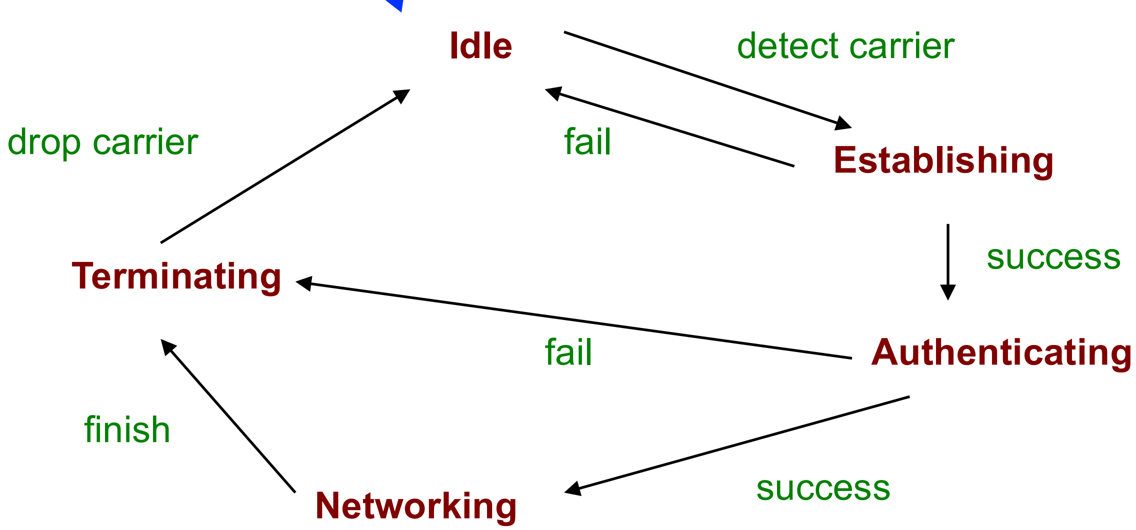
RFC 1171, RFC 1172, ...

Set of protocols organized in 3 layers

- Physical layer - any ANSI standard
- Data link layer - modified HDLC
- **LCP Link Control Protocol**

Reliable data transfer!

It can link routers!

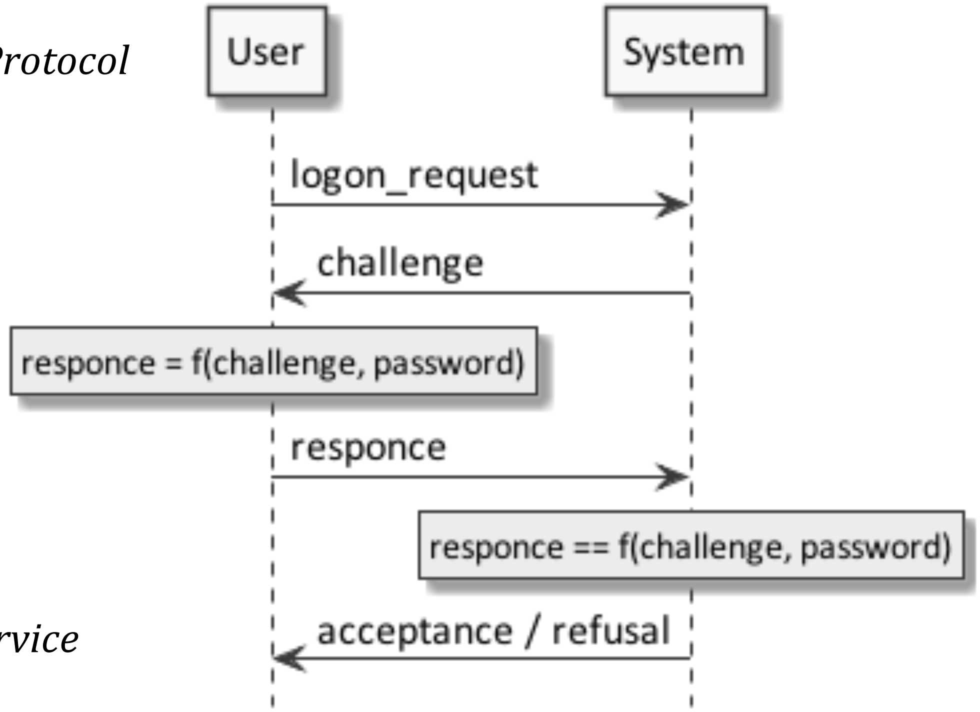


PPP General Features

- Control of connection parameters
- Flow control
- Means for diagnostic mechanisms
- Means for authentication mechanisms
- Compression possibilities
- Max. datagram size = 1500 octets

PPP Support Many Authentication Mechanisms

- PAP *Password Authentication Protocol*
  - name & password plain text transfer – easy to sniff
  - confirmation plain text transfer
- CHAP *Challenge Handshake Authentication Protocol*
  - No password transfer!



- RADIUS *Remote Authentication Dial-In User Service*
- IPSec

PPP Network Control Protocols

They work at **networking state of LCP**

Different instances for divers 3rd layer protocols

i.e.: DECNET, IP, OSI NP, IPX, AppleTalk

IPCP

- It provides IP addresses for: host, network mask, DNS servers
- Support header compression
- ...

PPP Usage

- Over asynchronous or synchronous serial links see: man pppd
- Over broadband connections:
  - PPPoE *Point-to-Point Protocol over Ethernet*
  - PPPoATM *Point-to-Point Protocol over ATM*
  - PoS *Packet over SONET/SDH*
  - PPTP *Point-to-Point Tunneling Protocol*
    between two hosts via IP

Summary

- Common computer wired interfaces
- Transmission media
- Data representations on a transmission line
  - asynchronous transmission
  - synchronous transmission
- Cyclic redundancy check
- Hamming codes
- Framing on
  - asynchronous links
  - synchronous links
- Point-to-Point Protocol
  - general features
  - authentication mechanisms
  - IP Network Control Protocol
  - usage

Questions

1. What for we use modems over PSTN in today network applications?
2. What for we use synchronous links over leased telephone lines in today network applications?
3. What is the difference between multi-mode and single-mode optical fibres?
4. Why do fibre cables replace copper ones?
5. What are the expected features of line codes?
6. What is the principle of asynchronous serial communication?
7. What is the principle of Manchester encoding?
8. What is the principle of MLT-3 encoding?
9. What is it CRC and what for is it used?
10. How many parity bits are needed to correct one bit in a frame of 256-bit length?
11. How frame synchronization can be done in serial asynchronous links?
12. How frame synchronization can be done in serial synchronous links?
13. Give an example of the SLIP (Serial Line IP) protocol usage.
14. Give an example of PPP (Point-to-Point Protocol) usage.
15. Why PPP is better than SLIP?
16. How can be done authentication in PPP?