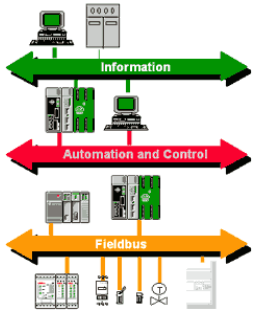
# Industrial Communication

Chapter 16

Gunnar Lindstedt



# Time and Data Ranges

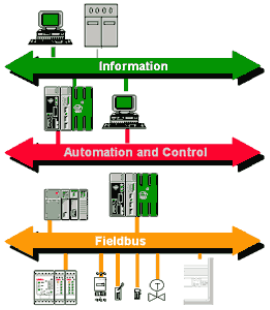



| Application | Network size | Amount of data | Reaction time | Costs |
|---|---|---|---|---|
| LAN,WAN | high | Very high | 1 s | high |
| Control + Automation | medium | high | 100 ms | low |
| intelligent decentralized I/O | small | medium | 10 ms | low |

Picture from:
HMS Industrial Networks



# Network "Products"




Open Industrial networks

Ethernet, Ethernet IDA, Ethernet/IP

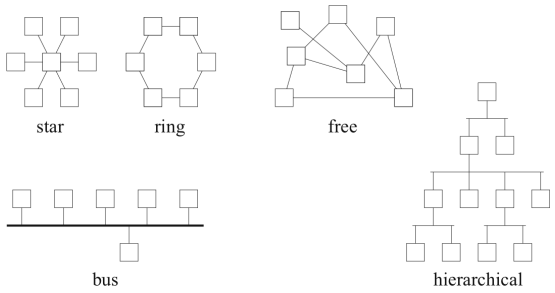
Ethernet, Profinet, Ethernet/IP, IDA, Profibus-FMS, Profibus-DPV1, ControlNet, Modbus, Canopen, Pnet, Foundation Fieldbus HSE, CC-Link, FL-Net, JPCN-1

Profibus.DP, AS-Interface, DeviceNet, Interbus, FIPIO, Sercos, CAN, Profibus-PA, Foundation Fieldbus H1, Lonworks, EIB, SDS

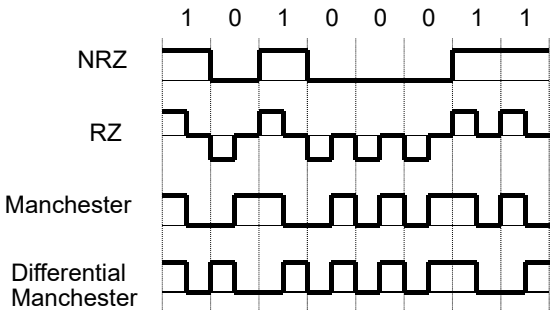
Picture from:
HMS Industrial Networks



# Network Topologies



# Bit Coding Principles






# Fundamentals

- Bandwidth, *W* (3 dB attenuation)
- Information, $I=\log_2 N$ (bits). (N: number of symbols)
- Capacity (bits/s) - [ baud (symbols/s) ]
- Max. Cap = $2\,W\log_2(V)$ (noise free; V:# of levels)
- Max. Cap. = $W\log_2(1+S/N)$ (theoretical)

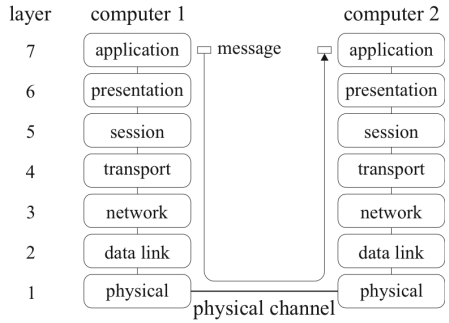


# OSI

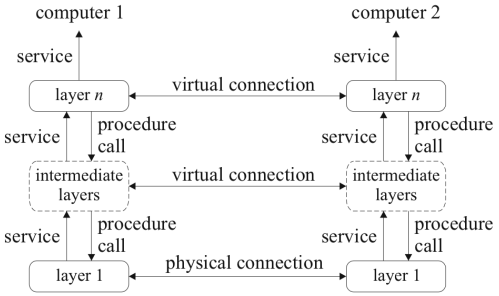
Open System Interconnection



# The OSI model

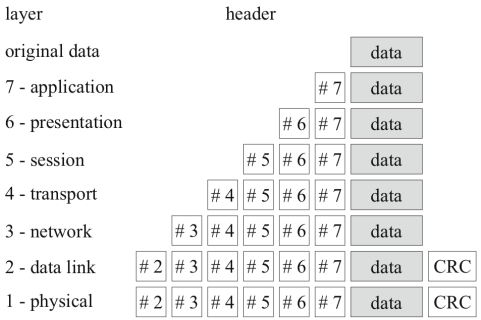


# OSI peer-to-peer Communication






# Layered Communication Protocols



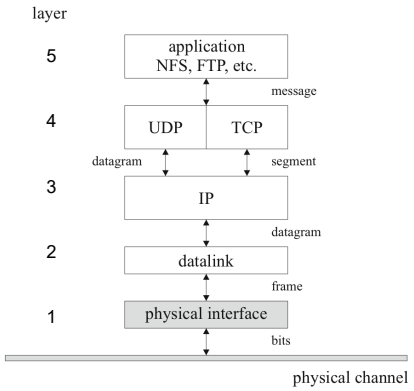



# TCP/IP

Transmission Control Protocol / Internet Protocol



# TCP/IP basic structure

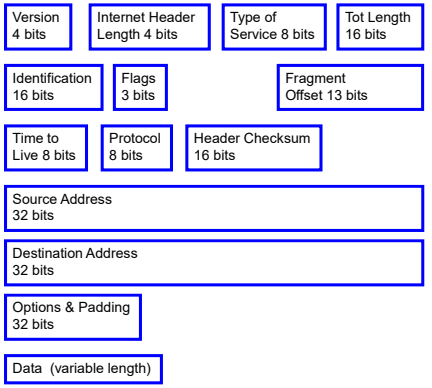


# IP layer

- Responsible for moving datagrams from one point to another
- Unique, multicast or broadcast
- IP address 32 bits, Four 8-bit blocks, 0-255 (134.34.6.222)
- IP v4 in use - IP v6 in new products today



# IP Datagram (IP v4)






# TCP

- Single source – single destination
- Establish connection, transfer data, close connection
- Acknowledgement, retransmission
- Provide services for FTP,SMTP, TELNET
- TCP header



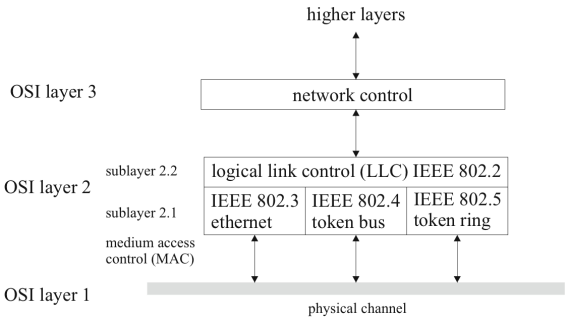
# UDP

- Connectionless - unreliable
- Multicast and broadcast
- Applications
  - Data collection
  - Data presentation
  - Real time applications (audio)
- UDP header – less complex

# Ethernet



## IEEE/OSI level 2



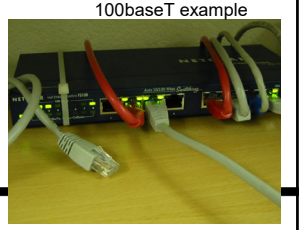



## Ethernet – Physical Layer

- Various media
  - Thick ethernet (10base5)
  - Thin ethernet, cheapernet (10base2)
  - TP, RJ45 (10baseT), cat5 (100baseT), cat5E (1000baseT), cat6 (10Gbase-T)
- Manchester coding

10base2 example

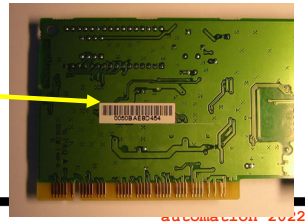
100baseT example



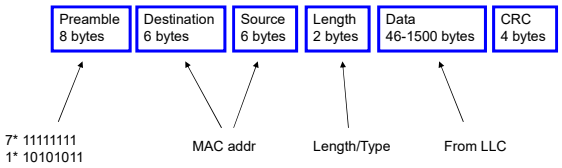
## Ethernet – data link

- CSMA/CD
  - Carrier-Sensing Multiple Access/Collision Detection
- MAC-address
  - Medium Access Control
  - 48 bit hardcode unique number

MAC address



# The Ethernet Packet



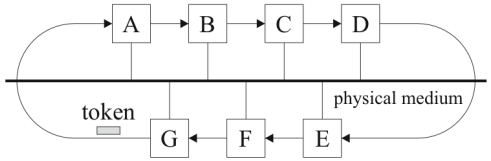



# Ethernet - CSMA/CD

- Carrier-Sensing (check that the line is free)
- Multiple Access (begin a new transmission)
- Collision Detection (detect if the information is garbled)
- Some 50 $\mu s$ travel time = time slot
- No real time guarantee!



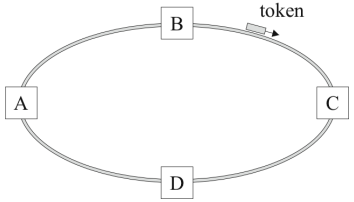
# Token Bus




**Deterministic!**



# Token Ring

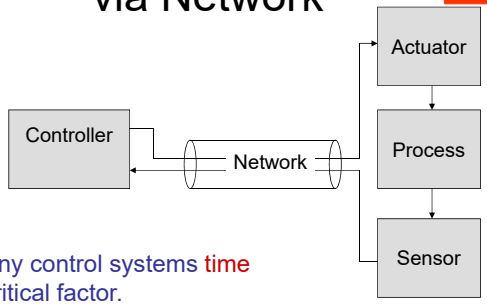



**Deterministic!**

# Fieldbuses



## Feedback and Control via Network




In many control systems time is a critical factor.
Will this structure work?



## Fieldbus

- Replace analog signals (cables) with a network
- Advantages
  - Easy installation
  - Simple maintenance
  - Less connection errors
  - Easy debugging
  - Simple reconfiguration
- Requires a new competence



## Fieldbus Requirements

- Noise immunity
- Fast
- Real time performance (deterministic)

# Fieldbus Features

- "The industrial automation LAN"
- About 100! different buses aiming at different applications (cars, discrete manufacturing, continuous production).
- "Smart" nodes
- Not only sensor and actuator signals



# Some Fieldbuses

- ASI
- PROFIBUS
- CAN
- DeviceNet
- ControlNet
- Interbus-S
- FIP
- Fieldbus Foundation

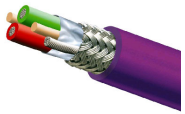
Overview information links:

http://www.weighing-systems.com/TechnologyCentre/fieldbus1.html

http://www.pacontrol.com/download/fieldbuscomp.pdf



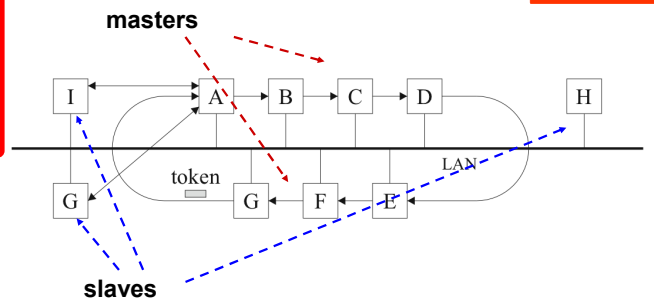
# Profibus



PROFI PROCESS FIELD BUS



# PROFIBUS Principle



## PROFIBUS

- Token bus with master/slave
- 500k-12Mbit/s
- RS485
- Max 127 nodes (PA 256)

http://www.profibus.com

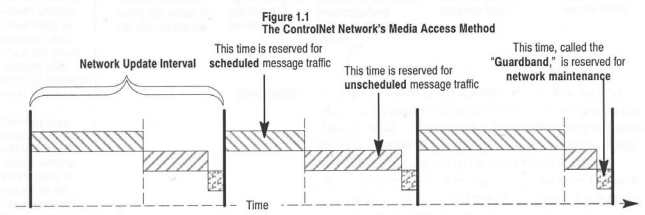


## Most Fieldbuses are not deterministic by design!

- The fieldbus definitions include no tool for direct timing control.
- Token passing principles together with maximum data block size provides the real time performance.



## ControlNet Timing






## Deterministic Fieldbus Examples

- ControlNet http://www.odva.org
- TTP http://www.tttech.com
- Foundation Fieldbus
  http://www.fieldcommgroup.org
- EtherCAT http://www.beckhoff.com

## Ethernet TCP/IP a fieldbus?

- Not by design!
- Today it is being (mis-)used (?)
- High performance – low cost
- Speed and limited load compensates for real time performance and determinism
- Development of "Lean TCP/IP stacks“ - IoT
- Redefined?



## Summary

- Communication is a key technology in automation
- Network topologies
- OSI
- Ethernet and TCP/IP
- Deterministic vs. non-deterministic
- Fieldbuses



## HMI

### Human-Machine Interface

[ MMI, MMC ]

(HMI chapter from previous book edition 1992, excerpt)



## Goals

- Understand the different purposes with HMI in Automation
- Know basic HMI design rules
- Be familiar with terms like “tagname database” and “animation links”
- In general terms understand the integrations of an HMI in a PLC system.

## Human and machines compensate for each other

- Power
- Speed
- Attention - alarms
- Memory
- “Intelligence”
- Rule based thinking
- Symbolic information



## Human and machines have to adjust to each other

- We can not have systems that humans can not handle
- High education and training more and more required

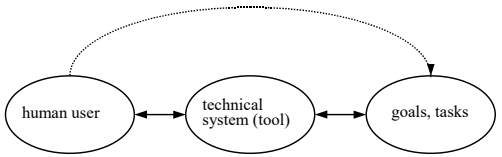


## Different HMI views @ IEA

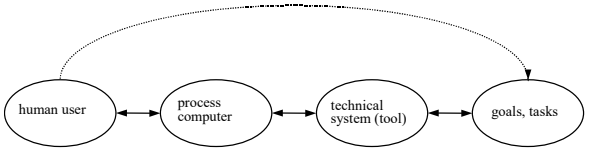
- Situation awareness
  - Dr. Lawrence Jones; Power applications
- Usability
  - Master thesis;  Anders Lyddby
- Complexity reduction
  - Tech Lic; Gianguido Piani



## Interactions

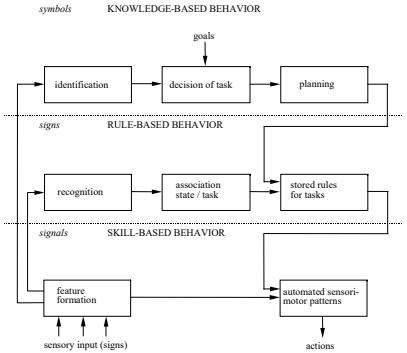


# The Process Computer as a View into the Process



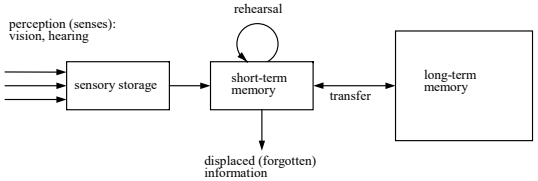



# Levels of Human Performance






# Dual Memory Model

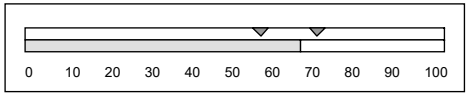





# Remember…

- Previous experience is powerful
- Social and cultural background
- Educational level
- Objectives and motivation

## Intuitive Presentation






## Message (1)

A502 POWERED: YES/NO

A502 POWER: ON/OFF



## How to Remember?

4687834000

or

46 - 8 - 783 4000

- Remember the 7 +/- 2 rule!



## About Color

- Powerful but dangerous
- 4-5 possible to understand. (Abs max: 7)
- Consistent use
- Redundancy needed
- Blink attribute on symbols - **not on text**

## Some Experiences of the Operator Role (1)

- The user HAS to be part of the design
- The system has to be able to grow according to the demands
- Easy interpretation of the man-machine interface



## Some Experiences of the Operator Role (2)

- Mental models have to be pictured
- TIME is a difficult variable to show!
- The system has to **help** the operator, not to be another burden!
- Reality is not a flat screen
- Different users need different presentations



## InTouch demo

- Tagnames
- Animation links